With special contributions by 50 of North America's leading Healthy House Professionals

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4TH EDITION

THE HEALTHY HOUSE

How to buy one
How to build one
How to cure a sick one

BY

JOHN BOWER

The Healthy House Institute

THE HEALTHY HOUSE, 4TH EDITION

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Disclaimer

Materials and techniques mentioned herein do not constitute medical advice. The listing of a particular manufacturer's product is not an endorsement of that product. Because individual tolerances to pollutants vary considerably, and because manufacturing processes change periodically, personal testing of materials is recommended for those with sensitivities. For extremely sensitive people, this should be done under the supervision of their physician. Testing procedures are covered in Chapter 5, Planning.

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Preface to the Fourth Edition

The field of healthy-house construction has advanced considerably since the first edition of *The Healthy House* was released in 1989. In fact, back then, I probably could have counted on one hand the number of people seriously involved in some aspect of healthy construction. However, in the intervening years, there have been literally thousands of research papers published on many different aspects of indoor air quality and the indoor environment—something that has given the field increased validity. As a result, the number of healthy-house designers, builders, and other practitioners continues to increase every year.

It's been my good fortune to meet quite a few of these healthy-house professionals, either by phone or, often, at the numerous conferences we've attended over the years. In this fourth edition of *The Healthy House*, I've given 50 of these individuals a voice by asking them to write a short sidebar to include in this book. They include builders, architects, designers, inspectors, physicians, educators, writers, consultants, and researchers. I didn't assign them specific topics—instead I simply asked them to write about some aspect of healthy houses for which they have special knowledge, or a related subject that is particularly dear to their heart.

Many of them wrote about design, planning, or general issues, so there are a number of sidebars to be found in the early chapters. But there are also more technical pieces later in the book as well. I chose these particular people because they are very down-to-earth and practical in their approach to healthy construction. While some have experience in dealing with indoor air quality in commercial buildings, offices, and schools, most of their combined expertise is in the residential field. I'm proud to say that many of them have been my teachers over the years, and I am very grateful for their contributions, and for being willing to share their hard-earned knowledge. I only wish there was enough room in this book for more such talented people to contribute.

When I completed the first edition of *The Healthy House*, I was amazed at how much material my research had turned up, and I never imagined that I would be working on a second edition, much less a third or fourth. But because there were so many new materials and so much new data available to me, this fourth revised-and-updated edition bears very little resemblance to the original 1989 version—and it contains approximately three times as much information. To help readers gain additional access to healthy materials and suppliers, there are now web sites listed for most of the over 600 companies found in the Resource section. Plus, there are over thirteen-hundred reference notes to help readers track down more in-depth information or technical research papers.

While many of the building materials currently in use contribute to polluted indoor air, there are other materials readily available almost everywhere that are quite benign. One of the keys to a healthy house is to choose materials carefully. But it is more than that. For example, many people continue to believe that houses are unhealthy because they are being built too tightly. Yet, the fact is, airtight construction is very important in healthy house construction. This is because a house acts as a system with the various subsystems and components continuously interacting—all according to a few simple laws of physics. When you understand how the components of a house interact, as you read the following pages, you'll see how important airtight construction really is, and how loose construction can actually cause indoor air quality problems. Of course, you'll also see that an airtight house must have a mechanical ventilation system. At first, this may seem expensive—choose alternative materials, make a house airtight, then add the cost of a ventilation system—but if you view the house as a system, you can sometimes save enough money on your energy bills to pay for the extras. But even if you spend a bit more, we're talking about your family's health, and that's always worth spending a little more money.

In some ways, houses have been getting healthier in recent years—for example, with the introduction of heating systems having sealed-combustion chambers, and zero-VOC paints—but in other ways houses are still filled with contaminated air. The energy crisis of the 1970s forced the American automobile industry to change fairly quickly, but the housing industry seems to be changing much more slowly. However, the way houses are being built is changing—in many ways for the better—and I'm proud that *The Healthy House* continues to be a part of that process.

Introduction

Americans are overwhelmingly interested in better health today. Most television news shows include regular health segments, and many have special health corespondents or doctors on their payrolls. In a poll taken by *Organic Gardening* magazine, 70% of American consumers said, if they had a choice, they'd buy organic fruits and vegetables at their local market—and more than half of them would be willing to pay as much as 20% more.[1] Yet, many of us are unaware of the health threats inside our own homes. While a survey found that one-third of building managers recognized that indoor air pollution is a "serious" health threat, almost none regard it as a serious risk in their own buildings.[2] But, it probably is.

A house is *not* simply a benign structure in which you relax. It's an active, enclosed system. And, when you are inside it, you become an integral part of that system. If your house is like many being built in the U.S. today, it is composed of various individual components that contain toxic chemicals. Carpeting and floor tiles are chemically treated to render them stain resistant. Wall coverings are chemically treated with mold inhibitors. Wood windows are made with chemically treated lumber. These treatments can be harmful in their own right, but when they outgas (release chemicals into the air) into the living space of your house, they can interact to form new toxic compounds.

Enter you and your family. You have now linked into this enclosed system for better or worse. Probably worse. As the components of your home outgas, they contaminate the air you are breathing. As they are inhaled, they are absorbed by your lungs and pass into your bloodstream. Some are absorbed through your skin. As an article in *Interior Design* pointed out, "our interiors, once our chief refuge from urban terrors, are now themselves seen as sources of danger."[3] When you consider the number of hours spent indoors, it only makes sense to build a healthy house rather than an unhealthy one.

The federal government has begun to promote the concept of healthy houses—but slowly. In fact, many products with known negative health effects are widely available and are being actively promoted by manufacturers and lumberyards. Examples include particle board (which is loaded with formaldehyde), and salt-treated lumber (which contains arsenic). Nations like West Germany, Canada, and Sweden are much more involved in promoting healthy building products and techniques. They have already learned that the ill health of their citizens is often related to housing.

What symptoms can you expect by living in an unhealthy house? Actually, you can experience anything from a headache, insomnia, or skin rash, to severe joint pain,

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1 James McCullagh, "A Mother's Crusade," Organic Gardening (April 1989): 32-37.

2 Bureau of National affairs (BNA), Indoor Air Pollution: The Complete Resource Guide, Volume 1 (Washington, DC: BNA 1988): I-63.

3 Stanley Abercrombie, "The greening of interior design," *Interior Design* (August 1991): 71-76.

anxiety, or depression. While much of the medical community is unaware of the true cause-and-effect relationship between indoor air quality and human health, there is a growing minority of health care professionals who are well-informed about the devastating consequences of living in sick houses. Some architects and builders are also starting to become aware of the problem. Yet, most houses continue to be built in unhealthy ways.

The good news is that healthy building materials and practices are available. It only takes a little more time, planning, and money—but not much—to build a healthy house instead of one that will put you and your family at risk. Surveys have shown that homeowners not only want organic vegetables—they also want healthy houses. *Professional Builder* magazine has been asking questions of home buyers for several years about healthy housing. In 1990, they found that over 80% of home buyers felt environmental issues were important[4], and in 1998 they found that home buyers would be willing to pay an average of $1436 extra for features that improved indoor air quality.[5] That doesn't seem like a lot of money, but it can make a difference. And the more educated home buyers are about healthy house issues, the more important they realize it is, and the more they are willing to spend. For example, a survey done in Bellevue, Washington found that home buyers would pay as much as $15,000-25,000 more for healthy-house features, based on a $240,000 home.[6] Of course, healthy features can also be incorporated into lower-cost housing, sometimes at little or no extra cost.

This book will show you how traditional house construction can actually be a *cause* of poor indoor air quality. However, more importantly, it will present hundreds of healthier alternative building materials and construction techniques. To help you locate suppliers, Appendix I contains the addresses and telephone numbers of organizations and manufacturers shown in **bold type** throughout the text. Some manufacturers sell their products direct to consumers and builders, but in most cases a manufacturer will refer you to a local distributor or retail outlet.

This is not a step-by-step instruction book on how to build one particular healthy house. Instead, it is a reference book that can help you buy, build, or remodel any house so that it won't make you sick.

Here's to your house, and to your health.

-John Bower

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[4] "How healthy are your homes,?" *Professional Builder & Remodeler* (December 1, 1990): 125.

[5] Roy Diez, "Will Eden Have A Healthy Home?"(Editorial) *Professional Builder* (July 1998): 9.

[6] Susan Bady, "Sales grow with green marketing program," *Professional Builder* (May 1994): 34.

Part 1:
FUNDAMENTALS

1. Indoor Air Quality

People in the United States spend between 80 and 90% of their time indoors. This time is typically divided between home, school, and workplace. However in the cases of young children, the sick, or the elderly, they may be just in one location for extended periods of time everyday—inside the home. Our homes may be our castles, yet they hardly protect us from indoor air pollution. Indoor levels of volatile chemicals are routinely measured at many times the level of the air outdoors.[7] [8] [9] In fact, the atmosphere inside most houses is typically 5-10 time worse than the outdoor air, and the concentration of individual air pollutants can easily be 100 times higher indoors than outdoors.[10] And because people spend so much time indoors, their actual exposure to chemicals found in the indoor air is generally 10-50 times greater than if they were continually exposed to outdoor air.[11]

Of course, the indoor-air-quality problem isn't just limited to houses. Offices and factories also can be filled with polluted air, although they can fall under the jurisdiction of workplace regulations—regulations that don't exist for houses. And schools can be polluted. One study found that nearly 80% of our schools have inadequate ventilation.[12] This is particularly important for young children, whose immune systems aren't yet fully developed. The **EPA**, in conjunction with the National PTA, the National Education Association, the Council for American Private Education, the Association of School Business Officials, the American Federation of Teachers, and the American Lung Association has created an *Indoor Air Quality Tools for Schools Action Kit*[13] to help school officials and maintenance personnel improve the air quality in their facilities.

This contaminated indoor air is much more dangerous than was believed just a few years ago—and the trend is getting worse. A World Health Association report

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[7] M. De Bortoli and others, "Concentrations of Selected Organic Pollutants in Indoor and Outdoor Air in Northern Italy," *Environment International* 12 (1986): 343-350.

[8] A.R. Hawthorne, R.B. Gammage and C.S. Dudney, "An Indoor Air Quality Study of 40 East Tennessee Homes," *Environment International* 12 (1986): 221-239.

[9] Theodor D. Sterling and Diana M. Kobayashi, "Exposure to Pollutants in Enclosed 'Living Spaces'," *Environmental Research* 13 (1977): 1-35.

[10] "EPA study identifies VOCs in public buildings," *Indoor Air News* (Fall/Winter 1988): 1.

[11] "A comparison of indoor and outdoor concentrations of hazardous air pollutants," *Inside IAQ* (Spring/Summer 1998): 1-7.

[12] "A survey: Indoor air quality in schools," *Center for Building Science News* (Summer 1998): 4.

[13] *Indoor Air Quality Tools for Schools Action Kit* , (Washington, DC: EPA). #055-000-00503-6. To order, call 202-512-1800, $22.00.

suggested that up to 30% of new and remodeled buildings may have excessive complaints related to indoor air quality.[14] According to one environmental scientist, "Your home may be more of a toxic waste hazard than the Love Canal or the chemical company nearby."[15] So, what is being done about the problem?

Some people criticize the **Environmental Protection Agency (EPA)** for not doing their job very well, but the air quality outdoors has improved—especially in major metropolitan areas. Actually, the **EPA** is more concerned about *outdoor*—not *indoor*—air quality. As far as *indoor* air pollution is concerned, the **EPA** has no regulations whatsoever. Why? Because, by law, they are *only* required to regulate outdoor air quality. However, they do fund vital research on indoor air quality issues, and their booklet *The Inside Story: A Guide to Indoor Air Quality*[16] offers a very good overview of the subject. They also sponsor a toll-free **EPA Indoor Air Quality InfoLine** that you can use to get basic answers to indoor-air-quality questions.

The Occupational Safety and Health Administration (OSHA) is charged with regulating air quality in the workplace, where there have also been improvements. However there is evidence to suggest that 15-20% of the population will react negatively to chemical exposures below OSHA's established thresholds.[17]

Inside our homes, the government leaves us almost entirely to our own defenses when it comes to air quality. The **Consumer Product Safety Commission (CPSC)** has jurisdiction over a few sources of indoor air pollution, yet the air we breathe every day continues to deteriorate.

HUD (U.S. Department of Housing and Urban Development) has a Healthy Homes Initiative. While this voluntary program is being run through **HUD**'s Office of Lead Hazard Control, it addresses a number of house/health/safety issues—particularly those affecting children. **HUD** also administers a PATH program to promote new technologies in housing, as well as energy-efficient construction. PATH stands for Partnership for Advanced Technology in Housing, and is a coalition of private companies and federal departments.

Florida Solar Energy Center (FSEC) has sponsored research and projects involving improved indoor air quality, dust-mite control, and energy efficiency. Their focus is primarily on houses in hot, humid climates.

Much of the work being done on healthy housing is by non-governmental agencies. For example, the American Institute of Architects has, for a number of years,

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[14] Environmental Protection Agency (EPA), *Indoor Air Facts No. 4 (revised): Sick Building Syndrome* (Washington, DC: EPA, April 1991).

[15] Irene Ruth Wilkenfeld, "Is Your Home Inhospitable?," *Heal Prints* (May 1987): 1-5.

[16] Environmental Protection Agency (EPA), *The Inside Story: A Guide to Indoor Air Quality* (Washington, DC: EPA, September 1993). #EPA/402-K-93-007.

[17] Charles C. Ossler, "Men's Work Environment and Health Risks," *Nursing Clinics of North America* 21 (March 1986): 25-36.

produced an *Environmental Resource Guide*,[18] and the **International Institute for Bau-Biologie and Ecology, Inc.** in Clearwater, Florida offers a correspondence course on natural/healthy housing[19] that tends to place an emphasis on electromagnetic-field reduction. Bau-Biologie is a German word meaning building biology. It is often defined as the holistic interaction between man-made structures and the health of all life and all living environments.

The Massachusetts Audubon Society has published a booklet on *Building an Environmentally Friendly Home*.[20] Plus, most major construction magazines have run stories on healthy building projects.[21] [22] [23]

The American Lung Association has been involved with housing and health issues on several fronts. For example, the American Lung Association of Minnesota has created a national **Health House Program** and sponsored the construction of a number of Health Houses around the country.[24] [25] They offer information for consumers, builders, and designers. The American Lung Association of Washington has developed a **Master Home Environmentalist Program** that prepares workers to go into the community and evaluate the healthfulness of houses, then make recommendations for improving indoor air quality. Their *Master Home Environmentalist Volunteer Training Manual* is an excellent resource on a variety of home health hazards.

There are labeling and certification programs in the U.S. that allow consumers to make more-informed environmental decisions about products. **Green Seal** and **Scientific Certification Systems (SCS)** both review a variety of products and place their stamp of

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[18] Early editions were self-published by American Institute of Architects, 1735 New York Ave, NW, Washington, DC 20006, 800-365-ARCH, but after 1996, editions and supplements have been available through John Wylie and Sons, New York.

[19] *Introducing Bau-Biologie,* (Clearwater, FL: International Institute for Bau-Biologie and Ecology, Inc., 1990).

[20] Nadav Malin and Alex Wilson, *Building an Environmentally Friendly Home* (Lincoln, MA: Massachusetts Audubon Society, August 1991).

[21] Kevin Ireton, "An Environmental Showcase," *Fine Homebuilding* (Spring 1992): 66-70.

[22] Clint Good, "The Practical Healthy House," *Journal of Light Construction* (November 1991): 38-40.

[23] Susan Bady, "Remodel Reduces Exposure to Synthetic Materials," *Professional Builder and Remodeler* (July 1992): 121.

[24] Dan McLeister, "Lung Association Works to Improve Indoor Air," *Professional Builder* (December 1996): 56.

[25] American Lung Association of Hennepin County, *A Guide to Healthy Living: Health House 1993* (Minneapolis, MN: American Lung Association of Hennepin County, March 1993).

approval on them if they meet certain health or environmental standards. They evaluate products with respect to recycled content, recyclability, impact on air and water pollution, solid-waste disposal, *etc*. Many of the items evaluated are not construction related (*e.g*. writing paper, refrigerators, *etc*.) however, currently, **Green Seal** has ratings and/or reports on architectural paints, sealants/caulking compounds, floor coverings, wallboard-fiberboard-flooring, and sealing ducts. In Canada, the **Environmental Choice Program** has a similar mission. These organizations have standards for things such as recycled paper, re-refined motor oil, paints, batteries, appliances, lumber, *etc*. While these certified products are often better for the environment, the purpose of these programs is not specifically focused on indoor air quality—and they don't address the needs of sensitive people. **Air Quality Sciences, Inc.**, a private testing lab, is starting a registry of products based on established indoor air quality standards. These registration programs generally charge a fee for their service, something that can exclude smaller companies.

There are also companies that now specialize in handling a variety of low-tox building products or environmentally friendly materials, either by mail-order or through local showrooms. These include **Building for Health Materials Center**, **Environmental Home Center**, and **Environmental Construction Outfitters**. There also are a some local-regional suppliers of healthy building materials, including **Eco Products** in Boulder CO, **Planitary Solutions** in Boulder CO, **Environmental Building Supplies** in Portland OR, and **Nature's Living Products** in Cincinnati OH, that offer materials such as paints and floor coverings, as well as cleaning products and other household items.

In some ways, the Canadian government is taking a more active role than the U.S. For example, **Canada Mortgage and Housing Corp. (CMHC)**, a Canadian federal agency, has, for years, regularly funded research projects and reports related to healthy housing.[26] They've also sponsored a Healthy Housing Design Competition,[27] in which winners were showcased at an internationally attended conference. Furthermore, they've funded a demonstration house built to meet the needs of environmentally sensitive people.[28]

Modern Construction Practices

Houses used to be built of native materials. If there were a lot of rocks in the area, the houses were constructed of stone. If trees happened to be plentiful, the houses were made of wood. Eskimos built igloos with what was available to them. Today, building materials are very similar throughout the civilized world. Plywood, fiberglass insulation, wall-to-wall carpeting, and chemically treated lumber are a routine sight at construction

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[26] Canada Mortgage and Housing Corp. (CMHC), *Builders' Series: Indoor Air Quality* (Ottawa, ON, Canada: CMHC, 1988).

[27] Canada Mortgage and Housing Corp. (CMHC), *CMHC'S Healthy Housing Design Competition, Guide and Technical Requirements* (Ottawa, ON, Canada: CMHC, 1991).

[28] Canada Mortgage and Housing Corp. (CMHC), *Research House for the Environmentally Hypersensitive* (Ottawa, ON, Canada: CMHC, 1994).

projects everywhere—even though these common building materials can lead to indoor air pollution and ill health.

Construction practices have evolved considerably over the last one-hundred years, but the most significant changes have occurred since World War II. With the invention of modern adhesives, plywood and particle board are now widely used in houses. They are notorious for releasing formaldehyde gas. Synthetic plastics of various types are also now used extensively in the construction industry. Simulated-wood-grain plastic doors, synthetic paints, synthetic carpeting, caulking, and foam insulation all contribute to an indoor environment that has never existed before in the history of the human race.

With the advent of indoor plumbing and electricity, we have introduced additional health problems into our living spaces. The water piped into our houses is contaminated with various chemicals which can be ingested, or absorbed through the skin. Some of these chemicals are easily vaporized, so they can also be inhaled while taking hot showers. Electricity has given us many conveniences, including such things as continuous cleaning ovens which emit various pollutants when turned on. And, all electric wires and appliances are surrounded by invisible electromagnetic fields which can cause—if exposure is strong enough and long enough— a variety of cancers.

When primitive people cooked over a fire outdoors, there was usually plenty of ventilation. But as early man sought shelter, he created indoor air pollution. Soot on the ceilings of prehistoric cave dwellings attest to the fact that we have been polluting the indoor air for thousands of years. Today, we have integrated our fires into our houses with wood stoves, oil heaters, and gas ranges. As a result, some of the most common indoor air pollutants are by-products of combustion. Attached garages allow more combustion by-products to enter living spaces from automobiles, lawnmowers, and motorcycles.

No, they don't build houses like they used to. But there is no reason to move backward to construction methods of the past. After all, many of those old houses were drafty and expensive to heat—and with today's labor costs, they would be very expensive to build. Plywood, drywall, caulking, and insulation were invented to lower the cost of housing, and to improve comfort and quality. The problem is that the inventors of these products often didn't consider about the health implications of what they were doing.

Post 1970s

When the world was hit with an energy crisis in the 1970s, millions of people added insulation and tightened up their houses. Weatherization programs helped homeowners seal up many of the cracks in their houses that air used to leak through. In order to save energy, we sealed ourselves inside our homes with no fresh air—we might as well have placed plastic bags over our heads. Without a doubt, saving energy is definitely a good idea. And tight construction is also a good idea. But fresh air is an even better idea. And the good news is that all three *can* be combined into a properly designed healthy house. After all, space capsules and submarines are among the best-insulated, tightest "houses" ever constructed, and the air quality in them is better than the air in many residences. That's because NASA and the Navy both use healthy materials. They also utilize exotic air-cleaning equipment, some of which is beyond what the average homeowner can afford—but some of their technology is reasonably priced. The bottom line is this: there are ways to have fresh air *and* low energy bills.

Modern Furnishings

It's amazing how many of our modern furnishings could not have existed a century ago. Synthetic fabrics, polyester padding, urethane foam, plastic tables, plywood shelving, plastic television cabinets, and sophisticated electronic equipment all have the potential to release pollutants into the indoor air. In fact, consumer products and activities are major sources of indoor pollution.[29]

Washing machines smell like synthetic detergent. Dryers smell like fabric softener. There is mold in the drip pan under a self-defrosting refrigerator. Mattresses are treated with flame retardants, and pillow cases are treated with formaldehyde. The paint on the wall is a potentially dangerous chemical soup. Many people are being made ill by all these modern furnishings—but most aren't aware of the cause-and-effect relationship. They often live with the muscle aches, run-down feeling, depression, and anxiety without realizing how their home is affecting their health.

Several mail-order companies now specialize in healthy furnishings. Some actually offer mattresses, upholstery fabric, and stuffing made from organically raised cotton.[30]

Modern Cleaning Products

There is an insidious list of pollutants under most kitchen sinks, in laundry rooms, and on shelves in garages. Detergents, spot cleaners, ammonia, scouring powder, dish-washing liquid, drain cleaners, insecticides, mouse poisons, hair spray, air fresheners, cosmetics, antiperspirants, soaps, shampoos, mouthwash, disinfectants, glass cleaners, mothballs, bleach, and fabric softeners all have the potential to contaminate our indoor air. As a result, many people are now demanding healthier products. And there *are* many less-offensive alternatives to the hazardous, toxic chemicals we have gotten used to.[31] These alternatives are not only more healthful, some are less expensive and work better.

Many synthetic cleaning products are considered household hazardous waste. They cannot legally be placed in sanitary landfills, yet we fill our homes with their odors.

Our Surroundings

In the past, most people lived in rural areas. As cities began to expand, diseases became more prevalent as more and more people lived closer and closer together. Streets and streams became open sewers. Water supplies became tainted. Because everyone needed a fire to keep warm and for cooking, the air began to be fouled as well. Today, we have the addition of automobile exhaust, factory emissions, lawn chemicals, agricultural chemicals, and cleaning chemicals.

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[29] L. Wallace, "A decade of studies of human exposure: What have we learned?," *Risk Analysis* 13 (April 1993): 135-139.

[30] Lynn Marie Bower, *Creating a Healthy Household: A complete guide for creating a healthy indoor environment* (Bloomington, IN: The Healthy House Institute, 2000).

[31] *Ibid*.

One study found that people living in polluted cities have a lower life expectancy.[32] So much so, in fact, that a person living in Washington, DC loses a year in life expectancy compared to a person living in Topeka, Kansas—simply because of outdoor pollution. It's more than likely that indoor air pollution takes a similar toll.

Outgassing

Outgassing refers to the release of gases during the aging and degradation of a material. These volatile organic compounds (VOCs) can negatively affect our health. New-car smell, and the film that forms on the inside of an automobile's windshield, are a result of outgassing from the plastic interior. The synthetic fabric, vinyl, and cushioning are, in effect, evaporating various gases into the air we breathe. It has been reported that the VOC level inside a new car can be dozens of times higher than the level recommended in indoor air.[33] Common VOCs found in cars include aldehydes, alcohols, plasticizers, aromatics, and alkanes—many of the same chemicals found in houses.

Most of the modern materials created in the last fifty years outgas to some degree. Synthetic carpeting, paints, adhesives, kitchen cabinets, and wall paneling have all been implicated. This outgassing is a universal component of indoor air pollution and it can easily result in sinus and lung irritation. Some of the chemicals released are so powerful they can damage the immune system. Formaldehyde is probably the most studied chemical outgassed by modern building materials—but there are many others that have hardly been studied at all. Outgassing can also sometimes damage antiques and art objects. When the Smithsonian Institution's curators transport artifacts for traveling exhibitions, they carefully monitor the inside of the enclosed packing crates to make sure the outgassing isn't damaging delicate objects.[34] Most of the materials recommended in this book have been shown to have minimal outgassing characteristics.

A Canadian study that examined the VOC levels in new houses found that as soon as the occupants moved in, the total level of VOCs rose slightly.[35] This was due to such things as occupant activities, furnishings, and cleaning products. The study also found that levels dropped to about half the pre-occupancy level after about six months, primarily due to the aging of outgassing sources such as carpeting, paints, and formaldehyde sources like kitchen and bath cabinetry. This study also found that ventilation had little effect on VOC levels—that removing the source of the VOCs would be more effective than ventilation in reducing overall levels.

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32 C. Arden Hope, "Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults" *American Journal of Respiratory and Critical Care Medicine* 151 (March 1995): 669-674.

33 Indoor air pollution in automobiles," *airfAQSExtra, Laboratory services Technical Update*, Air Quality Sciences, Inc. Atlanta, GA (Volume 6 Issue 1).

34 "The nations treasures take to the highway for a 12-city tour," *Smithsonian* (May 1996): 48-59.

35 "Pollutant source strength in new houses," *Solplan Review* (January 1998): 10-11.

There was an interesting study, undertaken to see how chemicals commonly found in the indoor air would affect telephone components and switching equipment, that has important implications for all aspects of the indoor environment.[36] It was learned that there are definitely chemical reactions continually taking place in the indoor air between the various pollutants that are present. As a result of these reactions, there are VOCs and other compounds being created that weren't there before. And these new compounds react with each other to create even more compounds. Thus, the indoor environment can be extremely complex, and it can be compared to a chemistry experiment in which dozens of random chemicals are combined without having any idea what will result. And this is the environment we are living in every day. As an example of what can happen, this report found that, if there are only 20 parts per billion of ozone in indoor air having an average level of ketones present, then irritating hydroxyl radicals will be formed. In fact, the concentration of hydroxyl radicals will be a whopping 10,000 times higher than if no ozone were present.

Many materials can absorb, then re-emit, various VOCs. This is called the sink effect, and because of it, you can remove a material that has been outgassing VOCs into the indoor air, and still have VOCs present because they were stored and released by other materials. Re-emissions from sink materials can result in longer exposures than would occur in the absence of sinks.[37] Carpet, draperies, furnishings, wood, and gypsum wallboard all act as sinks. One study found that carpet and drywall acted as sinks for specific VOCs found in latex paint, and that the VOCs were released very slowly, at very low rates.[38] This study predicted that it would take years for all the VOCs to be released, and that different VOCs are absorbed and released at different rates. Gypsum wallboard is a much stronger sink for formaldehyde than for other VOCs.[39]

Testing for outgassing is often done in special chambers that allow scientists to accurately determine exactly what chemicals are given off by different substances. There are a number of these chambers around the country and they are revealing frightening information about the modern materials we take for granted. An early leader in this research was NASA.

National Aeronautics & Space Administration

NASA has done extensive research into the outgassing of materials used in spacecraft. They are interested in how these chemicals effect the sensitive electronic and optical equipment—and also the health of the astronauts. Because astronauts must

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36 "Indoor chemical reactions provide challenges to researchers," *IEQ Strategies* (June 1997): 10-11.

37 "Predicting the behavior of indoor sinks," *Inside IAQ* (Spring/Summer 1993): 8. #EPA/600/N-93-010.

38 "VOC emissions from latex paint: Sink effects," *Inside IAQ* (Spring/Summer 1997): 1-4.

39 "Sorption and re-emission of formaldehyde by gypsum wallboard," *Inside IAQ* (Spring/Summer 1993): 8. #EPA/600/N-93-010.

perform many varied and detailed operations while on an expensive mission, NASA is very concerned about impairment of function. An unhealthy atmosphere inside a spacecraft can mean the crew won't be able to perform at peak efficiency.

Virtually everything that goes into a spaceship has been tested for its particular outgassing characteristics. Everything from fabric, paint, and caulking to adhesives, plastics, and foams is included in a computerized database. Some items—such as cameras, tapes, shaving cream, deodorants, *etc*.—are things found in the private sector, but many items are specialized and used only in the space program.[40]

NASA's outgassing testing is done in a closed chamber in which individual items are heated to a temperature of 120°F for 72 hours. This causes the volatile gases to be released at an accelerated rate. The gases are then analyzed and quantified. Vacuum testing involves placing materials in a similar chamber where a vacuum actually sucks out the various volatile chemicals that would normally outgas at a much slower rate. Actual air samples taken during space flights are also analyzed. A typical computer printout will list a material's name, the manufacturer, a generic description, testing data, and the chemicals that were outgassed, with amounts. As an example, one particular adhesive was found to give off the following gases:[41] Carbon monoxide, C5 saturated & unsaturated alpihatic hydrocarbons. Formaldehyde, Acetaldehyde, 2-butanone, Methanol, Methyl propionate, Methyl formulate, Benzene, Ethanol,Methyl isobutyrate, 2-propanone, Methylbenzene, 2-propanol, Hexamethylcyclotrisiloxane.

Obviously, there is a lot of valuable information in NASA's database. However, much of it is useful only to the space program, because many of the materials tested are not available to the general public. Actually, many of the products we routinely build houses of simply cannot be used in a spacecraft because of excessive outgassing. For example, residential fiberglass insulation outgases too much formaldehyde to be used by NASA, yet we continue to install it in our homes every day—without taking any special precautions. As with much of the information gained by the space program, this data will undoubtedly lead to many applications in the private sector.

Environmental Protection Agency

The **EPA** has sponsored a great deal of research on indoor air quality. This is done to better transfer valuable data to researchers, policy makers and consumer's groups. Although not responsible for *regulating* indoor air quality, the **EPA** has been mandated to *study* the subject. Their research includes measurement and monitoring, health effects, and source information.

The **EPA**, and private laboratories, have developed various testing procedures for analyzing the outgassing from building materials and household products. Large chambers are available for evaluating pieces of furniture, while small chambers are used

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40 Haluk Ozkaynak and P. Barry Ryan, "Sources and emission rates of organic chemical vapors in homes and buildings" (*Berlin: Proceedings of the 4th International Conference on Indoor Air Quality & Climate, Vol. 1, Volatile Organic Compounds, Combustion Gases, Particles and Fibers, Microbiological Agents*, 1987): 3-7.

41 MDAC-Houston Materials Testing Data Base, Report # 85-19534 01, (Tra Bond F113/F117-STEX), NASA computerized database.

for samples of various materials. This research is yielding data that is more pertinent to residential applications than NASA's research. Emissions and outgassing characteristics from such things as kerosene heaters, vinyl floor tiles, gas ranges, wall paneling, ceiling tiles, and wood stoves have all been studied.

Over the years, the **EPA** has also assembled extensive bibliographies and literature reviews that are available to researchers in the field.[42] This has recently been made available in a computerized database that contains reports and data from all over the world.[43]

Animal Testing

Often, when a material is analyzed for its outgassing characteristics, the result is a list of a dozen or more chemical compounds. Some of these compounds may have been studied extensively, but many have totally unknown health effects. To learn more about health effects, some labs are exposing animals to various pollution sources. The results can be alarming.

A typical test involves placing a sample of a material, inside a glass chamber, like an aquarium. A heating pad is placed under the chamber to warm the sample slightly—body temperature of 98.6°F is typical. Then air is blown through the chamber into another chamber containing mice. The test usually involves one hour of exposure, twice a day, for two days—in other words, 4 hours of exposure over a 48 hour period. When mice have been exposed to some carpet samples in this way, they actually died. This type of carpet testing is covered in more depth in *Chapter 18, Flooring*.

Major Indoor Pollutants

Many books and articles on indoor air pollution only deal with a handful of substances that can affect health. The major indoor air pollutants are usually listed as: carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen dioxide, asbestos, radon, particulates, ozone, and formaldehyde. These indoor air pollutants have been studied fairly extensively and their effects are pretty well agreed upon. They are, in fact, the major indoor pollutants. But there are actually thousands of other different pollutants that can be found in the indoor air. In fact, a typical house may contain a hundred or more different contaminants floating around at any one time.

Air pollutants are often divided into two major categories: gases and particulates. This is particularly useful when talking about air filters because there are two basic types of filters: particulate filters and gas-removal filters.

Some indoor air pollutants are said to be *organic chemicals* or *hydrocarbons*. An organic chemical, by definition, is a compound that contains carbon in combination with other atoms. Formaldehyde is one of the most commonly encountered organic chemicals. It contains one carbon atom, two hydrogen atoms, and one oxygen atom. A hydrocarbon

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[42] Environmental Protection Agency (EPA), *Bibliography on Indoor Air Pollution* (Washington, DC: EPA, June 1985). #EPA/IMSD-85-002.

[43] *Indoor Reference Bibliography* (Research Triangle Park, NC: National Center for Environmental Assessment). Contact: Beverly Comfort @ 919-541-4165.

is a type of organic chemical that contains only atoms of carbon and hydrogen. Benzene is a hydrocarbon containing 6 carbon atoms and 6 hydrogen atoms.

A complete list of all the possible indoor air pollutants would take many pages and would be meaningless to anyone but a research chemist. Some of the pollutants can resemble alphabet soup more than chemicals we breathe every day inside our homes: aliphatics, alkylbenzenes, keytones, polycyclic aromatics, chlorinated hydrocarbons, terpenes, alkanes, xylene, butyl acetate, ethoxyethyl acetate, *etc*. The health effects of many of these chemicals are poorly understood, yet there are countless people who have eliminated them from their lives and seen dramatic improvements in their health. Let's take a closer look at some of the major indoor pollutants.

Gases

By definition, a gas is a formless fluid that fills the space that contains it. Our atmosphere is composed primarily of the gases nitrogen and oxygen—but there are also a variety of other gases in the air. Some are the result of natural processes such as animal and human metabolism, or geographic phenomena such as volcanoes or swamps. Combustion gases have been around for years, but they are often concentrated inside tight, poorly ventilated houses. In recent years, gases released from manufactured products have been gaining a great deal of attention—and little of it is good news.

Volatile Organic Compounds (VOCs)

Volatile organic compounds, or VOCs, are common indoor air pollutants. Being volatile, they evaporate easily, and being organic, they contain carbon.

VOCs can originate from a variety of natural sources. The characteristic odor of mold is composed of VOCs, as is the smell of an orange or an onion. Baking bread also releases VOCs into the air. Indoor air typically contains 30-100 different VOCs that are readily measurable,[44] and others at low levels that are more difficult to measure. Some VOCs cause no health problems, but others are serious indoor air pollutants.

VOCs are also given off, or outgassed, from many manufactured products. Familiar sounding VOCs might include benzene, xylene, toluene, formaldehyde, and ethanol. These can all be released from typical building materials. One study determined that the following were the most common VOCs found in indoor air:[45] benzene, toluene. exlenes, styrene, ethylbenzene, ethyl methly benzenes, trimethyl benzenes, dimethyl-ethylbenzenes, naphthalenes, propyl-methylbenzenes, *n*-propyl benzene, diethyl benzenes, tetrachloroethylene, 1,1,-trichloroethane, trichloroethylene, dichlorobenzenes, trichlorofluoromethane, dichloromethane, chloroform, ethyl acetate, *m*-hexyl butanoate, 2-ethyl-1-hexanol, *n*-hexanol, 2-butyloctanol, *n*-dodecanol, *n*-nonanal, *n*-devanal, acetone, acetic acid, dimethylphenols, ethylene oxide, undecane, 2-methylhexane, 2-methylpentane, 3-methylhexane, 3-methylpentane, octane, decane, dodecane, tridecane,

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44 "VOC exposure metrics and 'sick building syndrome'," *Center for Building Science Newsletter* (Fall 1995): 6-7.

45 L.S. Sheldon and others, *Project Summary, Indoor Air Quality in Public Buildings: Volume 1* (Washington, DC: Environmental Protection Agency, Sept. 1988). #EPA/600/S6-88/009a.

methylcyclohexane, heptane, tetradecane, 2-methylheptane, cyclohexane, pentadecane, hexane, eicosane, 3-methylnonane, and 1,3-dimethyl-cyclopentane.

Because there are so many different VOCs found indoors, and because so few of them have been studied thoroughly, it's often easier for scientists to talk about the TVOC or *total VOC* concentration. This can be useful for cataloging, but it does nothing to identify the health effects attributable to specific compounds. One source has suggested that 200 micro grams per cubic meter ($\mu g/m^3$) is a level that has no effect on most people,[46] however some sensitive people could react to that level. Outdoor TVOC levels are generally about 100 $\mu g/m^3$, and one Canadian study found that indoor levels ranged from 100 to 100,000 $\mu g/m^3$, although most homes registered in the 1,000-3,000 $\mu g/m^3$ range.[47]

Formaldehyde

Formaldehyde is one of the most insidious of all the indoor air pollutants. It is also one of the most studied. Many people are under the impression that it's the cause of the majority of indoor air quality complaints. They are often surprised to learn that it's simply one of hundreds of different volatile organic chemicals polluting our indoor air.

Formaldehyde is very cheap to produce and it can be used in a wide variety of applications. It's used for embalming fluid and it can be released from products such as permanent-press fabrics, carpeting, particle board, plywood, insulation, paints, shampoos, and plastics. It's also found in tobacco smoke. With six-billion pounds being produced annually,[48] formaldehyde is a very difficult chemical to avoid.

Formaldehyde is colorless and it has a pungent odor only at very high concentrations. At the low concentrations often found indoors, it is odorless. Symptoms of exposure can vary considerably, ranging from burning of eyes, tightness in chest, and headaches, to asthmatic attacks, depression, and death. Symptoms typically start to occur at concentrations above 0.10 parts per million (ppm), and short-term exposures at 0.20 ppm can often be tolerated by healthy people.[49] But sensitive individuals often react to levels as low as 0.03 ppm—sometimes less. Acute symptoms have been observed in some people to as little as 0.01 ppm over a 5-minute period.[50]

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[46] Lars Molhave, "Volatile organic compounds" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 5, Plenary Lectures*, 1990): 15-33.

[47] Y. Tsuchiya and M. Kanabus-Kaminska, *Volatile organic compounds in the Canadian indoor air* (Ottawa, ON, Canada: National Research Council, Canada, 1990).

[48] Peter Fossel, "Sick House Blues," *Harrowsmith (U.S.)* (September/October 1987): 46-55.

[49] E. Neil Schachter and others, "A Study of Respiratory Effects from Exposure to 2 ppm Formaldehyde in Healthy Subjects," *Archives of Environmental Health* 41 (July/August 1986): 229-239.

[50] Irene Wilkenfeld, "Formaldehyde: A Dangerous Chemical," *The Human Ecologist* (Winter 1989): 18-19.

A survey of air samples taken from homes in southern Louisiana revealed that 74% contained detectable levels of formaldehyde. This study also found that approximately 60% of the samples containing formaldehyde had concentrations that were above recommended guidelines, some had concentrations over 5 times higher.[51]

Menstrual disorders of various types have been associated with formaldehyde exposure[52] and it has been shown to be a potent sensitizer. This means exposure to formaldehyde can cause an individual to become sensitive to other chemicals that were previously not problematic. The effects of this can be devastating, and many people have been forced to move out of their homes into almost sterile environments in order to regain their health. According to one source, "repeated exposure to high levels, or chronic exposure to elevated levels…seems to be sufficient to trigger hypersensitivity."[53] An article in the *Journal of the American Medical Association* says "it has been suggested that between 4% and 8% of the population could become sensitized to formaldehyde and experience increasingly severe and prolonged reactions to diminishing levels of the substance."[54] Other sources suggest that 10-20% of the population could be susceptible to formaldehyde at low concentrations.[55]

Formaldehyde has been shown to be carcinogenic and mutagenic in animals and, because animal studies can often be extrapolated to include human beings, as early as 1981 the National Institute of Occupational Health and Safety (NIOSH) recommended that "formaldehyde be handled as a potential occupational carcinogen."[56] However, in spite of long-term cancer concerns, it's becoming apparent that the chronic irritating symptoms associated with residential exposures, and the sensitizing characteristics, are a

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51 R. Lemus, A.A. Abdelghani, T.G. Akers, and W.E. Horner, "Potential health risks from exposure to indoor formaldehyde," *Reviews of Environmental Health* (January-June 1998): 91-98.

52 Thad Godish, *Indoor Air Quality Notes: Formaldehyde—Our Homes and Health #1, 2nd Edition* (Muncie, IN: Ball State University Department of Natural Resources, Summer 1989).

53 David Rousseau and W.J. Rea, *Your Home, Your Health, and Well-Being* (Berkeley, CA: Ten Speed Press, 1988): 43-44.

54 Phil Gunby, "Fact or Fiction about Formaldehyde?," *JAMA* 243 (May 2, 1980): 1697.

55 Mike Nuess and Stan Price, *Indoor Air Pollutant Fact Sheet: Formaldehyde* (Seattle: Washington Energy Extension Service, December 1987).

56 National Institute for Occupational Safety and Health, *Formaldehyde: Evidence of Carcinogenicity* (Cincinnati, OH: Department of Health and Human Services, Centers for Disease Control, April 15, 1981). Current Intelligence Bulletin 34, DHHS (NIOSH) Publication #81-111.

very real and more-immediate public-health problem.[57] Through irritation alone, formaldehyde impairs the upper respiratory tract's mucous membranes, whose primary function is to protect the body from foreign particles and bacteria.[58]

While formaldehyde levels in homes will decrease considerably with time, if a person has become sensitized to its effects, there may be no corresponding decrease in symptoms. The half life of formaldehyde outgassing ranges up to 6 years, but this can vary substantially, depending on the particular product and the geographic location.[59] As an example, emissions from a formaldehyde source with a half life of 3 years will be reduced to approximately 6% of the original level after a 12 year period. But if the half life is 6 years, it will take a total of 24 years to reach the 6% reduction level of emissions. A study conducted by the **Bonneville Power Administration** found that an initial concentration of just over 0.12 ppm was only reduced to 0.08 ppm after 4 years and to 0.07 ppm after about 8 years.[60]

The best method of controlling formaldehyde (and most other pollutants for that matter) involves actually removing the source from the house. This can be quite expensive if the source is insulation, particle-board subflooring, or kitchen cabinets. Because the outgassing rate is dependent on temperature and humidity,[61] lowering the thermostat or using a dehumidifier can sometimes reduce emissions significantly. Outgassing rates can be several times higher during a hot humid summer than in a cold dry winter.[62] Some sealants can be partially effective, as can air filters, and increased ventilation rates can help by diluting the concentration, but the best method of reducing concentrations is removing the source.

There is an ammonia fumigation method of permanently reducing the high formaldehyde levels often found in mobile homes. This process uses a very strong, toxic, ammonia solution (not household ammonia) and it has resulted in a 60% reduction in formaldehyde levels.[63] Because this procedure itself is potentially so toxic, it should only be done by a qualified person wearing an appropriate respirator, and the house will need to remain unoccupied during the treatment. Ammonia fumigation will result in a fine dust

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[57] Thad Godish, *Indoor Air Quality Notes: Formaldehyde—Our Homes and Health #1* (Muncie, IN: Ball State University Department of Natural Resources, Summer 1986).

[58] "Formaldehyde and mobile homes," *Safe Home Digest* (January/February 1992): 6.

[59] Godish, *Indoor Air Notes #1*.

[60] "Formaldehyde Emissions," *Builder* (January 1992): 328.

[61] Beat Meyer, "Formaldehyde Exposure From Building Materials," *Environment International* 12 (1986): 283-288.

[62] Vincent Garry and others, "Formaldehyde in the Home: Some Environmental Disease Perspectives," *Minnesota Department of Health* (February 1980): 107-111.

[63] Thad Godish, *Indoor Air Quality Notes: Residential Formaldehyde Control #2* (Muncie, IN: Ball State University Department of Natural Resources, Summer 1986).

of hexamethylenetetramine settling on interior surfaces. This is the end product of the reaction between the formaldehyde and the ammonia and should be thoroughly cleaned up after treatment. Because the ammonia is so strong (28-29%), and dangerous to handle, the **CPSC** does not recommend this treatment method.[64]

Ozone

Ozone is a naturally occurring oxygen compound that exists in the upper atmosphere. High above the planet, ozone is beneficial to our health because it blocks a certain amount of the sun's ultraviolet light from reaching the earth's surface. In the lower atmosphere, ozone is not so beneficial. It's one of the components of smog that can prompt an outdoor pollution alert in a major city, such as Los Angeles. When ozone levels are high outdoors, citizens are urged to stay indoors.

Ozone is a highly reactive gas with a pungent odor that can cause coughing, choking, headaches, and severe fatigue.[65] Other symptoms include eye, skin, and mucous-membrane irritation. It can cause a breakdown of red blood cells which can contribute to breathing difficulties. Blurred vision and chromosomal aberrations have also been noted. Art galleries have reported that ozone can lead to deterioration of artwork.[66]

Ozone can occur in the indoor air as a result of ultraviolet light, sparks from electric motors, electronic air cleaners, or negative-ion generators. It can also be given off by copying machines and laser printers. It's sometimes added to the air on purpose with ozone-generating machines, something indoor air experts generally agree is not a good idea.

Pesticides

Most pesticides are complex compounds that can release various gases over their life. In *Safety at Home,* **Beyond Pesticides/National Coalition Against the Misuse of Pesticides** reported that consumers in the U.S. buy and use a phenomenal 285 million pounds of toxic pesticides every year. The Coalition says these chemicals "are nerve poisons, can cause cancer, respiratory problems, birth defects, genetic damage, injure wildlife, and pollute the environment and drinking water."[67] According to the **EPA**, the general public is often misinformed or misled about the risks of pesticide exposure.[68] There are pesticides that have been banned in the U.S. that are still on some of our shelves—in 1992 it was estimated that 1 million households still had products containing

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[64] Consumer Product safety Commission (CPSC), *An Update on Formaldehyde* (Washington, DC: CPSC, October 1990): 11.

[65] Rena Corman, *Air Pollution Primer* (American Lung Association, 1969): 44.

[66] Judith A. Douville, "The Chemical Nature of Indoor Air Pollution," *Dangerous Properties of Industrial Materials Report* (May/June 1984): 2-8.

[67] National Coalition Against the Misuse of Pesticides, *Safety at Home* (Washington, DC: National Coalition Against the Misuse of Pesticides, 1991).

[68] Environmental Protection Agency (EPA), *Nonagricultural pesticides: Risks and regulations* (Washington, DC: EPA, April 1986). #GAO/RCED-86-97.

chlordane and 150,000 had products containing DDT.[69]

When used indoors, pesticides can be serious indoor air pollutants. After all, pesticides are formulated to kill living creatures, and they don't always distinguish very well between humans, pets, and pests. The greatest danger is just after a pesticide has been applied, but it's been found that house dust can be a significant reservoir for older pesticides, and a major contributor to human exposure—especially for infants and toddlers.[70]

Using pesticides outdoors often isn't much better. This is particularly true for lawn chemicals because, when applied, the overspray can drift with the wind onto food crops, through open windows, or onto people who happen to be downwind.[71] Lawn chemicals can also be tracked indoors on shoes, and be sucked indoors through foundation cracks if the lower part of a house is depressurized. One study found that children whose yards were treated with chemicals were 4 times as likely to be diagnosed with soft-tissue sarcomas.[72]

Fortunately, there are a wide variety of less-toxic methods of pest control that can be used in many routine residential applications. One the best comprehensive sources is a book titled *Common-Sense Pest Control*.[73] The **Bio-Integral Resource Center (BIRC)** and **Beyond Pesticides/National Coalition Against the Misuse of Pesticides** both offer very good information on less toxic pest control.

When chemical controls *are* necessary, you should use the least-toxic product, in the lowest dose, and take care to apply it carefully and according to the manufacturer's instructions.[74] If you suspect pesticide poisoning, or need information about a particular pesticide, you can call the **National Pesticide Telecommunications Network** at 800-858-7378 any time of the day or night, 365 days a year. At the same location, there is also a **National Antimicrobial Information Network (NAIN)** at 800-447-6349.

Of course, not all pesticides are especially toxic to humans. For example, boric acid is often used to poison ants and cockroaches, yet it is not particularly dangerous to

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69 Environmental Protection Agency (EPA), *National home and garden pesticide survey, Final report: Executive summary* (Washington, DC: EPA, March 1992). #RTI/5100/17-03F.

70 Environmental Protection Agency (EPA), *Project Summary: Nonoccupational Personal Exposure Study (NOPES)* (Washington, DC: EPA, April 1990). #EPA/600/S3-90/003.

71 Robert Abrams, *Lawn care pesticides: A guide for action* (Albany, NY: NY State Department of Law, Environmental Protection Bureau, May 1987).

72 J.K. Leiss and D.A. Savitz, "Home pesticide use and childhood cancer: A case-control study," *American Journal of Public Health* 85 (February 1995): 249-252.

73 Olkowski, William, Sheila Daar, and Helga Olkowski *Common-Sense Pest Control* (Newton, CT: The Taunton Press, 1991).

74 Environmental Protection Agency (EPA), *Citizen's Guide to Pesticides* (Washington, DC: EPA, September 1989). #OPA 008-89.

people. In fact, healthy-house builders often sprinkle boric-acid powder inside wall cavities, as a preventative measure, before the drywall is installed. That way it will always be there to act as a deterrent to insects yet, because it doesn't outgas anything, it won't effect the occupants. Nationally distributed brands of boric-acid powder include **Woodstream Corp.** (Victor Roach Killing Powder) and **Copper Brite, Inc.** (Roach Prufe). They are often available in hardware stores.

Combustion Gases

There are a number of gases formed during combustion, and the material being burned will determine the specific gases and their concentration. The most common combustion gases found in houses are released during the combustion of heating fuels. When synthetic or plastic materials burn during a house fire, they can release extremely toxic gases—something firefighters routinely protect themselves against.[75]

Carbon monoxide (CO) is produced by the incomplete combustion of materials such as natural gas, wood, coal, oil, kerosene, gasoline, and tobacco. It is colorless, odorless and especially deadly. This is because the hemoglobin in our blood takes up carbon monoxide much more readily than oxygen. In other words, our blood prefers to attach to carbon monoxide molecules rather than oxygen molecules. This means that small amounts of carbon monoxide in the air can lead to an oxygen deficiency in the bloodstream. This can result in impaired vision and brain function, irregular heartbeat, headaches, nausea, weakness, confusion, and death. When a wood-burning fire dies down to glowing coals, a great deal of CO is produced.

Carbon dioxide (CO_2) is also colorless and odorless. It is formed during the combustion of carbon-containing fuels and as a result of normal human metabolism. Every time we exhale, we add more carbon dioxide to the air. Unvented kerosene space heaters can introduce very high levels, causing symptoms such as headaches, loss of judgment, dizziness, shortness of breath, or asphyxiation. Fortunately, the level of carbon dioxide found in most houses is not considered dangerous, but it can result in stuffiness.

Sulfur dioxide (SO_2) is produced when sulfur-containing fuels are burned. It is colorless and can have an odor, depending on the concentration. Sources include kerosene space heaters, natural-gas or fuel-oil appliances, wood stoves, and fireplaces. When it comes in contact with moist mucous membranes, sulfur dioxide forms sulfurous acid, which can be quite irritating.

Nitrogen dioxide (NO_2) sources include natural-gas and fuel-oil appliances, kerosene heaters, wood burning, and cigarettes. NO_2 is highly toxic, irritating, has a pungent odor, and is reddish brown in color. Health effects include burning and choking sensations in the upper respiratory tract, changes in sensory perception, and irritation of eyes and skin. Combustion by-products are covered in more depth in *Chapter 25, An in-depth evaluation of six common pollutants*.

Particulates

Particulates are tiny particles floating around in the air. They can be composed of biological materials such as mold spores, pollen grains, or dust-mite feces; minerals such

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[75] Gerald Lionelli, "Chemical Exposure in Firefighting: The Enemy Within," *Fire Engineering* (February 1987): 38-43.

as asbestos or fiberglass fibers; or metals such as lead or arsenic dust. House dust is typically made up of all these materials, as well as tiny cotton fibers, human hair and skin flakes, fibers from clothing, bits of soil, aerosols from cleaning compounds, waxes, and food particles.[76] Wood and tobacco smoke are significant sources of particulates. Cigarette smoke can contain highly toxic heavy metals such as cadmium and radioactive polonium.

Larger particulates are often filtered out of the air by the nose and sinuses, but the smallest ones travel deeply into the lungs where they can lodge and irritate sensitive tissue.[77] About forty pounds of particulate dust will settle in an average six room home every year.[78]

Biological Pollutants

We are exposed to many different biological pollutants indoors, and they can cause a wide variety of symptoms. Mold spores from damp building materials, pollen from house plants, even dead-cockroach body parts, are responsible for typical allergic symptoms—such as runny nose and congestion—in tens-of-millions of people, as well as asthmatic symptoms. At least 30 species of bacteria that are pathogenic to humans have been isolated from cockroaches alone.[79]

Biological pollutants can also cause devastating symptoms. Legionnaire's disease, a vivid example, has certainly taken its toll in human life. Some molds can be equally deadly and an asthmatic attack due to exposure to various indoor particulates can be quite frightening. There were 4,580 asthma-related deaths in the U.S. in 1988.[80] And the incidence is rising—today, asthma affects some 3.7 million children, up from 2.4 million in 1980.[81] There were at least 34 cases of infants in Cleveland Ohio in 1993 due to *Stachybotrys atra* mold.[82]

Dust-mite allergy affects approximately 10% of the population. If the relative

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[76] Environmental Protection Agency (EPA), *Preliminary Indoor Air Pollution Assessment, Appendix A* (Washington, DC: EPA June 1987): 2.103. # EPA-600/8-87/014.

[77] W.K.C. Morgan, "The Respiratory Effects of Particles, Vapours, and Fumes," *American Industrial Hygiene Association Journal* 47 (1986): 670-673.

[78] "Dust to Dust," *USA Today*, October 28, 1986, D1.

[79] Richard Brenner, "Insect pests, Construction practices and humidity" (Washington, DC: *Proceedings of the Bugs, Mold, and Rot Workshop Sponsored by the Building Thermal Envelope Coordinating Council of the National Institute of Building Sciences*, May 20-21, 1991): 19-26.

[80] Williams, Gurney, "Allergy Proofing Your Home," *Practical Homeowner* (February 1991): 22–24.

[81] "Childhood Asthma Linked to Indoor Pollution," *The Delicate Balance* #1–2 (1992): 3.

[82] "Black mold linked to deaths in Cleveland," *Environmental Building News* (March 1998): 4-5.

humidity (RH) is kept blow 40-50%, the mites in their active life stages will die. Mites in their inactive life stages will not be killed at this RH, but they will remain inactive, and won't be a problem—unless the RH rises again. In old, leaky, drafty houses, the RH can get as low as 15-20% in the winter which is enough to kill the inactive stages, so those houses often don't have significant dust-mite problems in cold months.[83] While chemical controls are possible, the best method of controlling dust mites is to lower the RH.

Biological pollutants are often attacked with toxic chemical poisons. If this has been the case in your home, health-related information about the specific chemicals that were used can be obtained from the **National Antimicrobial Information Network (NAIN)** at 800-447-6349.

Mold is one of the most common biological pollutants found in houses, and it affects the health of millions of people. Dealing with a mold problem is covered in depth in *Chapter 25, An in-depth evaluation of six common pollutants*.

Asbestos

Asbestos is a mineral that will separate into strong, thin fibers. Because of its durability and heat-resistant qualities, it's been incorporated into a wide variety of products. Nearly thirty-million tons have been used in the U.S. since about 1900, but it has not been used in building materials since the 1970s. Asbestos was once widely used in insulation, vinyl floor tile, and drywall joint compound.

Inhaling asbestos particles can result in asbestosis—a serious lung disease—or various forms of cancer. Unfortunately, lung problems may not be apparent until 15-20 years after exposure.

In many of its uses, it's highly unlikely that asbestos will cause any health problems. For example, if an asbestos-containing product is solid, and not disintegrating, it probably won't release any fibers. However, there are many other applications where microscopic particles can be released into the air. In a number of cases, schools, libraries, offices, and hospitals have had to be closed due to airborne asbestos.

Asbestos removal and cleanup can be an involved process, requiring great care.[84] If removal is necessary, the **CPSC** has a free booklet, *Asbestos in the Home*, that lists general guidelines. They stress that anything containing asbestos fibers should be moistened before removal in order to prevent the very small particles from becoming airborne.[85] A more comprehensive booklet is available from the **EPA**.[86] Sometimes the best thing to do is to leave asbestos alone and cover it with an encapsulating sealant to

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[83] Ken Gehring, "Year-Round Humidity Control in the Energy Efficient Home" (Indianapolis, IN: *Proceedings of the 9th Annual International Energy Efficient Building Conference*, March 21-23, 1991): C24-C38.

[84] Environmental Protection Agency (EPA), *Asbestos Fact Book* (Washington, DC: EPA, August 1985).

[85] Consumer Product Safety Commission (CPSC), *Asbestos in the Home* (Washington, DC: CPSC, August 1982): 10.

[86] Environmental Protection Agency (EPA), *Guidance for Controlling Asbestos-Containing Materials in Buildings* (Washington, DC: EPA, 1985). EPA 560/5-85-024.

hold the loose fibers in place. For specific guidance on how to deal with asbestos, see *Chapter 25, An in-depth evaluation of six common pollutants*.

Metals

One of the most common metallic pollutants in houses is lead. In fact, lead paint can be found in millions of homes. Lead-painted windows can be a special problem because, as they are raised and lowered over the years, the lead paint erodes, and a considerable amount of powdery lead dust settles on the sill and floor. Children can easily get this toxic powder on their fingers and into their mouths.

A great deal of lead paint has been applied to the outside of thousands of houses, where it chalks off, contaminating the soil with lead dust. The lead dust then gets tracked indoors on shoes and builds up in the carpeting where playing children get it on their hands and into their mouths. This normal hand-to-mouth activity can lead to permanent brain damage.[87] It's often surprising to realize that children tend to ingest more lead by coming in contact with lead dust that has settled on window sills and in carpeting, than by chewing on lead-painted woodwork. See *Chapter 25, An in-depth evaluation of six common pollutants* for more information about problems related to lead exposure, testing, and abatement options.

As recently as 1989, toxic mercury compounds were used as fungicides in interior paints and drywall joint compounds. It's still possible to buy exterior paint containing mercury, and other heavy metals such as cadmium are occasionally used in interior formulations. Even the mercury in thermometers has the potential to be dangerous. It's been noted that, if 5 grams of mercury (the amount in two normal thermometers) is lost in a room and is not cleaned up, it will slowly evaporate and contaminate the indoor air more than the World Health Organization's 24-hour/7-day exposure limit—and the house will remain contaminated for seven years![88] Mercury is a systemic poison that can damage the nervous system and other body organs.[89] Mercury is a very toxic metal, and some people are even concerned about the small amounts of mercury that are used in amalgam dental fillings.[90]

The metal arsenic is a common component of the chemically treated lumber widely used for wooden decks, porches, and railings. This lumber has a greenish tint and is often described as being "salt-treated." It isn't table salt that is used, however, but an arsenic salt. Several lawsuits have resulted from individuals being made ill after working with treated lumber. One worker, whose job it was to build picnic tables, was so affected

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[87] *Preventing Lead Poisoning in Young Children* (Atlanta, GA: Centers for Disease Control, October 1991).

[88] H. Sverdrup and P. Warvinge, "A model for mercury exposure due to metallic mercury spills" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 4, Building and System Assessments and Solutions*, 1990): 225-230.

[89] *Handbook of Mercury* (Phoenix, AZ: Salesco Systems USA, 1996).

[90] Joyal Taylor, *The Complete Guide to Mercury Toxicity from Dental Fillings* (San Diego, CA: Scripps Publishing, 1988).

he vomited seven to eight units of blood—nearly half of his total body supply—before he was able to get to a hospital for treatment.[91] When tested, he and a coworker had arsenic levels in their hair and nails that were hundreds of times higher than normal. Although manufacturers warn against using chemically treated lumber on eating surfaces, this material is often used to construct picnic tables. Most building codes currently prohibit the use of treated lumber in locations where it will be directly exposed to the living space of a house, but it is occasionally used unknowingly indoors.

Fumes and Vapors

The terms *fume* and *vapor* are routinely used incorrectly to describe any gas or odor. But they actually have very precise technical definitions. Fumes are tiny particles that are usually created by high heat. They tend to remain airborne for a long time. Soldering and welding produce metal fumes, and burning some organic chemicals or plastics can produce fumes.

Vapors are the gaseous form of materials that are normally liquid at room temperature. Solvents such as turpentine and mineral spirits evaporate into vapors. When mercury-containing fungicides were used in paints, the metal evaporated into mercury vapor.

The most common vapor in houses is water vapor. Though not a pollutant itself, water vapor can lead to various pollution problems. For example, formaldehyde and other VOCs outgas faster, and mold and dust mites proliferate, at higher relative humidities. Too much moisture in a house can also lead to structural damage due to rot, decay, and insect infestation.

Smoke

Smoke is typically composed of a complex mixture of gases, vapors, fumes, and particulates. Tobacco smoke contains over 4,700 chemicals, at least 43 of which are known carcinogens.[92] Wood smoke is probably no better for people to breath, yet it is often a common component of indoor air.

Radiation

Not all health problems in houses are due to airborne pollutants. Some are due to invisible forms of energy—radiation. Radon and electromagnetic fields cannot be seen or felt, yet they are affecting our bodies in very real ways. In particular, various cancers have been associated with these forms of energy.

Radon

Radon is a naturally occurring radioactive gas. It is odorless and colorless and is found in the soil, to some extent, in most parts of the country. When radon filters through the ground and enters a house, it goes through a radioactive decay process. It is not radon

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[91] "Arsenic in Lumber," *Citizen's Clearinghouse for Hazardous Wastes, Inc. Environmental Health Monthly* (September 30, 1988): 1-10

[92] Environmental Protection Agency (EPA), *Indoor Air Facts No. 5: Environmental Tobacco Smoke* (Washington, DC: EPA, June 1989).

itself, but rather the decay process that causes an increased risk of developing lung cancer. The **EPA** estimates that up to 20,000 lung cancer deaths each year are attributable to radon. They have sponsored a great deal of radon research, and have some very good publications on radon mitigation. Some people feel nuclear power plants are a bigger health concern than radon, and that the **EPA**'s extensive radon work is designed to divert the public's attention from problems associated with nuclear-power emissions.[93]

While radon can be released from some building materials, in most cases materials aren't major contributors.[94] Of course, some building products occasionally do contain high levels of radon, for example when concrete is made with tailings from a uranium mine.

Radon is relatively easy to test for in the indoor air and, if found, the risk can usually be minimized. For up-to-date information on testing devices, contact your local or state board of health. Many hardware stores sell radon test kits. Additional radon information can be found in *Chapter 11, Foundations* and *Chapter 25, An in-depth evaluation of six common pollutants*.

Electromagnetic Fields (EMFs)

Invisible electromagnetic fields (EMFs) surround all live electric wires and appliances. Health effects depend on the strength of the field and the duration of exposure. Long-term exposure to high-strength fields has been shown to cause an increase in various forms of cancer in workers in several electrical occupations. The effect of short-term exposure to low-strength fields is very controversial, with the scientific community divided.

There are a number of people who have become hypersensitive to routine, minor, brief exposures to EMFs—levels that most of us are exposed to every single day. EMFs are covered in more depth in *Chapter 23, Electrical systems*.

Smoke Detectors and Fluorescent Lamps

A few readily available consumer products actually contain radioactive material. For example, some types of compact-fluorescent lamps[95] and some smoke detectors[96] contain tiny amounts of what is usually considered hazardous radioactive waste. The compact fluorescent lamps with *magnetic* ballasts are the ones to steer away from, so look for models with *electronic* ballasts to avoid the radioactive material. With smoke detectors, the *ionizing* models contain small amounts of radioactive material. They are claimed to be safe by manufacturers, but many people question the wisdom of supporting

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93 Nathaniel Mead, "The riddle of radon," *East West* (July 1990): 64.

94 John G. Ingersoll, "A Survey of Radionuclide Contents and Emanation Rates in Building Materials Used in the United States," *Health Physics* 45 (August 1983): 363-368.

95 "Electronically ballasted compact fluorescents," *Green-keeping* (March/April 1991): 12.

96 Mayell, Mark,. "Smoke Detectors: The Non-Nuclear Alternative," *East West* (April 1990): 80–81.

an industry that sells products that require radioactive material to operate—especially when safer alternatives are available.

Photoelectric smoke detectors contain no radioactive material. They are sometimes more difficult to find, and they generally cost a little more than the ionizing type—but they tend to respond much quicker to slow, smoldering fires, such as a mattress ignited by a dropped cigarette. Some models contain both ionizing and photoelectric sensors in the same case. There are a number of manufacturers of photoelectric smoke detectors, including **BRK Brands, Inc.** (First Alert), **Kidde Safety** (Nighthawk), and **North American Detectors** (American Sensors).

Most housing codes now require smoke detectors in houses, although they don't specify what kind. But codes often do specify that, in new construction, the detectors be wired into the house wiring. This is because people often forget to change the battery in battery-operated detectors. But, in the event of a power failure, a 110-volt model won't work any better than a detector with a dead or missing battery. So, some manufacturers now offer 110-volt models with a battery for back-up power.

People as Pollution Sources

It's possible to create a perfectly benign house, but there is one pollution source that can't be avoided—people. Besides occasionally smelling like goats, people and their activities can give off a wide variety of gases and particulates that can affect human health. It's widely known that viruses and bacteria can be passed from one person to another. Smallpox, measles, yeast infections, and AIDS are obvious examples. But activities such as oil painting, using household cleaners, and smoking are clear sources of pollution.

And there are a number of chemicals that can be given off by human (and animal) metabolism, that can contribute to indoor air pollution. A possible list could include:[97] Acetone, Diethyl Ketone, Acetaldehyde, Ethyl Acetate, Acetic Acid, Ethyl Alcohol, Allyl Alcohol, Hydrogen Sulfide, Amyl Alcohol, Lactic Acid, Ammonia, Methane, Butyric Acid, Methyl Alcohol, Carbon Dioxide, Phenol, Carbon Monoxide, and Toluene. These chemicals are released as normal by-products of living. They are not necessarily associated with illness, but some people can react quickly to small amounts of them.

Synergism

Synergism refers to the joint action of two substances. With synergism, 2 + 2 may equal 8. In other words, the combined action is greater than the sum of the individual actions. We have all heard about the danger of mixing alcohol and barbiturates. Together they can easily result in death, yet individually they are not nearly so lethal. Chemicals are rarely studied together because the number of possible combinations would be astronomical. Of the hundreds of known indoor air pollutants, many probably act synergistically.

Tobacco smoke and radon gas are an important and significant example. If there is

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[97] Richard A. Wadden and Peter A. Scheff, *Indoor Air Pollution, Characterization, Prediction and Control* (New York: John Wiley and Sons, 1983), 73.

radon in a room, there is a certain risk if getting lung cancer. But if cigarette smoke is also present in that same room, the lung cancer risk is about 15 times higher. The reason for this particular synergistic effect is because radon tends to cling to the smoke particulates in the air, resulting in much more radon being breathed into the lungs. When there is no smoke in a room, many of the radioactive particles attach to walls and furnishings where they decay harmlessly.

Summary

There are literally hundreds of naturally occurring and man-made pollutants floating around in the air of our homes. Sometimes they are in relatively small concentrations and they only result in subtle negative health effects. Most of the synthetic chemicals haven't been studied thoroughly because they simply haven't been around long enough. Many were invented after World War II and many more are being invented daily. "New and improved" actually means "new and improved—with unknown health effects." According to one writer, "Most of us are involuntary guinea pigs in unintentional research experiments on the safety of chemicals."[98]

While the general population may not *seem* to be bothered by low levels of pollutants, there is an increasingly large segment of society that has been sensitized to them by compounds such as formaldehyde. These people actually react to so many different chemicals, and in such small doses, that they are often termed "allergic to modern life." The devastating effects on their lives should be a warning to the rest us about the hidden dangers we all face indoors.

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[98] Ann Misch, "Better Living Through Chemistry?," *Utne Reader* (November/December 1993): 90-93.

2. Health Effects

Building-related illness and *sick-building syndrome* refer to conditions that have only been discussed in medical literature in the last couple of decades. A building-related illness is a well-defined medical condition that is related to a *specific* cause in a building. Legionaries' disease caused by bacteria living in an air-conditioning system would be an example. On the other hand, when someone complains of *non-specific* symptoms—such as headache, fatigue, dry throat, or malaise—and there is no readily apparent cause, the condition is called sick-building syndrome.

In other words, with building-related illness, the problem can be easily defined, but with sick-building syndrome, investigators just don't understand exactly what is causing the symptoms that are being reported. The building may very well be unhealthy, it's just that the cause isn't apparent—based on today's limited knowledge.

Some of the health problems that are being experienced inside buildings—*i.e.* sinus congestion or itchy eyes—may seem like minor inconveniences, but they definitely affect a person's well being, productivity, and quality of life. Consider something as simple as a runny nose. Wouldn't life be much more enjoyable without having to grab a handkerchief every five minutes? Certainly, some health effects caused by indoor air pollution are significant. We would all like to avoid symptoms such as severe depression and death. Of course, there are a wide variety of symptoms associated with poor air quality that are in between the extremes of runny nose and death (*e.g.* symptoms related to cerebral, respiratory, or pulmonary function) that we would all like to avoid.[99]

Who is at Risk?

People who spend a lot of time indoors are at risk of developing a building-related illness. That seems to include all of us and, in fact, it does—but some specific groups are especially at risk. Children, the elderly, and the infirm are more susceptible to any type of illness than the rest of the population. Some symptoms show up immediately, but others take years or decades to develop.[100] A Massachusetts report stated that "indoor pollution is a growing problem in the United States and accounts for 50% of all illness." [101] At first, 50% sounds like an exaggeration, but there are millions of people experiencing symptoms related to poor indoor air quality—and they aren't aware of the cause.

In reality, many of us are definitely not in very good health. For example, an

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[99] H.M. Ammann and M.A. Berry, "Health Risks for Indoor Air" (Berlin: *Proceedings of the 4th International Conference on Indoor Air Quality & Climate, Vol. 2, Environmental tobacco smoke, multicomponent studies, radon, sick buildings, odours and irritants, hyperreactivities and allergies*, 1987): 227-231.

[100] Robert McLellan, "Homesick in the '80s: environmental priorities in home construction," *Custom Builder* (June 1989): 37-38.

[101] Special Legislative Commission on Indoor Air Pollution, *Indoor Air Pollution in Massachusetts, Final Report* (Boston: Special Legislative Commission on Indoor Air Pollution, April 1989): 15.

article in the *Journal of the American Medical Association* estimated that 90 million Americans were living with a chronic medical condition in 1987, and 39 million of them had more than one chronic condition.[102] The sperm count in men has dropped in half over the past 50 years, something experts attribute to pollutants we are routinely exposed to.[103] We lose 150 million work days each year due to respiratory infections.[104] According to U.S. Senator George Mitchell, author of the Indoor Air Quality Act, "we now have clear evidence that the health effects of indoor air pollutants result in substantial costs to society in the form of reduced productivity, sick time, health care costs, and disability costs estimated in the tens-of-billions of dollars." [105] A Congressional Research Report has stated that "no one is immune to the effects of indoor air pollution." [106]

A newborn baby spending a great deal of time in a recently remodeled nursery is at increased risk due to the many chemicals being released by the new building materials. A young child can have a respiratory rate up to ten times faster than an adult, hence the child will inhale more indoor pollution per pound of body weight than an adult,[107] and a child's immune system is not fully formed until about age 10.[108] Conversely, the immune system of an older person is on the decline, putting them at an increased risk. Someone who is ill with an existing disease, or someone living in an area of high outdoor pollution, is also more susceptible to indoor pollution because their immune system is already overloaded.

Because we are all young, old, or sick at one time or another, we are all at risk at different times in our lives. Jet lag, shift work, hormonal changes, and everyday stresses can also make us more susceptible to indoor air pollutants.

Individuals who exhibit respiratory symptoms during a smog alert are likely to be more susceptible to indoor pollutants. Someone who's eyes burn or water when entering a carpet store, a fabric store, or a newly remodeled room could be reacting to formaldehyde, or other chemicals, and be in danger of developing more severe

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102 Catherine Hoffman, Dorothy Rice, and Hai-Yen Sung, "Persons with chronic conditions," *Journal of the American Medical Association* 276 (1996): 1473-1479.

103 "Experts question research showing sperm-count drop," *Chicago Tribune* (February 2, 1995): Section 1, p. 6.

104 Richard Garibaldi, "Epidemiology of community-acquired respiratory tract infections in adults," *The American Journal of Medicine* 78 (June 28, 1995): 32-37.

105 George Mitchell, "Senator George Mitchell—Guest Editorial," *Indoor Air Review* (March 1992): 3.

106 Mira Courpas, *CRS Report to Congress: Indoor Air Pollution: Cause for Concern?* (Washington, DC: Congressional Research Service, December 1, 1988).

107 Irene Ruth Wilkenfeld, "Is Your Home Inhospitable?," *Heal Prints* (Newsletter published by HEAL of Louisiana, Baton Rouge, LA) (May 1987), : 1-5.

108 E.J. Calabrese, *Pollutants and High Risk Groups* (New York: John Wiley and Sons, 1978): 187.

symptoms. Hyperactive children are also at risk.

Anyone with an immune-system irregularity is in jeopardy of contracting a building-related illness because of the danger of having their immune system overwhelmed. Asthmatics, those with heart disease, and individuals with respiratory disease are especially vulnerable. Smoking and drug abuse also contribute to risk. It's been estimated that up to one third of the population is in a high-risk group at any one time.[109]

Increased Sensitivity

There are many people exhibiting symptoms at much lower pollution levels than the general population. This tells us that a safe level of exposure for one person is not safe for everyone. In reality, we all have a different degree of tolerability because we all have a unique physical body and a unique metabolism. Some individuals can smoke several packs of cigarettes a day and live disease-free for 80 years, but there are others who are negatively affected by very minor exposures to second-hand tobacco smoke. Most of us fall somewhere between these extremes of extraordinary tolerance and extreme hypersensitivity. Yet, we may be all bothered by the very same pollutants that affect hypersensitive people—but only after a longer period of exposure to a higher concentration.

Hypersensitive people act as early warning signs to the general population in the same way canaries warned coal miners of polluted air in the mines. Canaries are more susceptible than most people to air pollution and they were taken into the mines to help predict when the air reached dangerously contaminated levels. When the birds stopped singing and died, the miners knew it was time to seek fresh air. Today's canaries are the individuals who are more susceptible than the population at large. The rest of us should become aware of what bothers them because, the odds are, similar things bother us as well. Their symptoms just show up immediately while ours may not manifest themselves for years.

Many people seem to be exhibiting more symptoms related to their environment than in the past. For example, allergies are much more common today than just 50 years ago,[110] and sensitivities to formaldehyde and other VOCs are increasingly being recognized. It's been suggested that people are exhibiting increased sensitivity because the average citizen today is genetically and biologically different from the average citizen of generations past.[111] This is undoubtedly related to the fact that the food we eat, the water we drink, and the air we breathe is totally different than the food, water, and air to which human beings have adapted over hundreds of thousands of years. Our bodies are having difficulty adapting to an environment that is radically different from any other

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109 Bruce Small, *Indoor Air Pollution and Housing Technology* (Ottawa, ON, Canada: Canada Mortgage and Housing Corp., 1983): 91.

110 Alan Scott Levin and Merla Zellerbach, *The Type 1/ Type 2 Allergy Relief System* (Los Angeles: Jeremy P. Tarcher, 1983): 25.

111 *Ibid*., 25-26.

environment in human history. Our ability to change our surroundings has simply outstripped our genetic ability to adapt to those changes.[112]

Two or three generations of eating prepared foods, processed flour, and food additives have resulted in subtle changes to our bodies. Sugar is no longer an occasional treat, it is a daily staple. Manufactured foods abound—and they have less nutritional value than the whole, real foods they have replaced. It is estimated that the average individual consumes at least one gallon of fungicides, bleaches, dyes, antibiotics, preservatives, moisturizers, and emulsifiers per year.[113] As a result of decades of eating less-nutritious foods and food additives, our systems no longer have the stamina to resist the assaults of environmental pollutants. The many negative health effects of our modern diet and life-style have been well documented by Charles T. McGee in *How to Survive Modern Technology*.[114]

The sad truth is that the air we breathe every day of our lives, both indoors and outdoors, is contaminated with chemicals that our evolutionary path has not prepared us for. This means our lungs must continually deal with an unnatural pollutant burden. This stress is occurring every minute of every day and it means our bodies have less ability to handle an acute pollution emergency. This constant exposure has resulted in people having less resiliency than they had in the past—and more illness. Much of this illness is attributable to the toxic, allergenic, and carcinogenic materials we use to build houses.

Subliminal Exposure

We are all exposed to a certain amount of air pollution that can be referred to as the background level, or subliminal exposure. Subliminal advertising supposedly relies on flashing a message on a television or movie screen so fast the viewer doesn't consciously see it. Movie-theater operators once thought that, by flashing a picture of hot buttered popcorn on the screen for a fraction of a second during a movie, they could get viewers to go to the lobby and line up to buy popcorn—without realizing why. This method of advertising turned out to be ineffective in reaching the subconscious mind, but subliminal exposure to air pollutants can effect people in a real, but subtle, way.

According to one scientist, "The greatest danger of pollution may well be that we shall tolerate levels of it so low as to have no acute nuisance value, but sufficiently high, nevertheless, to cause delayed pathological effects and spoil the quality of life."[115] We tend to become accustomed to the constant level of pollution around us because the

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112 David Schoonmaker, "Are You Home Sick?," *Mother Earth News* (March/April 1989): 90-94.

113 Andrew Nikiforuk and Barbara Binczyk, "The Pariah Syndrome," *Harrowsmith (U.S.)* (August/September 1982): 51-61.

114 Charles T. McGee, *How to Survive Modern Technology* (New Canaan, CT: Keats Publishing, 1979).

115 Rene Dubos, "Adapting to Pollution," *Scientist and Citizen* 10 (January/February 1968): 1-8.

effects are not suddenly devastating then, in later life, when the years of subtle exposure have contributed to chronic bronchitis, heart disease, or cancer, we have no idea why we are sick.

Pollutants can affect life in many ways, some of which are not immediately detrimental to health. Every one of our bodies contains pollutants not needed for growth and development. This is known as our pollutant burden, and it is often the result of subliminal exposure to chemicals. For a large proportion of us there is enough pollution in our system to cause measurable, physiological changes. For many people, these changes have no apparent significance, but for some they can be described as sentinels of disease. While disease itself may not be present, the groundwork is being laid. A smaller percentage of us have pollutant burdens high enough to cause an illness of some type, and for a few of us, the levels are fatal.[116]

The important thing for us all to realize is that we *are* subliminally exposed to chemicals, and a high percentage of society is already being subtly affected. Unfortunately, for many people, the results won't manifest themselves for decades. For others, the effect is immediately devastating.

Symptoms and Diseases

The symptoms and diseases that can be caused by indoor air pollution are many and varied. Symptoms of Legionnaires' disease include pneumonia, cough, fatigue, fever, muscle aches, nausea, *etc*.[117] It can also result in death. Radon and asbestos exposure can be fatal as well. While death is certainly the ultimate symptom anyone can experience, there is increasing concern over the many other "lesser" symptoms that are much more common.

The pollutants typically found in our homes can cause symptoms such as incoordination, dizziness, fatigue, nervousness, headaches, joint and muscle pain, abdominal pain, *etc*.[118] According to the World Health Organization, the following are common symptoms of sick building syndrome:[119] Irritation of eye, nose and throat; Dry mucous membranes and skin; Erythema; Mental fatigue; Headache; Airway infections; Cough; Hoarseness of voice; Wheezing; Unspecified hyper-reactivity; Nausea; and Dizziness.

Many people are concerned about the carcinogens found in houses, but are less concerned about other indoor pollutants. It is sometimes assumed that if a material

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116 Anthony V. Colucci and others, "Pollutant Burdens and Biological Response," *Archives of Environmental Health* 27 (September 1973): 151-154.

117 Gary L. Lattimer and Richard A. Ormsbee, *Legionnaires' Disease* (New York: Marcel Dekker, Inc., 1981).

118 David E. Root and Joan Anderson, "Reducing Toxic Body Burdens Advancing in Innovative Technique," *Occupational Health and Safety News Digest* 2 (April 1986).

119 L. Molhave, B. Bach, and O.F. Pedersen, "Human Reactions to Low Concentrations of Volatile Organic Compounds," *Environment International* 12 (1986): 167-175.

doesn't cause cancer, then it must be safe. Unfortunately, some indoor pollutants are teratogenic, meaning they can result in birth defects such as deformities or serious malformations. Those that are fetotoxic can result in death to unborn children.[120] Others may cause chromosomal damage that will show up in future generations. Heart disease and damage to the immune system are other common negative effects of indoor air pollutants. The fungus *Stachybotrys atra* is highly toxigenic, being associated with central nervous system complaints, eye and skin irritation, upper and lower respiratory tract problems, and chronic fatigue.[121] *Stachybotrys atra* has been found in some Cleveland homes, where it is suspected of resulting in spontaneous bleeding in the lungs of infants.[122]

People sensitized by such things as formaldehyde often report a variety of reactions to the other VOCs in the air. Some of these people are so sensitive to the synthetic modern materials in their environment they must live in very restricted surroundings to remain symptom free.

Non-specific Symptoms

Non-specific symptoms are those everyday complaints we all have from time to time that seem to have no particular cause. In actuality, they could easily be caused by indoor air pollution. Possible symptoms include headache, swelling, abdominal discomfort, drowsiness, ringing in ears, malaise, blurred vision, and fatigue.

Irritation

An irritant is a substance that abnormally stimulates a part of the body. Examples include the inflammatory response of the skin when exposed to a solvent-containing paint, or the inflammatory response of the sinuses to various VOCs. Many airborne gases and particulates can cause skin irritation resulting in acne and contact dermatitis.[123]

Neurological Effects

The brain is one of the most sensitive organs in the body. So it should come as no surprise that many solvents and VOCs are capable of causing a wide range of neurological symptoms such as confusion, loss of memory, dizziness, depression, anxiety,

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120 Martin L. Pernoll, "Abortion Induced by Chemicals Encountered in the Environment," *Clinical Obstetrics and Gynecology* 29 (December 1986): 953-958.

121 Eckardt Johanning, Phillip Morey, and Bruce Jarvis, "Clinical-epidemiological investigation of health effects caused by *Stachbotrys atra* building contamination" (Helsinki: *Proceedings of the 6th International Conference on Indoor Air Quality & Climate, Vol. 1, Health Effects*, 1993): 225-230.

122 National Institutes of Occupational Health and Safety (NIOSH), *Biological Hazards Health Evaluation: Cleveland Area Homes* (Atlanta: NIOSH, April 1996). #HETA 95-0160-2571.

123 An E. Dooms-Goossens and others, "Contact dermatitis caused by airborne agents," *Journal of the American Academy of Dermatology* 15 (July 1986): 110.

mood swings, hallucinations, apathy, lethargy, and insomnia. Neurotoxicity is often a primary health effect associated with pesticide use, and it is of particular concern because the brain cannot regenerate itself, thus neurological damage can be permanent.[124]

Mutation

Some chemicals can damage, or change, the DNA residing inside our cells.[125] This is very serious business because our DNA is what defines us—both as individuals and as a species. When this happens, most of the altered cells die—but a few survive to replicate themselves. These altered cells are different from the cells we were born with—they are mutations. If the cells affected are reproductive cells (sperm or egg), we can pass the mutation on to our children—with unknown consequences. Very few chemicals have been studied for mutagenicity. Some experts believe that, under the right conditions, most carcinogens can also be mutagenic. Vinyl chloride has been associated with an increase in chromosomal abnormalities.[126]

Birth Defects

Chemicals that cause birth defects are called teratogens. The drug thalidomide and grain alcohol are notable examples. Both have a negative affect on the developing fetus while it is growing inside the womb. Many solvents and heavy metals, such as lead, are considered by experts to be suspected teratogens.

In one study, women who were exposed to polychlorinated biphenyls (PCBs) had children with lowered I.Q., lowered reading comprehension, and problems related to memory and attention.[127] Another study found that women who were exposed to chemicals during their pregnancy were not only more likely to have children with birth defects, but fetal death was also more likely.[128]

Cancer

Asbestos, radon, and wood smoke are carcinogenic. Formaldehyde is carcinogenic in animals and is suspected of causing cancer in humans. Some studies have suggested that electromagnetic fields and fiberglass insulation are carcinogenic. With carcinogens, there is no level that is considered risk-free, but less exposure definitely

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124 "NRC says greater effort needed to screen and assess nerve damage from environmental chemicals," *Indoor Air Review* (April 1992): 2.

125 Thomas Maugh, "Biological markers for chemical exposure," *Science* 215 (February 1982): 643-647.

126 Dina Anderson and others, "Chromosomal analysis in vinyl chloride exposed workers," *Mutation Research* 79 (1980): 151-162.

127 Joseph Jacobson and Sandra Jacobson, "Intellectual Impairment in Children Exposed to Polychlorinated Biphenyls in Utero," *New England Journal of Medicine* 335 (1996): 783-789.

128 J. Zhang, W.W. Cai, and D.J. Lee, "Occupational hazards and pregnancy outcomes," *American Journal of Industrial Medicine* 21 (1992): 397-408.

means less risk. Some materials are not necessarily cancer *causing*, but are cancer *promoting*. Promoting agents work in conjunction with other materials to result in cancer.

Sensitization

A sensitizer is substance capable of enhancing the body's response to that substance. In other words, it will cause the body to become more sensitive to lower levels of exposure. Toluene diisocyanate (TDI), which is used to make some foam insulations, is a known sensitizer, as is formaldehyde.

Allergies and Asthma

An allergy is a well-characterized immune response involving antibodies and antigens. At least 60 million Americans, about 1 in 4, have allergies. Eight-million school and work days are lost annually due to allergies, and we spend over $600 million every year to get relief.[129]

Moisture problems in houses can lead to excessive mold or mildew growth, or increased populations of dust mites, thus aggravating allergies. A study of Seattle school children found that asthma symptoms (such as wheezing) were often associated with household water damage—something that often leads to mold or microbial growth—and cigarette smoke.[130] Surprising to many people, cockroach allergy affects 10-15 million Americans.[131] Allergies have also been recorded to various types of wood, paints, and furnishings. One study found that 15-20% of asthma cases were attributable to exposure to chemicals in the workplace.[132] Many of these same chemicals can be found in low concentrations in houses.

Poorly designed or constructed heating/cooling systems can generate and distribute allergenic material around the living space, while well-designed systems can help to reduce the concentration of allergens in a house.

Asthma is most likely a group of diseases that result in an inflammation of the bronchi (air passages into the lungs) and spasms in the muscles surrounding them. Asthmatics typically have inflamed bronchi, even when they're not in the midst of an attack. When they are having an attack, they generally feel short of breath, have a constriction in their chest, and begin wheezing. Other common symptoms are fatigue and coughing. In a worse-case scenario, death results. There are now at least 15 million Americans with asthma, of whom 5 million are under the age of 18.[133] The annual death toll is 5,500. Furthermore, the U.S. **Centers for Disease Control** has reported that, during the past 13 years, the number of children with asthma has doubled. And, according

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129 Gloria Hochman, "Allergic to everything," *Today's Health* (March 1986): 53.

130 W.C Maier, and others, "Indoor risk factors for asthma and wheezing among Seattle school children," *Environmental Health Perspectives* (February 1997): 208-14.

131 "Cockroach Allergy," *East/West* (October 1990):11.

132 "New study links asthma to chemical sensitivity," *Indoor Environment Review* (July 1997): 4.

133 "The Real Truth About Asthma," *Coping* (May/June 1998): 27.

to the American College of Emergency Physicians, asthma causes 9 million lost work days each year.

Asthmatics often react to common indoor pollutants such as dust mites, mold spores, cigarette smoke, house dust, aerosol sprays, and wood-burning stoves.[134] In addition, VOCs released by adhesives, cabinetry, and paints can trigger an asthmatic attack.[135]

Physicians specializing in allergy and asthma treatment often belong to the **American Academy of Allergy, Asthma, and Immunology (AAAAI)** or the **American College of Allergy, Asthma, and Immunology (ACAAI)**. Also, the **American Academy of Otolaryngic Allergy (AAOA)** has members who specialize in ear, sinus, and throat allergies. In addition, there are national patient support groups such as **Asthma and Allergy Network, Mothers of Asthmatic, Inc. (AAN/MA)** and **Asthma and Allergy Foundation of America (AAFA)** that have a number of fact sheets and brochures available.

Multiple Chemical Sensitivity (MCS)

Multiple chemical sensitivity (MCS) has been known by a variety of names. Total-Allergy Syndrome, Twentieth-Century Disease, Chemical Hypersensitivity Syndrome, Environmental Illness, Ecological Illness, and Immune System Dysregulation are all names for the same condition. MCS involves an increased sensitivity to a wide variety of chemicals encountered daily. These substances are often petrochemicals or their derivatives. The reactions and symptoms do not fit into the traditional allergist's definition, so they are usually not considered true allergies. Reactions can occur to automobile and diesel exhaust gases, artificial fragrances, synthetic fabrics, plastics, food additives, printers ink, *etc*. In short, practically everything in our modern, manufactured environment can cause problems. It's been reported that "approximately 15% of the U.S. population have an increased allergic sensitivity to chemicals found in household products."[136] The Labor Institute has found enough interest in MCS to publish a 95-page booklet, *Multiple Chemical Sensitivities at Work*, to educate working people.[137]

Some people are of the opinion that healthy houses are only necessary for very sensitive people, such as those with MCS. That's like saying food is only necessary for the starving. We all need healthy houses, it's just that those with MCS have a more critical need. Actually, most people with MCS were not born with the condition—many

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134 "What Triggers Asthma?" *Coping* (May/June 1998): 20.

135 Subatro Chandra, David Beal, and Andrew Downing, "Allergy Resistant Houseing—Principles and Practice (Miami, FL: Presented at the Environmental and Economic Balance: The 21st Century Outlook conference, November 6-9, 1997).

136 Meeting of the Board on Environmental Studies and Toxicology, *Evaluating Sensory and Hyperactivity Reactions from Exposure to Inhaled Pollutants* (Washington, DC: Commission on Life Sciences, National Research Council, July 27-28, 1987).

137 The Labor Institute, *Multiple Chemical Sensitivities at Work*, (New York, The Labor Institute, 1993).

acquired it as a result of living in an unhealthy house.

MCS reactions are sometimes compared to addictions.[138] Consider people living in major cities who don't realize they are sensitive to automobile exhaust. They are exposed to exhaust gases every day, and it slowly wears their systems down. The effect isn't devastating, and the symptoms aren't well-defined, but they just doesn't feel well. They don't know why they feel poorly, and they get used to it. Then, they go on vacation to the country, where the air is clean, and there is little traffic. Suddenly they feel alert, energetic, and symptom-free. But the vacation comes to an end and, upon returning home to the city, they feel worse than ever. Before the vacation, they had been getting a daily "fix" of automobile exhaust and, even though they felt poorly, they were on somewhat of an even keel. By staying away from the offending substance, they felt well, then re-exposure sent their health downhill quickly. This is similar to the experience of people addicted to alcohol. By avoiding alcohol, they feel well, but re-exposure—taking even one drink—can have a devastating effect on their health and well-being.

There are a number of factors that can predispose a particular individual to developing MCS. For example, some people are more susceptible because of *heredity*—they just happen to have genes that make them more likely to get ill. Some people develop MCS after a severe viral, bacterial, or fungal (*Candida*) *infection*. Others can trace their illness to a single heavy *chemical exposure* or to a smaller long-term chemical exposure. Increased *stress* also plays a role—either emotional, physical, positive or negative. And *poor nutrition* has also been implicated. In many cases, the onset of illness is related to a combination of these factors. A case study will help illustrate this condition.

MCS Case Study

As a girl LR grew up in a large metropolitan area where she experienced symptoms of depression, insomnia, malaise, and nervousness. Many of these symptoms got worse as she grew older but they were not nearly so severe when she was in a rural area. Whenever she went shopping with her family, she became weak and had to sit down often to catch her breath. She became increasingly uncomfortable around such things as cigarette smoke and exhaust gases. In college, she found her health was markedly better in an older dormitory. When she moved into a newly constructed apartment, her health deteriorated rapidly. An art major, her thinking got fuzzy in oil painting and watercolor classes.

After marriage, she and her husband moved into a new apartment where new building materials caused burning and watery eyes as well as severe mood swings. Her husband was unaffected, but LR's health steadily deteriorated until, after relocating several times, she and her husband moved into an older home in a rural area. Here she felt better than she had in years—although her health was still poor. They later purchased another house, again away from the city, that needed some major renovating. After several years of construction work on the house, running a part time furniture-refinishing business, and providing free-lance art work, LR's health collapsed.

She could hardly walk because of back and muscle pain. Her lungs ached. Her stomach was so irritated she could barely eat. Her vision was blurred. Her sinuses were

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[138] Theron G. Randolph and Ralph W. Moss, *An Alternative Approach to Allergies*, (New York: Harper and Row, 1980; New York: Bantam Books, 1982).

inflamed. Her gums were sore and bleeding. She hallucinated whenever she was able to sleep. She suffered chronic bladder and vaginal yeast infections. Practically every system in her body was affected.

She tracked down what she thought was the culprit—formaldehyde. It was emitted from the new carpeting, new bedroom furniture, new kitchen cabinets, new draperies, and new bed linens. When the bedroom was cleared of the suspected causes, her health seemed a little better. By now, the house had been completely rebuilt and, as planned, put up for sale. The idea was to make enough profit to build a new house and get out from under a mortgage payment. After the sale, the couple began looking for land to build on, and temporarily moved into a rental house that was old enough to have no new formaldehyde sources. That summer, LR's health seemed much better, however during the winter it rapidly deteriorated. Whenever the natural-gas furnace ran, LR felt horrible. She assumed insecticides had been sprayed into the ductwork, causing her problems. The fresh paint was also suspected.

As they continued to search for a building site, the couple moved into another rental they hoped would be healthier. This place was also old enough to not have any new formaldehyde sources. It seemed like a nice spot, with a woods and small stream on one side. However, once she got settled, LR's health steadily deteriorated. The house had natural-gas heat, was next door to a gasoline station, and across from a doughnut shop where truckers let their diesel engines idle while they drank coffee. It was here that she saw MCS mentioned on a television news program. Suddenly all of her symptoms fell into a pattern. It was now obvious that her current residence was one of the worst places she could have chosen to live. She now realized that she was reacting to not only formaldehyde, but to petrochemicals in general, and a wide variety of their derivatives. Every cleaning product under the sink was a problem, as were synthetic fabrics. Her wardrobe had to go. The upholstered furniture had to go. An unscented soap and detergent had to be found. Most importantly, a healthy house had to be built because it was obvious she was reacting to such things as carpeting, wall paneling, paints, and the natural-gas furnace.

Several years later, LR has regained a great deal of her health. Her house in the country is as pollution-free as possible, but she is very careful about trips into town because of the many possible chemical exposures. She remains so sensitive that upon returning from town, she must shower and launder her clothes to remove any traces of exhaust gases, cigarette smoke, and synthetic fragrances. Her artwork is now limited to using a metal mechanical pencil on 100%-cotton-rag paper inside a special box with a built-in activated-carbon air filter. One of her biggest regrets is that no one knew about MCS when she was in elementary school. She could then have avoided many of the everyday exposures that seemed so safe. Perhaps then she would not have lost so much of her tolerance.

Implications of MCS

People with MCS typically exhibit symptoms to extremely low levels of pollution—levels that are often assumed to be safe. They sometimes react to concentrations of pollutants so low they cannot be measured by conventional instruments.[139] Because of the experiences of individuals like LR, it's becoming obvious that people can be much more sensitive to indoor pollution than was once commonly believed. It is a sobering thought to realize that devastating health effects can occur to the indoor-pollution levels we are all exposed to every day.

After removing many sources of indoor air pollution from their homes, sensitive individuals often see an improvement in their health. For many of the people with MCS, this is sometimes done as a matter of immediate survival. In a Canadian study, 23 of 29 respondents reported daily symptoms prior to making healthy modifications to their house, and after the modifications were made, only 3 reported daily symptoms.[140]

In many situations, as the indoor environment is cleaned up, other members of the family begin to see improvement in their health, as minor symptoms go away. Suddenly, they realize that they were also reacting to poor indoor air quality, but to a somewhat lesser degree. The implication for society at large is that we may all be affected by the small concentrations of pollutants that surround us. It is just that those with MCS react sooner.

Sources of Information about MCS

There are doctors, sometimes called Clinical Ecologists or Environmental Physicians, who specialize in the treatment of MCS. The several hundred members of the **American Academy of Environmental Medicine (AAEM)** have developed a variety of techniques for helping people cope with the condition. Special diets can help those sensitive to food additives. There are neutralization techniques to counteract the effects of some inhalants. Treatment techniques vary between patients and physicians. It is agreed, however, that the most important thing that can be done to improve one's health is to avoid the chemicals causing the problem.

One of the concepts put forward by the **AAEM** is that of the *total load*.[141] A person's total load is the sum total of all their exposures to environmental stressors that come from food, water and air. We all have different total loads at different times of day and from season to season. If your total load is more than your body can stand, then you get ill. To regain your health, you must lower your total load—in other words, reduce your exposure to pollution.

There are national support groups in the U.S. for individuals with MCS. The **Human Ecology Action League (HEAL)** and the **Chemical Injury Information Network (CIIN)** are both non-profit organizations that can direct people to local support

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[139] Robert T. Edgar, Ervin J. Fenyves, and William J. Rea, "Air Pollution Analysis Used in Operating an Environmental Control Unit," *Annals of Allergy* 42 (March 1979): 166-173.

[140] Stephen Barron, *Survey of the Medical Impact on Environmentally Hypersensitive People of a Change in Habitat* (Ottawa, ON, Canada: Canada Mortgage and Housing Corp., April 30, 1990).

[141] Gary R. Oberg, *An Overview of the Philosophy of the American Academy of Environmental Medicine* (Crystal Lake, IL: Crystal Lake Center for Allergy, 1992): 10.

groups. Membership in these groups is growing rapidly as more and more people become sensitive to their surroundings. The **National Center for Environmental Health Strategies, Inc. (NCEHS)** is also an excellent source of information on MCS. **NCEHS** is heavily involved in advocacy work to get MCS recognized as a legitimate disability, and they offer a newsletter called *The Delicate Balance*.

MCS Referral & Resources is a non-profit organization offering "patient support and public advocacy devoted to the diagnosis, treatment, accommodation and prevention of Multiple Chemical Sensitivity Disorders" for professionals (both doctors and lawyers) and patients. They offers referrals, they collect and disseminate MCS information (on medicine, law, and policy), and they participate in advocacy projects.

Two good books on MCS for lay readers are *An Alternative Approach to Allergies*[142] and *Staying Well in a Toxic World*[143]. For a more in-depth technical background on the subject, the book *Chemical Exposures: Low Levels, and High Stakes*[144] is very highly recommended. This book notes that MCS has striking similarities to "Gulf-War syndrome" as well as to the complaints of women having adverse symptoms related to silicone breast implants. It also suggests that MCS "may signal an emerging new theory of disease: toxicant-induced loss of tolerance."[145]

Self-help books include *The Rebellious Body*[146] and *Overcoming Environmental Illness*.[147] Autobiographies that chronicle the struggles of chemically-sensitive people include *The Toxic Labyrinth*[148] and *A Canary's Tale*.[149] Very good general articles were published in *Chemical and Engineering News* in July 1991[150] and in *The Amicus Journal*

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142 Randolph, *An Alternative Approach*.

143 Lynn Lawson, *Staying Well in a Toxic World* (Chicago: Noble Press, 1993).

144 Nicholas A. Ashford and Claudia S. Miller, *Chemical Exposures: Low Levels, and High Stakes* Second Edition (New York: Van Nostrand Reinhold, 1998).

145 Ibid., xiv.

146 Janice Strubbe Wittenberg, *The Rebellious Body* (New York: Insight Books, 1996).

147 Myrna Millar and Heather Millar, *Overcoming Environmental Illness* (Vancouver, BC, Canada: NICO Environmental Health Strategies, 1996).

148 Myrna Millar and Heather Millar, *The Toxic Labyrinth* (Vancouver, BC, Canada: NICO Environmental Health Strategies, 1996).

149 Jacob B. Berkson, *A Canary's Tale* (Hagerstown MD: Jacob Berkson, 1414 Potomac Ave., Hagerstown, MD 21742, 1996).

150 Bette Hileman, "Multiple Chemical Sensitivity," *Chemical and Engineering News* (July 22, 1991): 26-42.

in Winter 1989.[151]

Summary

The symptoms attributable to building-related illness run the gamut of everything from sinus congestion to death. Practically any symptom that can be imagined can be caused by indoor air pollution. In fact, people with MCS report symptoms mimicking virtually every known disease.

Because we spend so much time indoors, it only seems logical to make our indoor environments as unpolluted as possible. While many modern buildings contain very poor air quality and, as a result, are a cause of unnecessary illness, houses—and offices, schools, libraries, in fact, all buildings—*can* be designed and built in a healthy manner. Living in a healthy house often reverses the negative health effects of living in a polluted one—and it can help insure that a building-related illness such as MCS will not develop in the future.

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[151] Linda Lee Davidoff, Multiple Chemical Sensitivities (MCS), *The Amicus Journal* (Winter 1989): 12-23.

3. Finding a Healthy House

Finding a healthy place to live can be a difficult process, but as all prospective home buyers and apartment hunters know, finding any house or apartment that satisfies all one's requirements is often difficult. Healthfulness is simply another requirement. Because all people are different, both in taste and genetic makeup, your healthy house may be quite different from your neighbor's. For example, one person may prefer hardwood floors, while another opts for ceramic tile, and both can result in healthy floors.

How Healthy is Healthy Enough?

When it comes to houses, there are degrees of healthfulness. Some houses are very unhealthy, some are pretty good, and some border on the hypoallergenic. An extremely healthy house is quite possible to build, but it can be expensive. It would certainly involve a host of inert materials such as steel framing instead of wood, walls of porcelain panels, custom-made cabinetry, and special insulation. A complicated air-filtration system would then be necessary to keep the indoor air pristine. While such a house may be necessary for some exquisitely sensitive people, most average, healthy people do not require a house built to such extreme standards. So, a person in reasonably good health may opt for some compromises. After all, a healthy immune system should be able to deal with minor levels of pollution. By making a few compromises, a reasonably healthy house, a *generically* healthy house, can be built at a modest increase in cost—sometimes at no increase. An example of such a house is described in *Chapter 26: Three healthy houses*.

While the ideal situation would be for everyone to live in as healthy a house as possible, reality tells us that simply isn't going to happen. Specialized healthy construction products may not be available locally, builders and architects may not want to work with unfamiliar materials, so costs may be too high. If a contractor is unaware of what goes into a healthy house, and he is asked to work with unfamiliar materials, he may be unwilling to comply, or he may ask for what seems like an exorbitant price. This isn't necessarily price gouging—he just needs to make sure his estimate will cover any unknown factors. This book is written to educate homeowners, designers, and builders alike about all aspects of healthy construction to minimize the unknowns.

Important Considerations

The three most important materials to avoid in a healthy house are: carpeting, combustion appliances, and manufactured wood products containing high levels of formaldehyde. This rules out many of the houses built during the last few decades. Carpeting has been promoted as being plush and luxurious, but it is often associated with indoor air pollution because of outgassing and biological contamination. Most manufactured wood products emit formaldehyde, but some are worse than others. If you avoid the more potent emitters like particle board and furniture-grade plywood, you may be able to live with construction-grade products, because they release considerably less formaldehyde. Combustion appliances include space heaters, boilers, water heaters, furnaces, and kitchen ranges fueled by natural gas, oil, coal, kerosene, or wood. Again, some of these devices are worse than others. The newer high-efficiency models with sealed combustion chambers don't release combustion by-products into the indoor air (unless they are broken), so they are much less polluting.

There are many other possible sources of indoor air pollution, but these three are often major contributors. If you don't have any severe health problems, eliminating carpeting, the worst manufactured wood products, and combustion appliances that don't have sealed combustion chambers will be a significant step toward cleaner indoor air. If you already suffer from a chronic illness, or are otherwise at risk of developing a building-related illness, you should be even more selective, and consider carefully all the materials that are actually within the living space. If your health is extremely poor, you should also evaluate the materials comprising the house's structure and exterior.

Building New or Remodeling

Because so many building materials in use today have the potential to pollute the indoor air, an existing house may need to be 20–30 years old to completely avoid outgassing sources. However, an older house may be contaminated with perfume, mothballs, tobacco smoke, mold, *etc*.—odors many healthy people simply don't care to be around. According to one report, houses that smell of tobacco take twice as long to sell as houses that are smoke-free.[152]

While most new houses seem designed to foul the indoor air, it is definitely possible to build a new healthy house. All it takes is a little common sense and some planning.

If you are going to be renovating a house while you are living in it, you should realize that many of the healthier materials listed in this book still require a period of outgassing. So, if there is a great deal of work to be done, you may need to live elsewhere for a while, but this will depend on your individual sensitivity. On the other hand, if you are careful, it's possible to isolate the dust and pollutants generated during construction by confining the work to one room at a time, running an exhaust fan in the window, and keeping the door shut. This may be enough to keep the rest of the house from being contaminated during the construction process. But if you are an asthmatic, it may be very difficult to keep 100% the dust to tolerable levels during a heavy construction project.

Pregnant women should be especially careful because they have greater oxygen demands and are more susceptible to asphyxiating chemicals that reduce the number of red blood cells in the body. Some solvents can cause an increased risk of miscarriage.[153]

If you're considering renovating an existing house, it's always a good idea to perform a radon test early in the planning process. That way, if radon mitigation is necessary, it can be incorporated into the project. Some real-estate agents routinely request a radon test when a house is sold.[154]

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[152] "From what we gather," *Journal of Light Construction* (January 1993): 6.

[153] Lisa Iannuci, "Worrisome little additions," *Practical Homeowner* (May/June 1990): 16-18.

[154] "Radon Update," *Safe Home Digest* (March 1991): 4.

Remodeling, especially for a sensitive person, can be stressful, because there are always unforeseen difficulties that crop up as a project progresses. There are almost always going to be a few compromises simply because it isn't possible to plan for every contingency. One couple minimized the inevitable problems by preparing 17 pages of detailed instructions that eventually became part of their construction contract.[155]

It's possible to remedy virtually every possible unhealthy feature in an existing house—but if extensive remodeling is necessary to make an existing unhealthy house into a healthy one, it may make more economic sense to consider new construction. With new construction, it's possible to select every single material with care—so you have control over the entire structure. You also have much more control over the tightness of a new house than you have with an existing house.

Costs

A healthy house may require the use of materials or techniques that increase the cost. Unfortunately, there is always a dollar sign involved—even when health is concerned—but it is best to select the healthiest materials you can afford. It's impossible to state precisely what it costs to build a healthy house because it depends on the particular materials chosen, the geographic part of the country, size of the project, *etc*. But as a rough estimate, the cost of a healthy house is often between 0% and 25% more than a conventional house. By carefully selecting materials, one woman built a new $142,000 healthy house, and calculated that the added cost of the healthy features was a modest $2,400, or about 1.7%.[156] In a Canadian study, healthy features boosted the base cost in new construction from as little as 4% to over 30%.[157] As healthy housing techniques become more widespread, these costs will inevitably drop. One architect asks, "What is your and your family's health worth?"[158]

It's always a good idea to do some initial cost estimating before a project is completely planned out. That way, if the estimate seems beyond your budget, it should be easy to downsize the house a bit to make it more affordable. Your health should be more important than an extra guest bedroom.

Architects Mary Kraus and Bruce Coldham carried out a cost/benefit analysis of healthy building materials.[159] They suggest spending your money where you will derive the most health benefit. For example, you will get considerably more benefit by spending

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155 Ronald Christman, "An Environmentally Sensible Home Remodel," *Environ* #11: 24-26.

156 Patricia Prijatel, "Building a Healthy House," *Consumer Connection* (1994): 17-21.

157 Oliver Drerup, Chris Mattock, David Rousseau, and Virginia Salares, *Housing for the Environmentally Hypersensitive* (Ottawa, ON, Canada: Canada Mortgage and Housing Corp., July 1990).

158 Tom Monte, "In Search of the Healthful House," *East West* (July 1989): 48.

159 Tim Schott, "Healthy Building is Here to Stay (sidebar)," *Custom Builder* (May/June 1992): 70-73.

$2,000 extra on an oak floor (instead of carpet) than by spending $3,500 extra on a low-tox insulation. They found that one of the best deals is a healthy solid-pine floor, which can actually be cheaper than unhealthy carpet. Choosing an electric range over a gas one also gives you a significant health benefit for no extra money.

While it is difficult to determine the dollar cost of poor indoor air quality (IAQ), insurance-industry observers agree that the costs may be unrecognized—and ascribed instead to more conventional medical conditions such as respiratory ailments, allergies, and asthma. A report on insurance costs found that "there is strong awareness and growing concern over the 'silent crisis' of IAQ and its potential to cause large industry losses." [160] Most people would probably rather spend a little more and have a healthy house, than have an unhealthy house that makes them sick, and go through the stress of a lawsuit or a battle with their insurance company.

If certain construction expenses are necessary to improve or maintain your health, they may be tax deductible. Deductible items include those things prescribed by a doctor such as air filters, and special transportation costs. Expenses that promote health, such as replacing a gas furnace with an electric heat pump may also be deductible if they are specifically recommended by your physician.

Because tax laws are constantly changing, it's important that competent tax advice be secured prior to taking deductions for remodeling a house. It may be necessary to obtain written statements from your physician, contractor, and real estate agent. All expenses should be documented by accurate records. Remember, medical deductions must be proven, they are not simply allowed. The burden of proof is on the taxpayer, but as long as the Internal Revenue Service's latest guidelines are followed, and a competent tax accountant's advice is adhered to, the appropriate medically related deductions should be allowable.

Occasionally a lender will be reluctant to provide a mortgage on a house that they consider unusual. While you may think that healthy houses should be the norm, your lender may not fully understand what you are trying to do. The best solution is to explain precisely why your house is not unusual, and why it will be marketable when it comes time to sell it. There are actually a number of mortgage programs available for energy-efficient homes that might be more willing to fund a house with health-oriented features. **RESNET** is a national clearinghouse for information of such mortgages. It you still run into difficulty with a lender, the **National Home Mortgage Co.** was formed to specifically to provide home financing for chemically sensitive people.

Housing Types

Even though a variety of different kinds of new healthy houses are being built every day by competent designers and contractors, building any new house—healthy or unhealthy— can seem daunting. When confronted with the possible negative health problems associated with conventional new construction, many people immediately start considering older houses, or alternative construction techniques. Following are some of the advantages—and disadvantages—of a few of the choices available.

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[160] Allen

Older Houses

A typical older house can have a number advantages when compared to a typical new house. In the first place, any questionable materials will have had a number of years to outgas. Brand-new plywood might be a significant source of formaldehyde but 30-year-old plywood may be completely outgassed. It will be difficult to even find much plywood in a house built before World War II. Older houses are also more likely to have hardwood floors and plaster walls. When the corner of carpeting is peeled back it's not unusual to find a beautiful hardwood floor that's been hidden for years. If the cabinetry is original, it could be made of solid wood. New cabinets today are constructed with formaldehyde-laden particle board or plywood.

Of course, if an older house was remodeled recently with conventional materials, it could easily have high outgassing levels. So, it might be better to look for a place "in the rough" and remodel it with healthy materials. It can be an expensive proposition to remove recent remodeling and redo everything with less toxic materials. In doing so, you end up paying for a house twice.

Another advantage to an existing house is that it's already built and you can easily evaluate the neighborhood. There is no need to guess whether or not an oil refinery will be built across the street. A sensitive individual can walk inside and see if the house has an adverse effect on them. It may even be possible to spend a couple of nights in a house to test your tolerance for an extended period. This is an excellent idea if sensitivities are severe, but it may not be possible if the house is occupied. A competent real-estate agent should be able to get permission if the house is empty.

On the negative side, existing houses can have a long and unknown history. You can never be sure what kinds of insecticides or termiticides have been applied by previous owners. Chemicals that were once considered safe, are now banned. Even though you can no longer purchase them, their residues will linger for years. In addition, a former owner may have been very fond of perfume, leaving the closets saturated with artificial fragrance. This can be an obvious source of irritation for a future resident who happens to be hypersensitive to perfume. Closets can also be contaminated with mothballs, or mold. If the previous owner had pets, a thorough cleaning may be necessary.

If a house has an old, worn-out furnace system, it certainly won't add any value to the house, and it can be replaced with a more healthful system. Older houses must be carefully evaluated for the presence of asbestos or lead paint, and clean-up or removal costs should be estimated before an offer-to-purchase is made. Older houses should also be evaluated for moisture problems which can lead to mold growth. Many pre-purchase home inspectors are quite good at spotting potential, or ongoing, moisture problems.

If you're in the market for an existing house, as you read this book, you should compile a list of health features that are important for your particular needs. The odds are you won't find the perfect house, but with some effort, you should be able to find one with possibilities. A little remodeling might be in order, and that can often be done before you move in.

Lustron Houses

There is one type of existing house that might be suitable for some sensitive people: a Lustron house. These houses were mass produced by a firm in Columbus, Ohio. In 1948, Carl Strandlund's Lustron Corp. began producing houses whose unique feature was that they were built almost entirely out of steel—about ten tons in all. Most of the press coverage at the time was favorable, but the enterprise eventually failed due to lack of planning. About 3,000 houses were produced, and many still can be found around the Midwest.[161]

These houses have an all-steel frame. The studs and rafters are all steel. All of the wall panels, both interior and exterior are porcelainized steel. The roof shingles are porcelainized steel. The exterior panels are two feet square and are reminiscent of those used on older gasoline stations. They were produced in several pastel colors, and with a little polish, they still look good today. The doors and windows are also constructed of steel. They are all built on concrete slabs, which had to be placed very accurately because these houses were built to very close tolerances on an assembly line.

For someone concerned with outgassing, one of these houses might be worth considering. They are not, however, perfect. Generally they are located in cities, where outdoor air pollution can reach high levels. They were originally heated with oil, and they are not very energy efficient. However, because they are bolted together, they can simply be unbolted and moved to a pleasant hilltop location in the country, and several have had their heating systems already changed. The meager insulation can be upgraded, but only up to a point—a significant disadvantage in cold climates.

Another disadvantage to these houses is that what you see is what you get. Because all the pieces fit together in a precise way, remodeling is difficult. The basic model was a 1,025-square-foot two-bedroom unit, although a few three-bedroom models were built. If that isn't large enough, adding an addition can be tricky—although two houses might be put together. Another drawback is the difficulty of hanging pictures on the steel-paneled walls. However, with a few magnets, they make great bulletin boards.

There is no registry listing the locations of Lustron houses. If you are interested in finding one, and your real-estate agent doesn't know what you're talking about, check with the local historical society or a local architect. Lustron houses are quite easy to recognize, and if there's one in your area, there could easily be several.

Mobile Homes

Mobile homes definitely fill a housing need, but they are notorious for emitting various chemicals into the indoor air, especially formaldehyde. It is released from the insulation, particle board, cabinetry, wall paneling, and carpeting, and because most newer mobile homes are built fairly tight and energy efficient, it can't easily escape. Some people have become so affected by the formaldehyde that upon leaving their mobile home, they are so sensitized to other chemicals they have trouble finding any tolerable housing. A Canadian study found that formaldehyde levels in new mobile homes ranged from 0.31 ppm to 0.90 ppm—well above the Canadian Ministry of

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161 Heather Ziegler, "House of future had steel walls," *The (Cleveland) Plain Dealer* (June 30, 1996): 8B.

Health's short-term guideline of 0.10 ppm by time of occupancy.[162] In the U.S., mobile homes must contain a warning about the adverse health effects of formaldehyde.

While newer mobile homes should generally be avoided, an older model can sometimes provide relatively healthful housing. Although it is probably constructed with plywood and wall paneling, a 25-30 year old model will have had many years to outgas. It will probably also have an outgassed asphalt-tile floor—although you may have to rip out recently installed carpeting to find it.

On the negative side, like an older house, the closets may be contaminated with perfume or mothballs, and roof leaks could have led to a mold problem. The electrical service may be inadequate for electric heat or an electric range. If painting or roof coating is necessary, work should be done before a sensitive individual moves in. Roof coatings are usually asphalt-based, so they are definitely a potential source of air pollution. However, many of the drawbacks can be overcome. For example, if a mobile home is located in mobile-home park, there may be a certain amount of continuous outdoor pollution due to the closeness of the neighbors—but that can be overcome by moving your unit to a more healthful location. Of course, in some jurisdictions, such a move might be thwarted by zoning regulations.

A general disadvantage is that older mobile homes are poorly insulated and not very energy efficient. But, because an older model may only cost a couple of thousand dollars, a high utility bill may be affordable.

Apartments

From an outgassing standpoint, older apartment buildings are preferred over newer mass-produced units. Like many older houses, they could easily have hardwood floors and plaster walls. Steam heat is often used in older apartments. Although the boiler may be gas or oil-fired, it will usually be in the basement, and if your apartment is on an upper floor, there may be no combustion by-products reaching there—unless the chimney is right outside your window. Even in small buildings, upper floors are preferable to minimize exposure to traffic odors. And side streets are healthier than busy thoroughfares.

In major cities, large multi-story apartment buildings may have indoor parking garages on the lower floors which can contaminate the lower apartments. Sometimes exhaust gases can travel up elevator shafts, stairwells, or other building cavities and reach the upper floors. However, life on the upper floors can often be quite tolerable. In fact, the best place to be in a city is as high up as possible, away from the ground-level pollution and smog.

A big danger in apartments is contamination by smells, gases, and odors from adjoining units. It is often possible to tell when the neighbors are smoking marijuana, spraying disinfectant, or painting, and odors from a neighbor's wood-burning fireplace can often seep through common walls. When hunting for a healthy apartment, one article suggests considering the following: neighborhood, traffic, parking, indoor public areas, the building in general, the apartment's (and the bathroom's) ventilation, odors, heating system, wall finish, floor coverings, storage, and appliances, as well as a careful

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162 Canada Mortgage and Housing Corp. (CMHC), *Field Study of the Indoor Environment in Mobile Homes*, (Ottawa, ON, Canada: CMHC, 1990).

evaluation of the bedroom.[163] Apartments are also often routinely sprayed or chemically treated for insects and other pests, either by the management or tenants.

Solar Designs

Solar houses have become popular in recent years. If designed correctly, they can provide a healthy environment. Two types of solar heating have evolved: active and passive. If designed correctly, both can provide heat in a healthy manner. Both will, however, usually require some form of auxiliary heat for extended cloudy periods. For this reason, adequate insulation is important, no matter which method is chosen. See *Chapter 7, Heating and cooling* for more information on solar heating.

Prefabricated and Kit Houses

Prefabricated houses have a certain appeal because they can be erected quickly, and kit houses are popular with owner-builders who plan to do much of the construction work themselves. While these types of houses certainly have the *potential* to be healthy, there are currently no companies producing prefab or kit homes that are specifically designed for improved health and indoor air quality. A healthy house typically requires careful selection of building materials—some of which may need to be special ordered—and airtight construction techniques. Because kit and prefab houses rely on mass-production, special materials or construction methods are generally unavailable.

Alternative Construction

There are a variety of alternative ways to build houses that have been revived in recent years. Though not gaining widespread acceptance, they certainly have their adherents. The techniques of adobe, rammed earth, straw bale, timber frame, and log construction, have become popular in the environmental movement because they use natural materials. They all represent alternatives to the conventional 2x4 framing used in most houses. But the materials that most affect indoor air quality are the interior finishing materials—not the structure. Many of these alternative methods are no more or less polluting than conventional construction, they are just different. In general, there are several disadvantages: the average builder may be unfamiliar with the techniques, building inspectors can be leery of something untried in their jurisdiction, insurance costs can be higher, and alternative techniques are generally more expensive than conventional techniques. See also *Chapter 13, Alternative Framing Materials*.

Temporary Housing

Occasionally, someone will suddenly find out that their devastating symptoms are being caused by their house, and the only solution is to move and move quickly. But it may not be possible to build a new healthy house, or find a tolerable apartment immediately. This can be a frightening situation and the choices can be limited, but there are choices.

Some people have been able to live in an older tent or camper in their back yard

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[163] Louise Kosta, "A checklist for apartment hunters," *The Human Ecologist* (Summer 1990): 13-14.

while healthy remodeling is done to their home. (New tents may be intolerable due to waterproofing chemicals, and new campers may be constructed with unhealthy materials.) Others have found refuge in a relative's or friend's house, but it can sometimes be difficult finding an existing house that is more tolerable than the one being remodeled.

Doctors who specialize in treating chemically sensitive individuals may be able to refer a person to a healthy place to stay. They may also know of a local support group for people with MCS. Often, support groups know of relatively healthy places to live. They may even have a member with an empty bedroom that is temporarily available.

It can also be possible to find a relatively safe room within your existing home, or such a room might be remodeled fairly quickly. This room can become an oasis.

An Oasis

An oasis is a safe and healthful room where you can feel comfortable—a place where you can get away from the contaminated air in the rest of the house. It is sometimes called a sanctuary or a safe haven. For many people, making one room into an oasis can be a reasonable alternative to moving. In order to begin, the room must be emptied of all furnishings, including draperies, clothing and carpeting. If this empty room continues to elicit symptoms, it may be necessary to seal some of the surfaces. Sometimes a low-tox paint can be used to seal the walls, but the fresh paint may need time to outgas. If an immediate place to stay is required, the walls, ceiling, and floor can be covered with aluminum builder's foil (For sources, see *Reflective-foil insulation* in *Chapter 17, Insulation*). This works best if all the seams are carefully sealed with foil tape. The resulting "metallic look" often results in a very safe environment.

If it is the heating season, and the existing furnace elicits symptoms, then all of the registers in the oasis must be taped shut and a tolerated auxiliary electric heater must be installed. If the mattress is suspected of causing symptoms, it should be replaced with a metal box spring covered with several cotton of wool blankets to provide padding. A room-sized air filter can also be helpful. For more information on creating and living in an oasis (or safe haven) see *Creating a Healthy Household* by Lynn Marie Bower.

After an oasis has been created for a sensitive individual to retreat to, the rest of the house can be tackled on a room-by-room basis. The oasis provides a safe environment needed for someone to build up their strength while their health improves. By spending eight hours of restful sleep in an oasis, a person can often cope with the rest of the house during the day, so remodeling need not be rushed.

Evaluating Your House

If you live in a house you think might be affecting your health, there are a number of questions that can help you determine if you have an indoor air quality problem. In *The Clean Air Guide*[164], **Canada Mortgage and Housing Corp. (CMHC)** suggests that if you answer "yes" to any of the following questions, your house may have poor air

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164 Canada Mortgage and Housing Corp. (CMHC), *The Clean Air Guide* (Ottawa, ON, Canada: CMHC, 1993): 6.

quality:

- Do you notice an odor as you enter the house?
- Do you feel better outdoors than inside your house?
- Do you feel better in other people's homes than your own?
- Are there times when you feel sick inside your house?
- Do you associate specific symptoms with particular odors?
- Are they worse in certain areas of the house?
- Are they worse at particular times of year?

Answering "yes" to any of the following questions may mean you have an indoor air quality problem related to *chemical* contamination:

- Is there a "new smell" or a chemical odor? (similar to that of a new car, new wood, gas, paint, fabric shop, carpet store, *etc*.)?
- Has a pest control company ever treated your house?
- Has the house been renovated recently?
- Are there new furniture or furnishings?

Answering "yes" to any of the following questions may mean you have an indoor air quality problem related to *biological* contamination:

- Does your house have an "old smell" (stale, musty, or earthy)?
- Does your house have a crawl space or basement?
- Does the crawl space or basement have a dirt floor?
- Do you sense that your basement is unhealthy for you (feelings of dampness, aversion or discomfort, *etc*.)?
- Does water come into the basement at certain times?
- Is there flooding when it rains, or during spring thaw?

If you have specific questions about the healthfulness of your house, there are growing numbers of consultants that can be of help. Many of these people have written sidebars for this book, and there are others throughout the country. In addition, **American PIE**, a non-profit organization, can answer some basic questions at no charge by phone.

If you would like to have the air quality in your house tested, you should realize that testing for every possible pollutant can be quite expensive—as much as several thousand dollars. This is because there are so many possible pollutants. Therefore, it helps to have at least a general idea of what the problem is related to before you decide to do any testing. That way you can test only for the major suspects. Comprehensive testing for all possibilities is rarely necessary. **Air Quality Sciences, Inc.** offers an IAQ test kit for a few hundred dollars that can be used to measure VOCs, formaldehyde, and mold on surfaces. **Advanced Chemical Sensor, Inc.** has a relatively inexpensive testing device for formaldehyde. They can also provide test monitors for a wide variety of other chemicals in the air. **Aerotech Laboratories, Inc.** offers a variety of tests for identifying mold, as well as for dust mites, and animal dander.

Summary

We all have different health and housing requirements, so it's important to analyze *your* specific needs and make a list of the features *you* require in a house. The various chapters of this book will help you create such a list. After determining your needs, you should be able to determine the feasibility of modifying your existing house, moving to a different house, or building a new house. Then you can proceed accordingly.

4. Site Selection

Outdoor pollution definitely affects indoor pollution.[165] This is because the indoor air originally came from the outdoors. If there is continual outdoor pollution, you will need continual filtration indoors to counteract it. But if the outdoor pollution is episodic, and you have a tight house, you can operate a ventilation system during periods of clean outdoor air and often get by with minimal filtration. Still, if possible, it is always best to live where the outdoor air is the cleanest.

According to real estate agents, the three most important things determining the value of a house are: location, location, and location. For them, a location on a corner lot, near schools, shopping, and work may indicate the ideal place to live. Location is a very important thing to consider when searching for healthy housing, but an entirely different set of criteria must be used. What a Realtor considers remote for convenience reasons may be ideal for health.

Specific Geographic Areas

People often wonder which part of the country is the healthiest place to live. Well-meaning friends are loaded with advice about the South being healthier, or the West, or the North. Unfortunately, there is probably no single geographic area that is ideal from a health standpoint. All parts of the U.S.—or the world, for that matter—have their unique benefits and hazards. The Southwest has been touted as having a dry climate perfect for asthmatics, but when Easterners migrated there, they brought pollen-bearing plants into the region. With irrigation, these plants have thrived and are spreading their allergens to the wind.

Seaside locations have also been recommended, but there is the possibility of mold growth, and an abundance of spores at certain times of the year. Excessive fog can be particularly conducive to mold growth. If there is any standing, stagnant water, it can be a breeding ground for a variety of harmful organisms. Frontage on water is a desirable location for many people, so the area may be polluted by neighbors with wood smoke or lawn chemicals. With the prevalence of oil spills, it would not be uncommon to find an oily sludge on any ocean beach in the world.

The fresh country air in the Midwest is often fouled with agricultural chemicals, or the mold spores and pollen associated with farming. Even a tractor in need of a tune-up can pollute the air to a great degree.

Large cities are notorious for their air pollution, and this may extend for several miles beyond the limits of the city itself. Traffic and strip development along major highways can often extend the cities unhealthy air into nearby towns.

Even though there is no single perfect place to live, there are pockets everywhere that can provide the fresh air necessary for a healthy building site. But the specific characteristics that make a site ideal will vary, depending on your personal needs. The

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165 G. Hoek and others, "Indoor exposure to airborne particles and nitrogen dioxide during an air pollution episode," *Journal of the Air and waste Management Association* 39 (1989): 1348-1349.

best spot for an asthmatic will be different from a site selected by someone with MCS. The spot may be in the Southwest or at the seashore. So, even though no single geographic region is perfect, if you know what to look for, good sites can be found practically anywhere. The most important thing to do, when analyzing a site, is to look around thoroughly. Neighbors can often supply a wealth of information about a prospective property. For example, they can tell you how often people apply lawn chemicals, who burns wood, where the abandoned landfill is, the frequency of mosquito spraying, *etc*.

Starting Your Search

If you are not familiar with a particular area, maps and aerial photographs can be very helpful. They are sometimes available at the local plan-commission office. Besides generally describing an area, planning office staff will be able to tell you what uses the zoning regulations allow. For example, it would be nice to know if a neighboring parcel is zoned for heavy industry.

Maps

It's always helpful to have a good map when beginning a search for a healthy site. With a map, you can easily see what surrounds a potential location. Unfortunately, commonly available road maps are of limited value. They certainly supply the names of roads and enable you to find your way around unfamiliar parts of town or the country, but they do not show the locations of houses. Nor do they show any topographic information such as hills, drainage patterns, ravines, *etc*. For this information, *$7^1/_2$ minute quadrangle maps* have been produced for the entire U.S. These maps are reasonably priced and are available either directly by mail through the **U.S. Geological Survey (USGS)** or at selected locations in most states. Each quadrangle map covers approximately $6^1/_2$ x $8^1/_2$ miles at a scale of 1" = 2000', and they are color coded.

Besides showing the locations of roads, they also show driveways and unpaved lanes. Rivers, ponds, and streams, as well as intermittent creeks, are also displayed. Houses and barns are easy to pick out, as are larger buildings such as factories. Real-estate listings often designate the township and section number, information that can also be found on these maps. The most comprehensive information, however, has to do with the topographic data. Originally produced from stereoscopic aerial photography, they show the elevation of the ground above sea level, so it is easy to pick out the top of a hill, where the valleys are, or how a ravine cuts through a particular piece of property. Other details include boundaries of state and national parks, high-voltage electric lines, gas wells, cemeteries, pipelines, some fence lines, and wooded areas.

It may be necessary to obtain several quadrangle maps to cover your entire county. Each map has a particular name, and state-wide indexes are available—so you know which maps to request. With quadrangle maps, you can easily learn a great deal about a piece of property. For instance, a map might show a natural gas well just beyond the property line, or a hidden farm field nearby, or several houses in an upwind direction that need to be investigated for burning wood. Property owners are not shown on these maps.

Another type of map that can be helpful is a plat map. Plat maps are usually available for an entire county and can be found in the local courthouse. They are usually contained in large, unwieldy books, but sometimes they are reproduced into a smaller $8^1/_2$" x 11" format for sale to the public by a local real-estate agent or an abstract company. The type of information available on a plat map includes the property owner and shape of the property. If you find a location that looks promising, a plat map will supply you with the owner's name and the owners of surrounding parcels. If a neighboring lot is owned by Acme Nuclear Power, Inc., then a phone call may be in order to determine what they plan to construct there. If a particular piece of property looks promising, even though it is not currently listed for sale, it might also be worth a phone call. If you are told about a piece of property by a real-estate agent, you should be able to locate it on a plat map and then look on a quadrangle map to see if there are any major drawbacks. This can save a tremendous amount of time driving around the countryside.

Aerial Photography

Aerial photographs can also supply a great deal of information about the surrounding countryside. Most major cities have one or more aerial photographers listed in the telephone book. Some specialize in photographing homes and businesses from the air. The ones who have mapping capability will have photos available that are taken from a higher altitude. These can be very useful for studying a particular area. If an area has already been photographed, prints can usually be purchased at a nominal cost. If new photos must be taken, the cost will obviously be higher.

The **USGS** has aerial photos available of the entire country. These are referred to as low-altitude photography (as opposed to satellite photography), and are used to produce the topographic quadrangle maps. Photo indexes are available, from which you can select individual photos. Their 9" x 9" prints cover from 3 to 7 square miles and are reasonably priced. Larger blow-ups can also be purchased.

The advantage of looking at an aerial photograph is the wealth of information to be seen. These bird's eye views allow you to see garden patches, dumping grounds, lawns, high-voltage power lines, *etc*. For some photos, a magnifying glass will prove helpful. To truly get the overall picture of an area, aerial photographs can be invaluable.

Spend Time at a Site

While maps and aerial photos can reveal a lot, it's always best to spend some time at a prospective site. Taking a day or two to learn about an area will reveal if it's compatible with your particular needs. Keep in mind that the air may be quite different on a weekend when people are out for a Sunday drive, than it will be during the week when a nearby factory is in operation.

The purpose of this chapter is to list a number of possible sources of air pollution to watch out for, not to recommend a specific location. Practically every site will have both positive and negative points and the only true test for someone with severe sensitivities is to actually visit the area and spend some time there. For someone with no apparent health problems, who is interested in finding a place safer than the norm, the guidelines can be more lax.

Specific Considerations

The healthiest location is simply the place with the cleanest air, soil, and water. A complete list of all the things to avoid would be quite long, but some things are more important than others. It's impossible to list everything to avoid, but the following paragraphs will discuss some typical considerations.

History

The history of a piece of property can be very important. Was hazardous waste ever stored or disposed on the site? Even though they are not visible, VOCs escaping from buried hazardous waste can migrate into the living space of a nearby house.[166] Has the lawn been heavily treated with pesticides and fertilizer? Some of this type of information might be obtained from neighbors, a local planning commission, or a county board of health.

Cities

Urban areas are often more polluted than rural areas simply because people are living closer together. Automobile and truck traffic, airports, lawn chemicals, pesticide spraying, and a wide variety of human activities all contribute to metropolitan air pollution. One study found retarded bone maturation in children living in polluted cities.[167]

Of course, cities have many advantages: libraries, museums, concerts, employment opportunities, access to health care, health-food stores, organic-food outlets, *etc*. An ideal location might be in an unpolluted area with good access to a city—or one side of a city may have cleaner air than another.

Topography

Some of the most polluted places in the world are in valleys. A valley can fill up with smog and air pollution much like a bowl fills with water. The floor of a valley can, therefore, be much more unhealthy than a site on the rim. The winds through a valley often travel in the direction of a waterway, making the lower end more susceptible to air contamination. Farm fields can introduce pesticides and fertilizers as well as exhaust gases into these geographic "bowls," filling them with a variety of pollutants.

On the other hand, hilltop locations are often healthy building sites. Breezes tend to bring in a constant supply of fresh air. Like being on the top floor of an apartment building in the city, a hilltop can put you above much of the surrounding air pollution, however there is always the possibility of contamination. If an oil refinery is located upwind, the hilltop may not be very desirable.

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[166] "Risk of VOC contamination for buildings near hazardous waste," *Indoor Air Quality Update* (February 1993): 6.

[167] H.W. Schlipkoter and others, "Growth and bone maturation in children from two regions of the F.R.G. differing in the degree of air pollution: results of the 1974 and 1984 surveys," *Journal of Hygiene, Epidemiology, Microbiology, and Immunology* 30 (1986): 353-358.

Moldy conditions in places such as swamps and damp woods should generally be avoided. Methane from swamp gas can also be a danger. Yet with a little planning, a swamp can be drained to provide a healthful place to live. Similarly, a damp woods can be cleared out sufficiently to allow the sunlight and a breeze to penetrate, creating a suitable building site.

Geology

Some geographic areas are known for high radon concentrations. Such spots should be avoided unless suitable radon-reduction strategies are incorporated into a house. Local or state boards of health should be able to identify high risk locations. Volcanoes are obvious natural polluters that should be avoided because of the possibility of breathing their toxic gases. One study looked at the toxicity of volcanic ash and found that, even though it contains amorphous silicates, it is much less toxic than free silica, which is a known cause of lung disease.[168]

Geophysical forces around earthquake fault zones result as stresses in the earth's crust change. These tectonic stresses cause fields to develop that have both electromagnetic-like and gravity-like components. At least one researcher has theorized that these brief fields can cause unusual phenomena to take place.[169]

In areas where mining or oil drilling are likely, you should check to see if oil and mineral rights are sold with the property. If not, find out who owns the rights and what they plan to do with them.

Prevailing Winds

In North America, climate patterns generally follow a path from west to east. Therefore, the prevailing wind usually comes from the west. In general this is true, but it can vary tremendously from place to place. It can also vary at different times of the year. Sometimes a particular location will experience an Arctic blast out of the north, and a week later a gentle southern breeze. The prevailing wind direction can also be very site specific. Two areas a mile apart can have entirely different wind patterns.

The local topography is partially responsible for the wind direction. A hill or mountain can cause the wind to blow around it rather than over, resulting in a predominately southerly wind in a certain area, even though the wind is generally from the west. Lakes, fields, and woods also have an effect on local wind direction.

The best way to determine the usual wind direction is to ask someone who lives in the neighborhood. Most people will know if the smoke from a factory tends to blow directly toward their house on a regular basis. Similarly, they will know if the dust from a gravel road is worse on one side or the other, indicating the prevailing wind direction.

It's important to remember that wind is a global phenomena, and there is no place on the planet that is immune from being polluted by wind from somewhere else. For

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[168] Thomas Martin, Garrison Ayars, John Butler, and Leonard Altman, "The Comparative Toxicity of Volcanic Ash and Quartz," *American Review of Respiratory Disease* 130 (1984): 778-782.

[169] M.A. Persinger, "Geophysical Variables and Behavior: XXII. The Tectonogenic Strain Continuum of Unusual Events," *Perceptual Motor Skills* 60 (1985): 59-65.

example, many of the chemicals found on Isle Royale, in Lake Superior near the Canadian border, were carried there from farm fields and factories in the Midwest and South.[170] High-altitude winds carry pollutants around the planet.

In some parts of the world, the action of the wind produces an abundance of positive ions in the air. Ions are simply electrically charged particles. Both positive and negative ions occur everywhere. However, an excess of positive ions in the air can result in an increase of serotonin in the body, and result in symptoms such as irritability, insomnia, tension, or upset stomach. There are even reports of increased rates of suicide, accidents, and crime when these positive-ion-producing winds are blowing.[171] [172] Physicians in these locales have even been known to postpone elective surgery until the wind stops.

While these dry winds don't blow all the time, they are so well known they are often given names. The Sharav in Israel has been shown to affect up to 25% of the population. In the U.S., the Chinook is known in the Pacific Northwest and the Santa Ana in California. Local residents generally know if the occurrence of these "devil winds" is common in a particular area.

Acid Rain

While there is little direct evidence that acid rain has an immediate effect on human health, there is some indirect evidence. It is known that acidic water will leach metals such as cadmium, arsenic, zinc, and aluminum out of the soil. Drinking water from lakes and streams where acid rain is common may result in a variety of diseases associated with ingestion of heavy metals. Acidic water may also cause less of the beneficial metal selenium to be taken up by the body, leading to selenium deficiencies.

While there are apparently no serious effects from acid-rain contact with the skin, breathing the trace quantities of sulfuric and nitric acid formed in the atmosphere can be injurious to human lungs. It has been suggested that high concentrations of acidic pollutants in the atmosphere were responsible for excess mortality in London in the 1950s, in the Meuse Valley in Belgium in 1930, and in Donora, PA in 1948.[173] Therefore, areas with excessive acid rain should be avoided.

Flora

Trees and plants have long bothered allergy sufferers. Ragweed and goldenrod pollen are well known examples. For someone with moderate allergies, simply avoiding the most common pollen-bearing plants may be sufficient. However, for someone with

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170 Michael Brown, "Toxic Wind," *Discover* (November 1987): 42-49.

171 A.P. Krueger, "Preliminary Consideration of the Biological Significance of Air Ions," *Scientia* 104 (September/October 1969): 460-476.

172 Alayne Yates and others, "Air Ions: Past Problems and Future Directions," *Environment International* 12 (1986): 99-108.

173 Thomas H. Maugh II, "Acid Rain's Effects on People Assessed," *Science* 226 (December 1984): 1408-1410.

severe sensitivities, a wider selection must be considered. Aromatic plants such as mint, and many flowers, have been known to elicit symptoms. For an individual sensitive to hydrocarbons, creosote bushes and cedar trees should be considered. Most softwood trees contain various terpenes, and other naturally occurring resins, that can cause reactions in some chemically sensitive people. Some commercial and public forest lands are routinely sprayed with chemicals.

There is a book titled *Allergy-Free Gardening*[174] that looks at the ability of living plants to trigger allergy symptoms. The author evaluates over 5,000 plants using several criteria, then rates them on a scale of 1 to 10, with 10 being the most capable of triggering symptoms. For example, oaks are rated 8-9, maples 7, birch 7, bald cypress 8, apple and crabapple 4. For plants that come in two sexes, males of the holly, poplar, sassafras, and yew families are rated 7-9, while the females of those families are rated 1.

The reason male plants are more problematic is because they produce pollen, while females don't. Plants that distribute their pollen by way of the wind are worse than those who rely on insects to carry pollen. In addition, lighter-weight pollen, and irregularly-shaped pollen are more likely to elicit symptoms.[175]

When evaluating a potential home site, you should certainly consider the plants in the area, but also the length of the pollen season. If the season isn't long in your area, you may be able to remain indoors more than usual, until the outdoor air clears somewhat. An airtight house with a mechanical ventilation system will be desirable, and the fresh air intake should be fitted with a filter capable of removing the outdoor pollen. That way the indoor air can be kept pollen-free.

Roads

Busy roads can be a source of polluting exhaust gases, and on major highways and Interstates this will include a significant amount of diesel exhaust—a known carcinogen.[176] The air near highways can also be contaminated with tiny bits of rubber due to tire wear, spillage of freight materials, and littering. It's been shown that small animals living near high-traffic areas have higher concentrations of lead, cadmium, nickel, and zinc in their systems.[177] There may also be a proliferation of gasoline stations or restaurants along busy roads, where fuel vapor and exhaust gases can build up. Gasoline stations can be especially polluting when the underground tanks are refilled and vent pipes spew a considerable amount of vapor into the air. Paved roads are often constructed of asphalt which can heat up in the bright sun and outgas somewhat. Asphalt

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174 Thomas Ogren, *Allergy-Free Gardening* (Berkeley, CA: Ten Speed Press, 2000).

175 "New Allergy Scale-Risk Scale Developed for Plants," *Environmental Building News* (May 2000): 3-5.

176 U.S. Department of Health & Human Services, *NIOSH Current Intelligence Bulletin 50: Carcinogenic Effects of Exposure to Diesel Exhaust* (Atlanta: NIOSH, Centers for Disease Control, August 1988). DHHS (NIOSH) Publication #88-116.

177 P.F Scanlon, "Heavy Metals in Small Mammals in Roadside Environments: Implications for Food Chains," *The Science of the Total Environment* 59 (1987): 317-323.

patching compounds can also create problems for some sensitive people. Concrete road surfaces are much more inert, but they are often patched with asphaltic compounds.

Rural gravel roads are notorious for being dusty. However, they will probably be less traveled than paved roads and will therefore have lower levels of exhaust gases. Dust used to be controlled by highway departments by pouring used motor oil onto gravel roads. This practice was discontinued when a commercially available road oil was developed specifically for the purpose. This product worked fine for controlling dust, but it's been banned in many areas because of its toxic potential. A water-based emulsion is currently available that meets newer environmental regulations, but it is still bothersome to some sensitive people. If you live on a gravel road that is usually sprayed to control dust, you can talk to the local highway department and ask that they not spray in front of your house. They are usually happy to comply with such requests.

Another option for controlling dust on roads is the same chemical that winter crews use to melt snow and ice—calcium chloride. It is applied in a water solution, usually in late spring, and it works by absorbing moisture from the air. This moisture helps to keep the dust down, much like misting the road with a garden hose. Calcium chloride has a slight odor and seems fairly well tolerated by most sensitive people, but it can cause automobiles to rust out prematurely.

You should also consider all modes of transportation, including railroads and airports. If heavily used, they can be sources of outdoor pollution. A study of 55,407 railroad workers found that exposure to diesel exhaust from train engines was significantly associated with lung cancer.[178]

Utilities

When considering a building site, it's important to look into the availability of various utilities. You should do this for any site, but if health is a significant factor, there are a number of special considerations.

Water

Besides naturally occurring contaminants, drinking water can contain a wide variety of man-made pollutants. Some chemicals are intentionally introduced at water-treatment plants. Tests are run on these public water supplies periodically and are available for public inspection. Water from private wells is not required by law to be tested, but it can be polluted because of the many chemicals that are continually seeping down into the aquifer.

Testing can be of limited value to some hypersensitive individuals. This is because the measurement methods may not be sensitive enough to record the low levels of contaminants to which they react. Sometimes more sophisticated tests can be performed. Check with your local board of health for nearby laboratories with these capabilities. Because so many of our water supplies have been contaminated, the best solution may be to filter the water. This is discussed more completely in *Chapter 22, Plumbing systems*.

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[178] E. Garshick and others, "A retrospective cohort study of lung cancer and diesel exhaust exposure in railroad workers," *American Review of Respiratory Disease* 137 (1988): 820-825.

If you're considering a piece of undeveloped property that doesn't yet have a water supply, you can talk to neighbors to see what they do for water. If wells are common in the area, you might have a neighbor's well-water tested before having your own well drilled.

Sewage

Municipal sewage systems are a convenient way for cities to process the hundreds-of-thousands of gallons of waste disposed of every day. Today's treatment methods are tremendously better than simply dumping raw sewage into a river, however there are still contaminants being discharged into waterways from which drinking water is taken. During heavy rains, sewage is often discharged directly to the receiving stream, bypassing the treatment process. This is deemed tolerable by regulatory agencies because the waste is diluted by the excess rainfall. For these reasons, a location directly downstream from a municipal waste-water treatment plant can be undesirable.

Manholes or waste-water pumping stations have been known to overflow occasionally causing sewers to back up into houses. This can result in an obvious health hazard and neighbors will usually know if these occurrences are commonplace.

When municipal sewage treatment isn't available, septic systems are often used to treat the sewage from individual houses. If properly constructed and maintained, they will cause no health problems. If built in a swampy area or on a hillside, there is the possibility of effluent leeching to the surface. Because shallow water wells can be contaminated by a septic system, boards of health generally recommend at least a 100' separation, and the well should be located on higher ground than the septic system.

Natural Gas

Natural gas appliances are often avoided in healthy-house construction. For some hypersensitive people, an all-electric subdivision is preferable to one supplied with natural gas. However, because the country is crisscrossed with natural-gas pipelines, and the fuel is so popular, it may not be possible to avoid it completely. The local gas company will be able to tell you if there are any vent pipes, regulator stations, or underground storage areas nearby, and neighbors will be able to tell you if these are known to leak gas into the air.

Electricity

Utility poles are often treated with a toxic preservative which can outgas for many months. If a new pole must be placed on your property, it's possible to request a salt-treated pole rather than a creosote-treated pole. Even though the salt treatment contains an arsenic compound, it will be considerably less odorous. In either case, poles should not be located near garden areas. Underground service is preferable, because no pole will need to be near the house.

There is a great deal of concern about power lines causing cancer, but other non-cancer-related symptoms—such as disturbances in the cardiovascular system, central-nervous system, and lowered sexual capability—have also been noted.[179] These symptoms may be due to the electromagnetic fields surrounding the wires. Some people have reported increased sensitivities to these fields after a strong inciting event such as exposure to a strong unnatural field, dental work involving metallic fillings, *etc*. Symptoms can include leg cramps while passing an electrical transformer, or slurred speech when near a computer terminal.[180] Biological effects of magnetic fields include irritability, fatigue, dizziness, altered appetite, headache, itching, burning, numbness, *etc*.[181] Electromagnetic fields decrease in strength rapidly with distance, so it is wise to live as far as possible from high-voltage power lines. The strongest fields are near lines carrying very high voltages—such as 765,000 volts. Fortunately, most lines in residential areas carry considerably less voltage. Still, some lower-voltage lines have been shown to have fields strong enough to be concerned about.

According to Russian researchers, microwaves can induce dizziness, heart pains, irritability, diminished intellectual capacity, loss of hair, *etc*.[182] Cataracts have been noted in workers exposed to microwaves from radar installations.[183] In Vernon, NJ parents in the vicinity of a high concentration of microwave satellite communications antennae found that the incidence of Down's syndrome was far higher than the national average.[184] Sources of microwave contamination to avoid include radar installations, both commercial and military, and microwave communication towers. Microwaves, and other forms of electromagnetic radiation are covered in more depth in *Chapter 23, Electrical systems*.

Television

An individual with severe sensitivities can be somewhat isolated from the world due to intolerance of exhaust gas, newsprint, fragrances, printing ink, *etc*. For them, television may be a primary source of entertainment. For this reason television reception should be considered. Traditional antennas have a limited range and may not function

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179 Andrew A. Marino and Robert O. Becker, "Hazard at a Distance: Effects of Exposure to the Electric and Magnetic Fields of High Voltage Transmission Lines," *Medical Research and Engineering* 31 Ref. (November 1977): 6-9.

180 Susan Molloy, "Electromagnetic Field Reactions," *The Reactor* (Newsletter published by Environmental Health Association of San Francisco) (March/April 1987): : 6-7.

181 E.E. Ketchen, W.E. Porter and N.E. Bolton, "The Biological Effects of Magnetic Fields on Man," *American Industrial Hygiene Association Journal* 39 (January 1978): 1-11.

182 Paul Brodeur, *The Zapping of America* (New York: W.W. Norton & Co., 1977), 36.

183 *Ibid*., 55.

184 Nancy Shute, "The Other Kind of Radiation," *American Health* (July/August 1986): 54-59.

well in certain geographic areas. Cable TV is now available in a great deal of the country and may be a reasonable alternative. Home satellite dishes can open up a tremendous number of stations to someone who is generally confined to home. A professional salesperson can evaluate a particular site for satellite reception.

Industry

Factories can be obvious sources of pollution. While clean air and water standards are stricter today than they were in 1900, additional progress is still necessary. Billions of pounds of pollutants are released annually into the environment by industries. In 1987 alone, 235 million pounds of toluene, 235 million pounds of ammonia, 186 million pounds of acetone, 182 million pounds of methanol, and millions of pounds of other chemicals were released.[185] Accidental spills and smokestack emissions are not uncommon—even in a strictly run nuclear power plant. The average factory can release pollutants into the environment and never be caught violating the law because of lax enforcement measures by regulating agencies. Of course, not all factories are polluters. Many assembly plants, for example, are relatively clean. The danger with them is for someone bothered by exhaust gases because of the increased amount of traffic around such a facility.

Smokestack industries have long been regarded as being dirty. Many were built years ago, before today's pollution-control regulations came into effect, and cleaning them up can be difficult. Tall smokestacks were developed to discharge pollutants high up in the atmosphere. This causes the contaminants to descend to earth in areas far from the plant. Therefore, living near such a smokestack may be healthier than living several miles down wind. The acid rain in the Eastern U.S. is attributed to the smokestack emissions in the industrial Midwest. So, with a tall smokestack, the pollutants are simply dumped in someone else's backyard.

Agriculture

Farm fields are usually worked several times each season and every time a tractor drives through the field more pollution is added to the air. Plowing dry soil can stir up a considerable amount of unhealthy dust, which contains not only soil, but also micro-organisms that reside there. Chemicals applied in previous seasons can also cling to soil particles and be transported by the wind. Planting can contaminate the air further with seed dust, and molds living on the seeds. Fertilizing and spraying pesticides create their own obvious air pollution. Harvesting creates more dust from the crops themselves, and additional mold spores.

While a dust-related illness can be very devastating, as can mold allergy, the greatest danger related to farming involves the use of pesticides. Even the residues remaining on cotton after it has been processed into clothing can be intolerable to some hypersensitive people. In agricultural areas such as the Midwest, pesticides seem to be one of the major contributing factors in the development of MCS. While pesticide producers and many government agencies consider exposure to agricultural pesticides

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[185] Jerry Poje, Norman Dean, and Randall Burke, *Danger Downwind: A Report on the Release of Billions of Pounds of Toxic Air Pollutants* (Washington, DC: National Wildlife Federation, March 22, 1989).

acceptable, it must be remembered that pesticides are formulated to kill living creatures, and human beings are living creatures. People exposed to toxic levels of organophosphate pesticides report altered brain functions such as understanding the speech of others, recognizing printed or written words, social withdrawal, anxiety, *etc*.[186]

Although not considered agricultural areas, golf courses are often treated with just as many chemicals as farms—pesticides, herbicides, fertilizers, *etc*.—sometimes more.

The Neighborhood

Nearby houses can be sources of unhealthy wood smoke as can subdivisions that are served primarily by natural gas. Gases and particulates from chimneys, clothes-dryer vents, and kitchen-range hoods can send the by-products of combustion directly toward neighboring houses. Chemical lawn treatment has become very popular in recent years, as have the complaints of people bothered by the chemicals. Some communities have been active in enacting stricter regulations for lawn-treatment applicators because of the potential danger they pose to the population at large.

A nearby landfill can pollute the air with dust, mold, and the odor of garbage. There will also be an increase in truck traffic and associated exhaust gases. More importantly, older landfills without soil liners can pollute the ground water as various contaminates seep deep into the ground. This can poison nearby water wells.

The compost piles used by organic gardeners can generate large quantities of mold spores and should generally be avoided by a mold-sensitive individual—unless they can be located downwind of a house. Municipal compost piles that process yard waste or sewage sludge can also be problematic.[187]

Summary

In summary, there are many, many things that can affect the healthfulness of a given location. For this reason, it's important to know as much about a site as possible. If you have walked around the property, spent a day or two there, looked at some maps, driven around the neighborhood, and talked to people living nearby, you should have a good feeling about its suitability.

If you have learned enough to talk about a particular area for 30 minutes, then you probably will have learned if there are any significant pollution sources nearby. The important thing is to make an educated decision, one made with your eyes wide open. Of course, if you are very sensitive, your nose may tell you more than your eyes.

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186 "Pesticides May Alter Brain Function," *Science News* 129 (February 8, 1986): 88.

187 "Scientists at odds over compost emissions," *Environmental Health Letter* (October 16, 1992): 201-202.

Part 2: THE SYSTEM APPROACH

5. Planning

It's important to plan even a small construction or remodeling project carefully. That's because it can be very expensive to discover half way through a job that two products are incompatible, or a particular material is unavailable in your geographic area, or your contractor refuses to use a product with which he has no experience. This chapter will help you understand the importance of planning, and how it relates to indoor air quality. It's important to read this chapter in conjunction with the next four chapters to get a good understanding of how the various parts of a house interact. You see, you need to do more than simply select healthy building materials to end up with a healthy house. The materials must also be put together in a healthy way.

During the planning stages of any project, many decisions need to be made, and designing a healthy house is no exception. Some of the decisions will be the same for any house, such as number of bedrooms, bathrooms, *etc*. Will it be single-story or multi-story, Colonial or Cape Cod, *etc*. The site location, lot placement, and view will should also be considered. But, in a healthy house there are additional things to consider, some of which will seem unusual to designers and builders of conventional houses.

Because some of the materials and techniques discussed in this book are unfamiliar to some builders, a detailed set of plans is important to minimize delays and misunderstandings. Building materials or techniques that may be unfamiliar to the contractor should be carefully called out on the plans. If a project has been planned out carefully, there should be very few questions by the time construction begins.

Whether you decide to build new or remodel, it's important to select a competent builder and designer who are sympathetic to your requirements. Ask for references and see how well they were able to work with past clients. If you have an architect or builder who is unfamiliar with healthy construction materials and techniques, you may have to educate them. To do so, first familiarize yourself with the work to be done by reading the appropriate chapters in this book, then let your builder or designer read those chapters as well. In that way you can discuss intelligently the work to be performed.

If you are very sensitive, it is extremely important to test some materials for personal tolerance early in the design phase, especially those materials actually exposed to the indoors (*e.g*. cabinets, paints, floor coverings, *etc*.). Tolerability testing is covered later in this chapter.

Assessing Your Needs

All your needs and requirements should be written down. As the list begins to grow, you will notice that some needs conflict with others. For example, eliminating air pollution may be number one on your list, yet your spouse may want to be able to smoke. Compromises are a significant part of planning. Perhaps your spouse would consider giving up smoking in exchange for a concession on your part.

The basic needs to be addressed include: room number, size, and layout. If you find that you do not have enough money to add all the healthy features you want, you may need to build a smaller house. Much of what we think we need in the way of rooms has been told to us by designers, builders, and real-estate agents. For them, bigger is better because it means more profit for them. Most people don't really need a duplication of rooms. If a breakfast room is available, the dining room is rarely used. Does a family of three really require three bathrooms, or both a living room, a den, and a family room? Much of the high cost of today's housing is a result of buyers being sold more than they actually need. All houses should reflect the owner's true requirements—not just what is currently popular in home and garden magazines.

A little-used room increases the mortgage payment, plus it needs to be furnished, heated, and cleaned regularly. This involves a great deal of expense and effort for a room that is used only a few times a year. Individuals with a chronic illness may not have the energy to clean a large house. Similarly, they may not have the energy to entertain guests on a regular basis, so a large house may not be necessary or desirable.

People with MCS will undoubtedly have more stringent requirements than healthy people who want to remain healthy. With sensitive people, every component of a house will need to be considered,[188] [189] but healthy people may decide to only worry about the most serious indoor pollution sources.

A House is a System

One of the most important ideas to emerge in recent years is the concept that a house is much more than an assemblage of materials. Instead, building scientists and researchers now view a house as an interactive system. This means all the different components and sub-systems of a house actually work in conjunction with each other to create an indoor environment for the occupants. A change in one part of a house can easily have repercussions elsewhere in the building. For example, adding insulation and weatherizing a house usually means the heating system runs less in the winter, so utility bills are lower. But weatherizing a house can also affect the way moisture migrates through walls and ceilings. Some newly-tightened houses begin experiencing a higher relative humidity indoors—and mold growth. Weatherization also slows down the natural air-exchange rate, resulting in indoor air that's more stale and polluted. Tightening a house can also have a negative effect on how a chimney functions. So, unless you understand how the various components of a house interact, you can accidentally create some very real health problems.

We routinely see the human body as an integrated system consisting of several sub-systems (circulatory system, nervous system, *etc*.), and an automobile as a system consisting of various integrated components (engine, transmission, steering, *etc*.). While houses have always acted as systems, an understanding of those systems is more important with today's houses than with those built a hundred years ago. That's because tight, well-insulated, energy-efficient houses are less forgiving than the loose, drafty, energy hogs built in the past. It's even been suggested that a tight house be viewed as

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188 Mary Oetzel, "Build for Health," *The Human Ecologist* #21 (Spring 1983): 2-7.

189 John Bower, "Building Healthy Houses," *Journal of Light Construction* (August 1992): 21-23.

more than a system, but "as a spacecraft." [190]

In some ways, it's easier to create a serious health problem in a tight house than a loose house. In Canada, moldy houses are likely to have a low natural air-exchange rate —in other words, they are tightly built without adequate ventilation.[191] The answer isn't to build loose houses. The answer is to understand how houses function like systems, and then build them accordingly.

The health of a house is in a constant state of change.[192] The indoor air quality at any particular time is affected by a number of factors related to the occupants and the structure itself. The structural factors include the temperature of materials, the tightness of the house, the age of the materials or house, the type of foundation, the layout of the rooms, and the type of building materials used. The occupant factors include the number of people in a house, their ages, their activities (cooking, cleaning, hobbies, bathing, *etc*.), as well as the products they use to furnish the house. All of these factors are in constant flux, so the interactions are different at different times of day, month, or year. The goal is to understand the interactions, and minimize the factors that result in poor indoor air quality. Because there are a wide range of occupant life-styles and habits, the same house could be healthy for one family, but unhealthy for another.

Viewing a house as a system is being widely promoted at cutting-edge builder's conferences, and the system approach is becoming more widely accepted by engineers, researchers, architects, designers, and utilities. For example, in New England the Northeast Utilities published a booklet titled *The House as a System* to better educate their customers.[193] In the northwestern part of the U.S., the **Bonneville Power Administration** has an excellent Super Good Cents program[194] [195] that relies heavily on the system approach, as does **Canada Mortgage and Housing Corp.**'s R-2000 energy-efficiency program, and the Canadian Home Builders' Association's *Builders' Manual*.[196]

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190 Jim White "Systems Interactions in Housing" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 4, Building and System Assessments and Solutions*, 1990): 335-340.

191 Canada Mortgage and Housing Corp. (CMHC), *Testing of older houses for microbiological pollutants*, (Ottawa, ON, Canada: CMHC, December 1991).

192 Don Jones, James LaRue, Helene Roussi, and Alan Wasco, *Weatherization and Indoor Air Quality* (Cleveland, OH: Housing Resource Center, 1992).

193 Northeast Utilities, *The House as a System*, (Hartford, VT: Northeast Utilities, 1988).

194 Bonneville Power Administration (BPA), *Super Good Cents Construction Manual* (Portland, OR: BPA, September 1986).

195 Bonneville Power Administration (BPA), *Super Good Cents Technical Reference Manual* (Portland, OR: BPA, September 1986).

196 Canadian Home Builders' Association (CHBA), *Builders' Manual* (Ottawa, ON, Canada: CHBA, 1994). Available from **Canadian Home Builders' Association**.

In the southeastern U.S., the **Advanced Energy** *Builder's Field Guide* is an excellent example of how to apply the system approach to house building.[197]

Tight Construction

During the energy crisis of the 1970s, millions of homeowners added insulation to their homes to save on their heating/cooling bills. Soon, the concept of *superinsulation* evolved.[198] [199] [200] Superinsulation combines some passive solar elements with considerably more insulation than usual. It also requires a house to be built as tight as possible, with fresh air being provided through a mechanical ventilator. So, superinsulation is more than just additional insulation. In fact, the early designers of superinsulated houses recognized four design factors that interacted as a system: 1) high levels of insulation, 2) an air-tight and moisture-tight envelope, 3) limited window area, with most windows facing south, and 4) mechanical ventilation. With a little forethought, these principles can be applied to existing houses as well as to new construction.[201] [202]

If a superinsulated house isn't built tightly it can develop moisture problems that are hidden inside building cavities.[203] If it has too many south-facing windows, it can overheat in the winter. And if it doesn't have a mechanical ventilation system, the indoor air quality will deteriorate. To function well, a superinsulated house must have all four features planned out together. But even when these four factors were carefully considered, the air quality in some early superinsulated houses suffered. This lead to some negative publicity that persists to this day.

As it turns out, the poor indoor air quality in some superinsulated houses is due to the simple fact that early designers missed a fifth design principle—*use healthy materials*. NASA builds spacecraft, and the Navy builds submarines with the same four design considerations and they don't have poor indoor air quality because they're built

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197 N.C. Alternative Energy Corp. (NCAEC), *Builder's Field Guide* (Raleigh, NC: NCAEC, 1994).

198 J.D. Ned Nisson and Gautam Dutt, *The Superinsulated Home Book* (New York: John Wiley & Sons, 1985).

199 John R. Hughes, "The Superinsulated House," *Fine Homebuilding* #9 (June/July 1982): 56-59.

200 Robert Corbett, Wally Hansen and Jon Sesso, *Superinsulation A Housing Trend For the Eighties* (Butte, MT: National Center for Appropriate Technology, 1980).

201 Ed McGrath, *The Superinsulated House* (Fairbanks, AK: That New Publishing Company, 1981): Chapter IX.

202 John Hughes, "Retrofit Superinsulation," *Fine Homebuilding* #20 (April/May 1984): 35-37.

203 G.E. Sherwood, *Condensation Potential in High Thermal Performance Walls - Cold Winter Climate* (Madison, WI: Forest Products Laboratory, May 1983). Research Paper FPL 433.

with very inert materials. So, superinsulated, tight houses can indeed be healthy. A Canadian publication puts it simply: “The common perception that houses must be leaky to have good indoor air quality is a myth.”[204]

Selecting Materials

Careful material selection has been a hallmark of healthy construction since the concept was first conceived. But, as with all houses, a healthy house is much more than an collection of materials. In fact, it is possible to build a house of totally inert materials and have poor indoor air quality due to moisture problems, inadequate ventilation, or pollutants like radon seeping into the living space. Still, material selection is of prime importance.

A house is composed of hundreds of individual components, some of which are more polluting than others. Fortunately, there are healthy materials that can be substituted for virtually every unhealthy product currently in use. But there are two significant difficulties people run into when specifying healthy materials: some are quite expensive, and some aren’t readily available in all parts of the country. In spite of this, it *is* possible to build a healthy house with readily available materials, at a reasonable cost—if you realize that a healthy house is a system. When you understand how the various components of a healthy house interact, you can assemble a combination of healthy and unhealthy materials in a cost-effective and healthy manner.

In order to avoid expensive and time-consuming changes after a project gets underway, it’s important to select as many materials as possible during the design phase. If any changes are necessary after construction begins, they should be approved by the homeowner.

Healthy Design Principles

There are four design principles pertinent to a discussion of healthy construction: *Elimination*, *Separation*, *Ventilation*, and *Filtration*. (Filtration is often combined with ventilation, but we’ll discuss it separately.) As an example, if you have a strong poison in the house, the best thing to do is to *eliminate* it—get it out of the house—or at least replace it with a less-potent poison. If there is some particular reason that it needs to be in the house, the second best thing to do is to *separate* it from the living environment—place it inside sealed container. Thirdly, because the container may not be perfectly sealed, the area should be *ventilated*—provided with fresh air. And lastly, the air in the area can be *filtered* to remove air pollutants released by the poison.

There are a number of ways to use these four principles. If only one or two are used, there will certainly be some improvement in indoor air quality, but the most impressive results are obtained when all are used in combination—and the house is considered a system. Using all four principles together is also the most cost-effective approach.

Elimination

Eliminating potential pollutants is by far the most important way of getting clean

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204 Drerup, *Housing for the Environmentally Hypersensitive*: 8.

indoor air. Some products emit such large quantities of pollutants that it would be virtually impossible to ventilate sufficiently, and if an entire house is outgassing, the only feasible way to separate the pollutants from the living environment is for the occupants to leave and not live in the house any more. Unfortunately, some individuals *have* had to abandon their homes because of excessive indoor pollution.

The best way to eliminate indoor air pollutants is to not use polluting materials in the first place. There are alternatives to most of today's popular building materials that are either non-polluting or considerably safer. When substituting a material that is imperfect, the two principles of Separation and Ventilation can be used to insure that the air remains clean. Filtration is also useful, but the other three principles should generally be used first.

The most important things to eliminate have already been mentioned: carpeting, manufactured wood products having high formaldehyde emissions, and some combustion appliances. There are substitutes for these items that will be discussed later.

If problematic materials are very old, they may have outgassed sufficiently for the pollutants to have actually eliminated themselves. In fact, many older houses were built with materials that didn't outgas as much as their modern counterparts—older carpeting may be wool instead of a synthetic fiber, and wall paneling could be solid wood instead of plywood. Of course, some older products contained pollutants that are no longer allowed in modern materials—*e.g.* asbestos insulation and lead-based paint.

If an existing house has a pollutant source that must be removed, the work should be done with care, and it must be well planned. Sloppy removal of asbestos or lead paint can result in a bigger problem than existed in the first place. Keep in mind that just because a pollutant is present, doesn't mean it's a problem. For example, when asbestos is a component of a durable material such as asbestos-cement siding, it's generally not releasing fibers into the air, so it's considered inert. Only when such materials are damaged during removal is asbestos dust generated and inhaled into the lungs.

If removal involves materials inside the living space, such as carpeting or particle-board subflooring, the work should be well planned to minimize dust, and the new materials should be carefully selected *prior* to any work being done. Too often, someone replaces an offending material with what they thought was a healthier alternative—only to find out it's just as bad.

Eliminate also applies to furnishings and home-maintenance products such as cleaners, polishes, and disinfectants. These items are often toxic, and they can be responsible for a great deal of air pollution inside an otherwise healthy structure. Fortunately, there are many healthier alternatives that can be substituted.

Separation

There are several ways to separate a pollutant from the indoor living environment. The most effective is to encapsulate the material completely, to totally surround it and seal it entirely. It's been suggested that nuclear waste be encapsulated within glass to protect the environment. Encapsulate implies a 100% seal—something rarely possible. In house construction, separation usually means placing a barrier between a pollution source and the living space. While 100% separation is seldom possible, 95-99% separation is often easily achieved.

For a high-tech look, metal foil can effectively separate an offending wall paint from the living space. But the seams between sheets of foil must be taped to provide a good seal. Some environmental sealants can reportedly seal in most emissions with 4-5 coats, but it may take several weeks—or months—of outgassing before a very sensitive individual can tolerate the sealant itself.

Insulation, plastic jacketing on electrical wiring, and plastic plumbing drain lines can often be effectively separated from the living space behind well-sealed drywall. Of course, this may not be necessary if materials such as low-tox insulation are used. But applying the principle of separation is often considerably less expensive than a healthier insulation.

Separation can also be applied to cupboards, cabinets, and closets. For example, simply placing an offending household object inside a cupboard will separate it from the occupied rooms. While the object will continue to outgas inside the cupboard, it will pollute a much smaller volume of air than if it were in a large room. Whenever the cupboard is opened, this polluted air will disperse into the living space, where it will be quickly diluted. The diluted air may not be a significant problem if the house is ventilated properly, but if an object has a particularly strong odor, it's best to eliminate it. If that's not feasible, closets and cabinets can be ventilated.

Ventilation

A house built, furnished, and maintained with *unhealthy* materials can require a great deal of ventilation to dilute the concentration of pollutants being released into the indoor air. This can require a large—and costly—ventilation system that will undoubtedly be excessively noisy, expensive to install, and expensive to operate.

Healthy houses also need ventilation systems, but not to dilute the pollutants released from building materials, furnishings, or cleaning products. They need ventilation systems to dilute the pollutants, and moisture, generated by the occupants themselves, and their activities. This typically doesn't require a great deal of ventilation. So, if you build a house with healthy materials, outfit it with healthy furnishings, and maintain it with healthy products, you can usually get by with a small, low-cost, inexpensive-to-operate, quiet ventilation system.

There are many different ways of ventilating a house, and most houses will benefit from two ventilation strategies: local ventilation and general ventilation. Local ventilation involves removing a pollutant from a particular locale quickly. This is actually fairly common in houses in the form of kitchen and bathroom exhaust fans. Venting a closet is also a form of local ventilation. Central ventilation involves slowly moving fresh air into entire house, and at the same time slowly removing stale air from the entire house. General ventilation is important because occupants don't spend all their time in one room—they move throughout the house, and they need fresh air wherever they go.

The vast majority of houses in the U.S. don't have general ventilation systems. But just because something isn't commonplace, doesn't mean it isn't important—and necessary. After all, automobiles didn't used to have seat belts, air bags, air conditioning, power steering, radios, and pollution-control systems. Someday, we'll wonder why it took so long for central ventilation to become widely available in houses.

As important as ventilation is, it does have an important limitation. Ventilation can't be relied on to remove *all* the contaminants in a building—it can only *dilute the concentration* of contaminates. That's why the first two principles (Elimination and

Separation) are important to reduce the concentration of pollutants before the ventilation system is called upon to do its job. Ventilation is covered in more depth in the next chapter.

Filtration

Filtration can definitely remove pollutants from the air. However, filtration is best used after the three other healthy-house design principles have been employed—as a part of a systematic approach to clean air. In that way, filtration can be used to polish the air in the house, or to clean the air entering through the ventilation system. That's because, like ventilation, filtration can't remove all the contaminates from the air—it can only reduce their concentration.

Relying on filtration alone to clean up the air in a polluted house requires high-powered, expensive equipment that is costly to operate and maintain, and noisy—and it probably won't be as effective as using Elimination, Separation, and Ventilation together. Filtration is covered in depth in *Chapter 8, Air filtration*.

Feng Shui

The ancient Chinese practice known as feng shui is occasionally mentioned in conjunction with healthy house construction. Feng shui involves arranging buildings, rooms, furniture, and decorations in such a way that it will "achieve maximum harmony with nature."[205] Said to be a cross between science and art, feng shui seeks to link man to his destiny on many levels—natural, man-made, local, and cosmic—by balancing ch'i, or life-giving energy. When this balance is accomplished, people will notice an increase in personal strength and luck.

A complete discussion of feng shui is beyond the scope of this book. For those interested in more information, there are many good books on the subject.[206] [207] While the philosophy of feng shui is different from the focus of *The Healthy House*, the two approaches can usually be incorporated together.

Getting Started

When someone sits down to design a conventional house, they typically start with the floor plan and the exterior style. Then they progress to details, such as wall and roof construction, cabinet layout, and electrical and plumbing layouts. Finally a heating/cooling system is fit in and, if a ventilation system is considered at all, it's usually an afterthought. Somewhere in this process, an air filter *might* be mentioned, but there is typically little discussion beyond, "Yeah, put one in."

When you understand the implications of a house being a system, you'll

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205 Sarah Rossbach, "Feng Shui," *East West* (December 1987): 52-58.

206 Kirsten M. Lagatree, *Feng shui: arranging your home to change your life* (New York: Villard, 1996).

207 Kam Chuen Lam, *Feng Shui handbook: how to create a healthier living and working environment* (New York : Henry Holt, 1996).

recognize that heating/cooling and ventilation are sub-systems that should be considered much earlier in the design process. In most houses, the degree of tightness is not considered at all, but because it has a definite effect on how a house functions as a system, it too should be considered early in the design process. In fact, in a healthy house, it's best to consider ventilation, heating/cooling, filtration, and tightness before anything else.

Ventilation

There are many different ways to ventilate houses, and each has advantages and disadvantages. Some approaches interconnect the ventilation equipment with the heating/cooling equipment. But they can also operate independently.

The ventilation system's capacity, strategy, and design should be based on the outdoor climate, house size, number of occupants, heating/cooling equipment, tightness of the structure, whether a house has a chimney, how conscientiously healthy materials are used, and the sensitivities of the occupants. These factors all affect each other and interact. When you begin to see how the various aspects of house design are interrelated, it will be apparent that a ventilation strategy should be selected very early in the planning process.

Heating/Cooling

It's also important to consider the heating/cooling system early in the design phase because it's often the most complicated sub-system in a house, and several components can have an impact on health. If a house is very well insulated (perhaps superinsulated), the heating/cooling requirements are going to be very low. In fact, some superinsulated houses have so little need for heat in the winter they easily get by with a couple of baseboard heaters.

There are a variety of different ways to heat and cool a house, each of which has advantages and disadvantages. For example, a forced-air furnace/air conditioner can be fitted with a better-than-average filter, but some sensitive people are bothered by the fact that there is a warm electric motor in the airstream—a motor that outgases to a small degree. Natural gas is an inexpensive heating fuel in many parts of the country, but if the chimney doesn't function correctly, combustion gases will enter the living space. Some electric heaters are low-polluting, but they can be expensive to operate.

The selection of a heating/cooling strategy will be influenced by the size of the house, the climate, amount of insulation, tightness of the structure, ventilation strategy, and any sensitivities of the occupants. Again, all these factors interact.

Air Filtration

Air filtration can be integrated into a ventilation system, or it can be part of a forced-air heating/cooling system, or there can be a stand-alone filtration system. Therefore, the selection of filtration equipment needs to be coordinated with the design of the other air-movement systems in the house.

Tight Construction

Some of the advantages and disadvantages of various ventilation strategies, and of certain heating/cooling strategies, are directly related to the tightness of the house. The degree of tightness also has an effect on chimney function, indoor pollution levels, and it can either cause or prevent moisture problems. Although many people condemn tight construction, it is actually an excellent idea in a healthy house—if you view the house as an interactive system.

Special Needs

There are many special needs that should be considered during the design and planning phase. If food allergies are a problem, it might be important to be able to close off the kitchen with a door to keep cooking odors from permeating the rest of the house. A powerful exhaust fan over the range should be considered, and it may be necessary to allow room for an extra refrigerator or freezer.

Someone sensitive to laundry odors emanating from a washer and dryer will want to consider placing those appliances in a special room—perhaps one attached to a bathroom, so that the moisture from both rooms can be exhausted together.

Clothing and storage requirements also need to be addressed. It's important not to store clothing in an oasis because of possible contamination of the room's air by the clothes, dresser, shoes, *etc*. Dressers can be built into closets, and closets can be vented to the outdoors. This can be done with a small exhaust fan or in conjunction with a whole-house ventilating system. Soiled clothing can contain mold as a result of dampness due to perspiration, or it can be contaminated with perfume or cigarette smoke if the wearer has been around users of such things.

Books, magazines, and newspapers can be bothersome to someone sensitive to printing ink or mold. They can be stored in bookcases with glass doors. Bookcases can be vented to the outdoors, but for most sensitive people this isn't necessary.

If entertaining is important, it must be remembered that clothing and hair act like sponges, absorbing a wide variety of chemical odors. Guests bring these odors into your home along with the perfumes and other scented products they are wearing on purpose. Unless a powerful ventilation system is installed, these odors will be absorbed by the walls and furnishings of your house. The aroma of your guests can linger for weeks after they have gone. This can easily result in eroding health in someone sensitive to artificial fragrances. A good alternative is to do your entertaining outdoors, on a deck or patio during fair weather. Garden parties can be quite enjoyable and it is cheaper to construct and maintain a large covered patio than a large rarely-used living room.

If you operate a business in your home, it may be necessary to isolate it from the living space if a family member is bothered by printed materials, the plastic case on a computer, or the odors emitted from a photocopying machine or laser printer.

Many houses are now specifically designed for handicapped access—even though no one in the family currently uses a wheel chair. This is because, as we all grow older, a certain percentage of us *will* become disabled at some point. Accessibility can be easy, and inexpensive to do—if planned for early. It can also be retrofitted into existing houses, although there will often be some compromises.[208] The **Center for Universal Design** offers a newsletter, literature, and conferences for people involved in planning, design, production, renovation, financing, and marketing housing for those with disabilities. And

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[208] Wendy Talrico, "Retrofitting Houses for Seniors," *Journal of Light Construction* (October 1989): 32-33.

the **National Association of Home Builders** publishes a *Directory of Accessible Building Products*.[209]

Some sensitive people have decided to share their homes with others. This can be both a humanitarian gesture and a source of income. Many people, on suddenly discovering they are being made sick by their house, find there is no place to turn for accommodation. It may be worth considering an extra bedroom for such use.

Garages

A garage often contains a number of toxic chemicals in the form of paints, solvents, fertilizers, insect repellents, *etc*. But the largest polluter is generally the family car. A hot automobile inside an attached garage can give off a variety of offensive odors that easily seep into the living space.[210] Houses with attached garages typically have gasoline concentrations that are 10 times outdoor levels, but the indoor concentration of gasoline can sometimes be as much as 50 times higher than the outdoor level.[211] One study found that benzene concentrations from gasoline-fueled vehicles can reach hundreds of parts per billion in attached garages, and the benzene can migrate into the living space exposing the occupants.[212]

If we still rode horses every day, we'd never have a barn attached to the house because the animal odors would be objectionable. Yet houses routinely have an attached garage which contains much more unhealthy odors. Detached garages are often preferred to keep exhaust gases, and other pollutants, from seeping into the living space of a loosely constructed house.

An attached garage should have an exhaust fan installed to minimize any contamination of the air in the house.[213] The fan can be controlled by a timer so, when a hot automobile is pulled in, the fan can be turned on and allowed to run for an hour or so until the exhaust gases have dissipated. Sometimes it is recommended that a 100-cfm

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209 National Association of Home Builders (NAHB), *Directory of Accessible Building Products (Washington, DC: NAHB, 1994)*. For information, contact NAHB Research Center, 400 Prince George's Blvd., Upper Marlboro, MD 20772, 301-249-4000.

210 Clifford Weisel and Nicholas Lawryk, "Gasoline and methanol exposures from automobiles within residences and attached garages" (Helsinki: *Proceedings of the 6th International Conference on Indoor Air Quality & Climate, Vol. 2, Chemicals in Indoor Air: Materials Emissions*, 1993): 195-200.

211 R.B. Gammage and others, *Measurement of Volatile Organic Compounds (VOC) in Eight East Tennessee Homes* (Oak Ridge, TN: Oak Ridge National Laboratory, September 1988): 25. #ORNL-6286.

212 E.J. Furtaw Jr., M.D. Pandain, and J.V. Behar, "Human Exposure in Residences to Benzene Vapors From Attached Garages" (Helsinki: *Proceedings of the 6th International Conference on Indoor Air Quality & Climate, Vol. 5, Ventilation*, 1993): 521-526.

213 John Bower, "Trouble With Attached Garages" (letter), *Journal of Light Construction* (October 1989): 5.

exhaust fan be running *continuously* in an attached garage. As an alternative, you can run a pair of 6" diameter ducts from the garage ceiling up through the roof to a pair of turbine roof ventilators, such as the whirlybird ventilators made by **Lomanco, Inc.** This is a form of passive ventilation and it will continuously ventilate the garage without the electricity. Of course, this can't be done if there is a room over the garage—unless you want a pair of ducts running up through that room. In either case, make sure the exhaust fan or the passive ducts don't cause a chimney in the garage to backdraft.

If you insist on an attached garage, make sure it is sealed as tightly as possible to prevent garage air from entering the house. Make sure the service door into the house is weather-stripped, and consider an automatic closer. And, don't locate a forced-air furnace/air conditioner in an attached garage.

Another danger with garages (attached or not) has to do with automatic door openers. Children have occasionally become trapped under malfunctioning automatic overhead garage doors.[214] In fact, the **CPSC** reported 48 fatalities between 1982 and 1988.[215] While federal regulations now require manufacturers to include safety devices on automatic openers, they can become damaged. If you want an automatic opener, be sure it is installed correctly, and kept in good repair.

Building Codes

Most of the materials suggested in this book will comply with building codes. But occasionally a residential inspector will be unfamiliar with a particular material because it's not commonly available. Showing the inspector some product literature will usually satisfy any questions. In some cases, it may be necessary to obtain a variance from the code requirements. If you plan to use any unusual materials, it's important to present your case in a well-thought-out and documented manner early in the planning stages—not at the last minute when changes can be expensive.

Worker Education

Not all builders, carpenters, plumbers, and heating/cooling contractors have worked with hypersensitive people. Therefore, they may not be aware of some of the problems that can arise when working on a project for a person who is bothered by a wide variety of common pollutants. For example, during the construction process, workmen can introduce offending odors into the house from such things as cigarette smoke, fragrances, paint odors, *etc*. that cling to their clothing and hair. Or they may not realize the importance of using a particular brand name, and decide to use a similar product, but one that has not been tested for personal tolerance.

Because of the potential for problems resulting from poor communication, lack of understanding, or unfamiliarity, it's a good idea to provide workers with enough information to fully understand the scope of the project. Sometimes this can be accomplished by a brief talk, a sign on the jobsite, or a letter. One healthy house jobsite

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[214] Ruthanne Gordon-Sullivan, "Dangers Lurking Behind Automatic Garage Doors," *Alliance Monitor* (Spring 1992): 4-5.

[215] Sal Alfano, "Safer Garage Door Openers, *Journal of Light Construction* (July 1993): 24-26.

had a sign stating the following: "Notice, Chemical Sensitivity. Absolutely no materials are to be used or stored in this building without prior approval."[216] It often helps to give a contractor a copy of this book to read. **The Healthy House Institute** also has a 13-part video series that follows the construction of a healthy house in a step-by-step manner. Some people loan the appropriate episode to various workers and subcontractors, to give them a better idea of what needs to be accomplished. It's often relatively easy to get workmen to watch a video at home in the evening—then they are more receptive to reading a chapter in this book.

Owner's Manual

Once your project gets underway, be sure to have your contractor save all the instruction sheets and owner's manuals. They can be kept in a 3-ring binder for future reference. Don't throw anything out. Instruction sheets for adjusting door thresholds, and the temperature setting on shower valves are documents homeowners should have. Even a small insignificant package insert might be helpful in five years, if you run into an operation or maintenance question. Warranty papers can be especially valuable. Some builders provide a list of routine maintenance tips, along with emergency procedures and phone numbers.[217]

It can also be very useful to take a number of photographs during the construction process to keep with the owner's manual. You might consider photographing each wall after the wiring, plumbing, and ducts are in place, but before the insulation is installed. These photos can be numbered and their locations noted on a floor plan. In this way, if you need to do some remodeling in the future, or you suspect a hidden problem of some sort, you will be able to look at the photos and know exactly what is inside a wall—before you decide to tear it open.

Evaluating Materials

There are a variety of ways to evaluate the healthfulness of materials. For example, with careful research, you can often determine the precise chemical makeup of a product. But, if you don't have a background in chemistry, physics, medicine, and psychology, you may have no idea what the information means. In fact, we are routinely exposed to a great many chemicals that experts know very little about.

In the healthy-house field, many of the early recommendations were based on seat-of-the-pants evaluations of materials. Over the years, many of the evaluations have been validated by research and additional knowledge, yet some remain seat-of-the-pants evaluations—and some recommendations have been found to have no basis in fact. For someone wishing to pursue the known, documented health effects of various materials a Material Safety Data Sheet (MSDS), is the best place to start.

An MSDS can definitely provide a certain amount of information, but with

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216 John Hughes, "Allergy Free in Ottawa," *Fine Homebuilding* (April/May 1988): 70-73.

217 Kathy and Gary Wheatley, "Service manuals make a good impression," *Journal of Light Construction* (May 1991): 11.

sensitive people, personal tolerability testing is still very important. This is because sensitive people react to all kinds of things—many of which aren't listed on an MSDS—and a sensitive person's metabolism is unique to them. They can also react to low-level exposures that aren't necessarily dangerous to healthy people. Of course, as researchers learn more about how pollutants subtly affect the body, they may determine that what we once thought was a safe level of exposure is, in fact, unsafe.

Material Safety Data Sheets

The Occupational Safety and Health Administration (OSHA) has issued right-to-know regulations for the workplace.[218] [219] Material Safety Data Sheets (MSDS) are a big part of those requirements. The regulations were written to insure that hazardous chemicals produced, imported, or used within the U.S. are evaluated, and that information is given to the affected employers and employees. An MSDS should be available to all employees for each hazardous chemical they come into contact with.

An MSDS is a printed form, on which a manufacturer provides an emergency phone number and information about the harmful ingredients in a product. Required by law, it contains basic information such as a product's name, boiling point, flammability, *etc*. You can get an MSDS for virtually any material on the market. Some may be available through local building supply centers but often you'll need to contact a manufacturer to obtain one.

An MSDS also lists hazardous ingredients and negative health effects. However, an MSDS does not always list *all* potentially hazardous ingredients—some formulas are considered proprietary or trade secrets by their manufacturers. In such cases, specific health-related information will be given to a physician in the event of a medical emergency, but it's not listed on the MSDS. An emergency phone number is included for this reason. Also, when the percentage of a hazardous ingredient is below a certain level, it may not be listed. For example, if a hazardous ingredient, other than a carcinogen, comprises less than 1% of a product, it need not be listed. Carcinogens need not be listed on an MSDS if they are present in quantities less than 0.1%. As a result of all this, it's not unusual for an MSDS to be incomplete or misleading.

Exposure Limits

When a hazardous ingredient *is* listed on an MSDS, the amount causing negative health effects may be listed as a TLV (Threshold Limit Value), PEL (Permissible Exposure Limit), or LD_{50} (the Lethal Dose that kills 50% of lab animals). TLVs can be described in different ways: based on exposures over an eight-hour workday, a fifteen-minute exposure, or an instantaneous exposure. The smaller the TLV, PEL, or LD_{50}, the more hazardous the substance. For example, the TLV for grain alcohol is 1,000 ppm (parts per million), turpentine 100 ppm, and formaldehyde 1 ppm. Just because a product contains only a tiny percentage of a hazardous substance doesn't mean it's safe—always

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[218] Occupational Safety and Health Administration (OSHA), *Chemical Hazard Communication* (Washington, DC: OSHA, 1990). #OSHA 3084.

[219] Occupational Safety and Health Administration (OSHA), *Hazard Communication Compliance Guidelines* (Washington, DC: OSHA, 1991). #OSHA 3111.

look at the TLV, PEL, or LD_{50}, as well as the percentage.

Unfortunately, TLVs, PELs, and LD_{50}s have not been established for many hazardous ingredients. When this is the case, an MSDS can give you a false sense of security, because you will have no idea how hazardous the product really is.

Health Effects

The health-effects section of an MSDS will list short-term (acute) or long-term (chronic) health effects, based on different routes of exposure (inhalation, ingestion, absorption through the skin, eye contact). All the information on an MSDS is meant to be applicable to healthy adult workers during an eight-hour day. More susceptible people, such as children, the elderly, the sick, or people exposed to a substance for twenty-four hours a day, can be affected much more readily or severely. Chemically sensitive individuals, many of whom react to extremely low levels of hazardous substances, are not addressed on an MSDS at all.

Physical Properties

An MSDS will often list the vapor pressure, vapor density, percentage of volatiles, and evaporation rate of a substance. These physical properties can be used to gauge the outgassing rate, but they can be difficult to analyze.

Despite rather serious drawbacks, an MSDS can be a good starting point in researching the healthfulness of a product. While they definitely contain some valuable data, the information is often difficult to interpret. A good pamphlet to use in deciphering an MSDS is *How to Read a Material Safety Data Sheet*.[220]

Personal Tolerability Testing

Someone with no known sensitivities may not need to test materials for personal tolerance. By simply choosing the various low-tox products mentioned in this book, they should be able to maintain their good health. However, very sensitive people should always test materials—especially those directly exposed to the living space—because, according to one engineer, "individual testing is the only known way to guarantee that you will be able to tolerate your home."[221]

For sensitive people, tolerability testing of new materials can be difficult. This is especially true if you're living in an unhealthy house—because you may not know if you're reacting to the house or to the new material. If you have an oasis in your home, or some room that doesn't affect you negatively, that can be a good place to do the testing. If the entire house is problematic, testing should be done outdoors—away from pollution sources. This may mean driving some distance away, and allowing your body to "clear" before beginning the testing. This may take an hour or two, depending on your particular sensitivities.

There are several ways materials can be tested, and it's sometimes necessary to

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220 *How to Read a Material Safety Data Sheet* (San Diego, CA: American Lung Association of San Diego and Imperial Counties, 1988).

221 Bruce M. Small, *The Susceptibility Report* (Cornwall, ON, Canada: Deco Books, 1982): 30.

use a different method for different materials. Some people are delayed reactors. This means they don't experience symptoms until after several hours have elapsed. If this is the case, a diary of exposure methods, materials, and symptoms, over several days will often turn up a pattern. Because many people have allergies to foods or pets, an exposure diary should include references to them as well.

Office Procedures

It's important to emphasize that, when sensitivities are severe, all testing should be done under the supervision of a qualified physician. It's always a good idea to have a professional around if you have an unusual or life-threatening reaction.

Some doctors have set up *environmental control units* for testing purposes, but they can be quite expensive—often running into thousands of dollars. For information, contact the **American Academy of Environmental Medicine**. With this type of testing, a person enters the sterile environment inside an environmental control unit, and is given only spring water to drink. After a while, the body becomes totally devoid of symptoms. At this point, when a substance is introduced into the clean environment, a reaction can be noted almost immediately.

There are a variety of office procedures that a doctor may use in testing your tolerance to various building materials or to specific environmental pollutants. Scratch tests and intradermal tests are good for determining allergies to conventional allergens such as mold, and pollen.[222] The provocation-neutralization intradermal test can be used to evaluate sensitivities to pollutants like formaldehyde.[223] By using this procedure, a physician can cause a reaction to take place (provocation), and turn the reaction off (neutralization). Kineseology, or muscle testing, is also sometimes used to evaluate how a person reacts to various substances.

Personal Testing

If your doctor gives you the OK to do testing on your own, there are a number of things to keep in mind. First of all, if you're going to test a single material, it's important to make sure the sample is not contaminated by something else. For example, when testing paint, don't coat something that could possibly outgas itself—such as a piece of plastic or a newspaper. Coating a piece of glass, or metal foil will give you a more realistic evaluation. When in doubt, test the material to be coated first—without any paint—then, if no reaction is noted, paint it, and test again.

Two or more materials may need to be tested simultaneously. For example, if drywall, joint-finishing compound, and paint are going to be used together, that's how they should be tested. If you test them individually, and each seems fine, what happens if they react with each other? Paint often helps to prevent drywall from outgassing, but some paints can react with joint compound. So, it's best to test all three in combination.

Sometimes a small sample is sufficient for testing purposes. To test a small

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[222] Levin, *Type 1/ Type 2*, 44-45.

[223] Sherry A. Rogers, "Diagnosing the Tight Building Syndrome" (Atlanta, GA: *Proceedings of Indoor Air Quality '86, American Society of Heating, Refrigeration, and Air Conditioning Engineers*, 1986), 772-776.

sample, place the sample in a clean glass jar and screw on the lid. Then, place the jar outdoors in the sun. The sun warms up the sample and causes it to outgas at an accelerated rate. When the jar is then opened, the amount of outgassing will be comparable to a much larger sample that might be found in a house. The purpose is to cause an accelerated rate of outgassing to take place, thus simulating a larger sample.

Larger samples can consist of a piece of the product itself. Examples of large samples include a cabinet door (or an entire cabinet), a piece of painted drywall, or a section of vinyl flooring. To test paints and clear finishes, a large sample is best—2' x 4' is usually a good size.

Most materials outgas to some degree and they must be allowed to air out until they're odor-free, before being tested by a sensitive individual. Someone with a good sense of smell, who isn't especially sensitive, can determine when a sample has no odor. When using a glass jar for testing, leave it open for a few days before sealing it and placing it in the sun.

It's important to label samples accurately. Be sure and record the date they were prepared, when they were tested, and when they became tolerable. This is necessary because, while samples may be prepared at the same time, some will probably outgas sooner and be ready for testing before others, so they can get mixed up. What you need to know is how long it takes after application before a material is tolerable. Everything outgases eventually, but you want to use materials that outgas in hours, days, or weeks—not months, years, or decades. If a sample isn't tolerable immediately, set it aside and test it again later. Testing can take time, so be sure to plan ahead. For very sensitive people, some products, such as paints, can take several weeks of drying before they're aired out enough to begin testing. Preparing several different samples at one time can minimize delays.

If you've painted your house and are bothered by the paint odor, but haven't pre-tested anything, then you won't know how long it will take before your house will be tolerable again, and you'll be plagued with fears that it may never outgas sufficiently. On the other hand, if you know precisely how long a finish takes to outgas, a project can be scheduled accordingly. For example, if a fresh paint odor is not bothersome at all, a sensitive person may be able to live in the house during application. A mildly offensive odor may require the use of extra window fans for several days. Some people are so sensitive to all paint odors, that they must vacate the house for some time until the odor dissipates completely. This is something that is better to know before starting a painting project, than after the paint is on the wall.

Testing can often help—a lot—when selecting materials. However, testing isn't foolproof. For example, you may not be bothered by a 4'-square piece of painted drywall, but the outgassing from 2,000-3,000 sq. ft. of painted drywall in a house may take longer to become tolerable. Plus, accelerated outgassing in a glass jar isn't the same thing as allowing a product to outgas slower at its natural rate.

Although it isn't common, sometimes a paint will be tolerable when tested by itself, but not tolerable when used to repaint a room. This can be the result of fresh paint reacting with old paint. This sometimes happens when the first coat isn't given enough time to cure. It can also happen when one kind of paint is used over a different kind of primer. For someone apprehensive about how tolerable a paint will be once applied, it's a good idea to just paint one room (perhaps a little-used room), and see how tolerable it is before painting the entire interior of the house.

There are 4 ways to personally test a sample for tolerability.

SNIFF TESTING is easy. Simply sniff the sample with your nose. A short sniff is recommended initially. If no reaction is noted, it should be followed by a longer sniff. Immediate reactions can include clogged sinuses, inflamed sinuses, headache, dizziness, feeling "spacey", *etc*. Symptoms are highly individualistic so your symptoms could easily be different from someone else's. If you test in a very relaxed place that's free of pollution, it should be fairly easy to sense any minor changes in your system. If you test in a noisy, polluted area, there may be too many background factors to notice any subtle changes in your body. An individual who lives a healthy life-style in a healthy house, will probably be able to read their body fairly accurately.

While a human nose can be very sensitive to odorous pollutants, this method of testing can also be used with materials that have no apparent odor because the outgassed molecules are still absorbed into the sinus tissues.

TOUCH TESTING involves touching a sample and determine whether or not it's tolerable. For example, many people report that wearing synthetic clothing gives their skin a tingly, crawly, or burning feeling. This is a reaction to the synthetic material, indicating an intolerance. Occasionally a red spot or hives will develop when performing touch testing. The method is simple—place a small sample on the back of your hand for awhile. Sometimes a reaction will be noted immediately, but it could develop over the course of an hour or so. Again, it's important to do testing in an unpolluted, relaxed atmosphere.

SLEEPING WITH A SAMPLE is one of the more reliable methods of personal tolerability testing. You don't actually have to put the sample in your bed—you can set it next to the bed, or close by on a night table. Sometimes you can place a sample inside your pillowcase—such as a piece of aluminum foil that has been coated with paint or a clear finish. This method of testing exposes you to a relatively large sample over several hours, so it simulates a real-world exposure fairly well. If your bedroom is relatively pollution free, and you normally sleep well, you should be able to notice any changes in your sleep pattern. For example, a sleepless night, nightmares, or an unusually sound sleep could indicate intolerance. If you don't often sleep well because your bedroom doesn't have particularly good air quality, you might consider sleeping outdoors, or in a less polluted room to do this type of testing.

PULSE TESTING involves learning to take your own pulse. A physician, or another health care worker, can teach you how to do this, or you can purchase an electronic instrument to assist you. First, you need to determine your average, normal pulse rate. This is done by taking your pulse every two hours and recording it. Normal may be anywhere from the mid 50s to the mid 80s. During the actual test, your pulse rate should be taken 5 minutes before testing and 20, 40, and 60 minutes after you've been exposed to a sample. To get the most accurate reading, you should take your pulse for a full minute each time, then be sure to write it down. The exposure method can be either sniff or touch testing—whichever seems to give you the best results. Any form of physical activity will invalidate the test—even something as simple as going to the bathroom. Eating an allergy-provoking food can also invalidate a test. Any noticeable change in pulse rate will indicate that your body is reacting to the sample, but an increase of 10 beats per minute, or more, usually indicates a reaction.

Summary

There are a number of ways to evaluate materials. With sensitive people, there is no single preferred method of testing for personal tolerance—and reactions can be varied. There has been at least one case of someone sensitive to natural gas falling into a coma upon returning home after an absence. This is why an individual with extreme sensitivities should only do tolerability testing under a doctor's supervision. For the majority of sensitive people, the reactions won't be severe, in fact some can be fairly minor. But minor reactions should not be ignored—they are a warning sign that your body is uncomfortable around something.

As you read through this book, some of your initial requirements will undoubtedly change, but that's all part of the planning process. A designer's first idea is rarely their best. All good designs evolve. Your list of needs will have many additions and revisions by the time construction begins. Don't be afraid to change your mind. In fact, you should probably change it several times. By keeping all four healthy design principles (Elimination, Separation, Ventilation, and Filtration) in mind during the entire planning phase, indoor air pollution can easily be minimized. Once the planning process is complete, you should have a thorough understanding of what will go into your healthy house.

The following four chapters should be read together to get a good understanding of how various components of a house interact and function together—as an integrated system composed of various components and sub-systems.

6. Ventilation

Mechanical ventilation is widely misunderstood—even by some professionals. In fact, words such as infiltration, air exchange, and natural ventilation are routinely used incorrectly. This leads to a great deal of confusion. Following is a comprehensive overview of the subject of ventilation. For much more in-depth information about residential ventilation and additional resources, see *Understanding Ventilation* by John Bower.

Mechanical ventilation (or an operable window) is required by most building codes to rid a bathroom of excess moisture and odors—but in most parts of the country there are virtually no requirements for ventilating the rest of the house. However, two states—Minnesota and Washington—now require whole-house mechanical ventilation as a part of their energy code.[224] This has come about because regulators understand that more energy efficient houses are tighter, so they have less natural ventilation, thus they require mechanical ventilation. In the future, building codes everywhere will, no doubt, require that all houses have whole-house mechanical ventilation systems.

What is Ventilation?

Ventilation is simply the bringing in of fresh air and the exhausting of stale air. When this happens, an *exchange* of air takes place in a house. The speed at which the exchange takes place is called the *exchange rate*. When air moves within a room, or from one room to another room, it is not being exchanged—it is being *circulated*. Forced-air furnaces and air conditioners are primarily designed to circulate air in a house—not exchange it. Ventilation systems are specifically designed to exchange the air in a house as well as circulate it.

Exchanging the air in a house is important in order to *dilute* the concentration of pollutants and moisture found in the indoor air. If the concentration of indoor pollutants is too high, it can negatively affect the health of occupants. If moisture levels are too high, mold growth or rot will result. Pollutant concentrations can also be reduced through the healthy house design principles of Elimination, Separation, and Filtration and by a few other processes. These strategies are best used in addition to ventilation—but they are not a substitute for ventilation because they cannot supply oxygen to people in the living space, and they cannot reduce indoor moisture levels.

This all sounds simple enough, but there is still a great deal of confusion about how air gets from here to there.

Should a House Breathe?

Many people are of the opinion that a house should breathe. A house should definitely have an exchange of air, but houses can hardly breathe like human beings. People have muscles that cause lungs to expand and contract, thus moving air through

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[224] "Minnesota Energy Code to Require Mechanical Ventilation," *Journal of Light Construction* (March 1999): 15.

nostrils and mouth. Houses don't have muscles, their walls can't expand and contract, and they don't have an autonomic nervous system to drive such a process.

In a way, loosely built houses seem to breathe "automatically." While they don't breathe like people, there are some simple physical laws that describe how air moves into and out of all houses. When you understand the physics behind air movement, and how it relates to other aspects of house construction, you'll see that a house does and should breathe—but not in the same sense that a person or animal breathes. After all, airplanes don't move through the air in the same way as birds, but both airplanes and birds do fly.

What Causes Air to Move?

For air to move from one place to another, there must be an *air-pressure difference* to push it or pull it. Air-pressure differences can be placed in three categories: 1) natural pressures resulting from natural processes such as the wind, 2) accidental pressures caused by mechanical devices, such as clothes dryers, that move air into or out of a house for a purpose other than ventilation, and 3) controlled pressures caused by ventilating fans.

When a fan causes air to move directly, it is called *active* air movement. When air moves indirectly because of a fan, or because of something else causing an air-pressure difference, it is called *passive* air movement. For example, when a window fan *actively* blows air outdoors through a window, an equal volume of air will *passively* enter through another window.

Natural Ventilation

Mother Nature has two techniques for moving air into and out of houses—*wind* and *stack effect*. Both of these natural phenomena periodically apply pressures to houses and cause air to move into and out of them. When this happens it's called *natural ventilation*.

Wind

It's easy to visualize how the wind causes air to move into a house. If the wind blows against the exterior side of a wall, it exerts more pressure on the outside than exists inside. This difference in air pressure pushes a certain amount of air through the cracks and gaps in the structure, into the occupied space. In an old leaky house, you can often feel a draft near a loose-fitting window frame as a winter wind pushes cold air inward.

When the wind causes an air-pressure difference that moves air into one part of a house, something is also happening on the opposite side of the house—air is leaving. You can't just keep blowing air into a house like a balloon. Whenever a certain amount of air enters, an equal amount will leave somewhere else.

So, wind doesn't just cause outdoor air to enter a house, it also causes indoor air to leave. On a windy day you can open the windows and see this occurring. The curtains will billow inward on one side of the house and billow outward on the opposite side.

In reality, the movement of the wind can be complicated by the shape of a house, the pitch of the roof, and nearby trees or hills. For example, the wind often strikes a house at an angle, and turbulence is created at corners and roof overhangs. But, in general, the wind causes air to move into one side of a house and out the opposite side—but only when the wind is blowing. On a calm day, even if the windows are open, there will be no air movement into or out of the house—at least not due to the wind.

Stack Effect

Stack effect is based on the principle that warm air rises. This is what makes a chimney (or stack) work—warm air rises inside it naturally. With the wind, Mother Nature moves air from side to side through a house. With stack effect she moves air up and down through a house.

When warm air rises, it creates an upward pressure. A hot-air balloon lifts off the ground because of this. In fact, with a sensitive pressure gauge, you could climb on top of a hot-air balloon and measure an air-pressure difference between the inside of the balloon and the outside of the balloon. This same phenomenon occurs in houses.

When a house is filled with warm air in the winter, the warm air exerts an upward pressure on the upper half of the building. This causes air to escape through any gaps and holes located there. When this happens, an equal volume of air enters through gaps and cracks in the lower half of the house. Stack effect and wind often occur simultaneously, but the total volume of air entering a house always equals the total volume of air leaving.

There are two factors that determine how much of an air-pressure difference is caused by stack effect—the temperature difference between the indoors and the outdoors, and the height of the building. The greater the temperature difference, the more stack effect. And the taller the building, the more stack effect. So, a two story house in the middle of winter will have more air moving through it due to stack effect than a one story house in the autumn. If the indoor and outdoor temperatures are the same, there is no air movement at all—at least not due to stack effect. In cold climates, stack effect is often responsible for over-ventilation during the coldest part of the year in houses that are not tightly constructed.[225]

In the summer, if a house is air conditioned, stack effect works in reverse. The cool indoor air falls and leaks out through the cracks and gaps in the lower half of the house and warm outdoor air enters through holes in the upper half. In many climates, stack effect isn't very pronounced in the summer because the indoor/outdoor temperature difference isn't great as it is during a cold winter.

Accidental Ventilation

There are several things in a house that aren't considered ventilating devices, but do cause air-pressure differences that result in air moving into and out of a house. This is called *accidental ventilation*.

Clothes dryers and most central vacuum cleaners blow air outdoors when they're operating. When this happens, an equal volume of air will enter somewhere else—through the various cracks and gaps found throughout the house. These devices aren't designed to ventilate, they're designed to dry clothes and clean up dust. But they do ventilate—accidentally—whenever they're operating.

Most flapper-type dryer-vent closures don't seal very well so, if something else

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[225] Mark Riley, "Indoor agy conservation; The R-2000 home program experience" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 5, Plenary Lectures*, 1990): 143-147.

causes an air-pressure difference between the indoors and the outdoors when the dryer isn't operating (perhaps the wind), air can enter a house through a dryer exhaust. **Heartland Products, Inc.** has a Dryer-Vent Closure that seals much better and is easy to clean when lint builds up. It can be found in some building-supply stores, purchased directly from the manufacturer, or mail-ordered from **Home Trends**.

A chimney is another common accidental ventilating device, although we generally don't think of it as such. When a chimney is in operation, warm combustion by-products are rising up it, and leaving the house. It's actually functioning just like an exhaust fan, and when air is leaving a house via the chimney, an equal volume of air will be entering somewhere else—through the gaps and cracks in the walls, floors, and ceiling of the house. If you replace a furnace having a chimney with a furnace that doesn't have a chimney (*e.g.* electric heat or sealed-combustion gas), you lose the accidental ventilation that was provided by the chimney. In some cases, after a non-combustion-fired heating system was installed, houses have developed moisture problems in the living space because the moisture was no longer accidentally being vented to the outdoors by the chimney.[226]

Forced-air heating or cooling equipment also provides some accidental ventilation unrelated to chimneys. This is because most ductwork is very leaky. Let's say there are leaky ducts in a crawl space. Air leaks into them (or out of them, depending on which ducts they are), and this causes an air-pressure difference between the crawl space (which is generally considered outdoor space) and the living space. This air-pressure difference causes air to move through the cracks in the floor between the crawl space and the living space—accidental ventilation. In reality, this type of accidental ventilation can be very significant because a forced-air heating/cooling fan is quite powerful. Well-sealed ductwork minimizes this effect.

There is one more way accidental ventilation takes place, and it also involves forced-air heating/cooling equipment. Simply closing doors between rooms can result in air-pressure differences between those rooms, and also between the indoors and the outdoors.[227] For example, consider a house that has a single return-air grille in a central hallway, and supply registers in each room. During operation, the heating/cooling fan blows air into the rooms through the supply registers, the air moves through the rooms and into the hallway, where it enters the return-air grille, and the cycle repeats. If a bedroom door is closed, the air enters that room through the supply register, but it has difficulty getting into the hall because the door is closed. This causes an air-pressure difference between that room and other parts of the house, and between that room and the outdoors. This air-pressure difference then causes air to move through gaps and cracks in the house, resulting in accidental ventilation.

There are a number of ways to minimize air-pressure differences between rooms when doors are closed. Sometimes an inch or two is cut off the bottom of doors. Having several return-air grilles (in various rooms) also helps. In addition, you can install what

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226 Bill Eich, "Water hazards and your building's health," *Journal of Light Construction* (August 1989): 28-30.

227 J.D. Ned Nisson, "Don't Ignore Leaky Ducts," *Journal of Light Construction* (April 1990): 40-41.

are called “transfer grilles.” This simply involves two grilles that are mounted on either side of a wall between a bedroom and the hallway. Transfer grilles are often placed over a doorway and they can be offset from each other to prevent light from shining through. It is also possible to install “jump ducts” between the bedroom and hallway. A jump duct is simply a short length of duct above the ceiling (in the attic) that connects between a grill in the bedroom ceiling and another grille in the hallway ceiling. All of these methods will help relieve an air-pressure difference when doors are closed between rooms.

Controlled Ventilation

Besides the natural and accidental ways air is exchanged in houses, air can also be exchanged “on purpose.” This is called *controlled ventilation*, to distinguish it from uncontrolled (or out-of-control) ventilation, which is either natural or accidental. According to one engineer, if combined with a tight house, mechanical ventilation allows “the user to take control over where, when, and how much ventilation occurs, with minimal heat loss.” [228]

There are several strategies when it comes to controlled ventilation but they can be divided into two categories: *local* ventilation and *general* ventilation. As was mentioned earlier, most houses will benefit from having both of these types of controlled ventilation.

Local Ventilation

A local ventilation system is designed to improve the air quality in one part of a house quickly. Many houses have some type of local ventilation in the form of a bathroom exhaust fan or a kitchen-range hood. These local-ventilation fans are designed to remove polluted or moisture-laden air from one place quickly—before it can travel into another part of the house.

Bathroom exhaust fans are necessary to move unpleasant toilet odors outdoors, and to rid a bathroom of the excessive moisture generated during bathing or showering. Too much moisture in a bathroom often leads to mold growth.

A kitchen-range hood removes pleasant cooking odors, as well as by-products of combustion released by combustion-fired ranges—or burnt food. It also removes moisture generated by cooking and washing dishes.

Local-exhaust fans can also be used in home offices to remove odors from photocopiers and laser printers, as well as in home workshops, and artist’s studios. Sometimes local exhaust fans are installed in closets to keep them fresh. Many healthy houses use a local exhaust fan in the garage.

If you have anything that must be inside the house, even though it’s a pollution source, it can be ventilated. Use your imagination. If you are highly sensitive to your mother-in-law’s perfume, you could place her in a glass booth that’s vented to the outdoors.

If a house does not have any local-exhaust fans, the polluted, moisture-laden air will disperse into the rest of the house and contaminate the entire living space.

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[228] Marc Rosenbaum, “Controlled Ventilation,” *Chicken Little Chronicle* (June/July 1990): 7.

General ventilation

A general ventilation system is designed to slowly exchange the air in the entire house. This is important because people generally don't confine themselves to a single room. Fresh air is needed in *all* occupied rooms.

While a general ventilation system can be designed to overcome pollutants and moisture-laden air in a house that has no local ventilation, the entire ventilation process will be much more efficient if local exhaust fans are used judiciously.

It was pointed out earlier that, if a general ventilation system is used in an unhealthy house (one built, maintained, and furnished with unhealthy materials) to dilute the concentration of pollutants in the air, it may need to be very large and powerful. This means it will be expensive to install and to operate, and it will probably be noisy.

In a healthy house, with local ventilation in the kitchen and bathroom, the only pollutants the general ventilation system will need to deal with are those released by the metabolism of the people (and pets), and their activities. While we don't often realize it, activities such as reading, and watching television release small quantities of air pollutants. Printing ink can outgas from a book or newspaper, and a television or VCR will outgas various pollutants from the warm electronics and plastic cabinet. Still, if most of the materials used to build, furnish, and maintain a house are healthy, a general ventilation system can be quiet, small, and low-powered, thus it will be inexpensive to install and inexpensive to operate.

Ventilation Strategies

When the air pressure indoors is greater than that outdoors, a house is said to be *pressurized*, or experiencing a *positive* pressure. When the air pressure indoors is less than the air pressure outdoors a house is *depressurized*, or experiencing a *negative* pressure. Sometimes, part of a house is pressurized and part of it depressurized. Pressurization and depressurization are neither good nor bad, but they can occasionally result in adverse effects. Fortunately, disadvantages can be minimized by thoughtful planning, careful selection of a heating/cooling system, and airtight construction—remember, all parts of a house interact as a system.

There are three basic ventilation strategies: *exhaust* ventilation, *supply* ventilation, and *balanced* ventilation. Most of the time, local ventilation relies on the exhaust strategy, and the majority of general-ventilation systems tend to use either the exhaust or balanced approach.

Exhaust Ventilation

Exhaust ventilation blows polluted, stale, or moisture-laden air outdoors, causing a house to be depressurized. When this happens, an equal volume of outdoor air enters somewhere else. A disadvantage to exhaust ventilation is the fact that some pollutants can get sucked into the living space. For example, if the incoming air enters through cracks in the basement, radon can get sucked indoors. One study found that when a house was depressurized, negative pressure was measurable in the soil as far as 42' away from the foundation and 9' deep.[229] Depressurization can also have a negative effect on chimney function, and it can result in hidden moisture problems in hot, humid climates. If hot, humid air is sucked through random cracks and gaps into an air-conditioned house, moisture can condense on the back of the cool drywall—inside building cavities. However, when these drawbacks are adequately addressed, this can be a useful ventilation strategy.[230]

Supply Ventilation

Supply ventilation blows fresh air into a house, causing the house to be pressurized. There is only one disadvantage to this approach—it can cause hidden moisture problems in cold climates. When warm, moisture-laden air is blown from the living space through random cracks and gaps toward the outdoors, moisture can condense inside building cavities—for example, on the back of the cold sheathing. Although supply ventilation isn't commonly used, it does have advantages. For example, it can prevent radon from entering a house, and it can cause a chimney to function more effectively.

Balanced Ventilation

Balanced ventilation uses two fans that operate simultaneously, one to blow fresh air indoors and one to blow stale air outdoors—so the house experiences a neutral pressure. This avoids the negative effects of both pressurization and depressurization—but it costs more to install and to operate because it requires a system with two fans.

Heat-recovery ventilation is a special form of balanced ventilation that is more energy-conserving.[231] In a typical heat-recovery ventilator (HRV), the incoming fresh airstream and the outgoing stale airstream pass very close to each other (without touching and contaminating each other) inside a special *heat-recovery core*. During the winter, the warmth from the outgoing air passes through the core and warms up the incoming air. In an air-conditioned house in the summer, the warmth from the incoming air passes through the core into the cool outgoing air. An HRV, thus, tempers (preheats or precools) the incoming air. No heat is actually generated, but some of the existing heat is recycled. An HRV doesn't bring the incoming air all the way to room temperature, but the process is much more energy conserving than bringing in 0°F air in the winter and 100°F air in the summer.

Most of the general ventilation systems available today are heat-recovery ventilators—and they tend to be the most-expensive ventilation systems on the market.

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229 J. Raloff, "Toxic gases can penetrate concrete blocks," *Science News* (December 16, 1989): 391.

230 David Philbrick, Martin Thompson, and Mike O'Brien *Installing non-heat recovery ventilation systems* (Corvalis, OR: Extension Energy Program, Oregon State University, June 1989).

231 Bill Rock Smith, "Heat-recovery ventilators," *Journal of Light Construction* (March 1994): 31-36.

For more information about HRVs, the booklet *Heat Recovery Ventilation for Houses*,[232] is somewhat out-of-date, but it still contains a good deal of useful information.

In many instances, balanced ventilation systems without heat-recovery, supply systems, or exhaust systems, are more cost effective than HRVs and, if designed well, they can do just as good a job.

The Importance of Holes

There's something about ventilation that has, thus far, been implied, but not stated: for an air-pressure difference to cause an exchange of air in a house, the house must have *holes* in it. If there are no holes in the structure, it doesn't matter how much of an air-pressure difference there is between the indoors and the outdoors, there won't be any air exchange. This is why tight houses don't have much natural ventilation—there just aren't enough holes for the wind or stack effect to push much air through.

The holes in a house can be *deliberate* (cut through a wall on purpose), or *random* (miscellaneous holes in the structure that are often hidden or too small to be visible). All houses have some random holes, it's just that tight houses have fewer and smaller ones than loose houses.

Air moves through random holes passively when a house is either pressurized or depressurized. If a fan is connected to a deliberate hole, air will pass through that hole actively when the fan is operating. If the fan is not operating, but something else applies pressure to the house, air can move through a deliberate hole passively.

The air that passively enters a house through random holes is called *infiltration*. *Exfiltration* is air that passively leaves a house through random holes. Infiltration and exfiltration can be caused by anything that results in an air-pressure difference between the indoors and the outdoors.

Design Considerations

There are many different manufacturers of residential ventilation equipment. Some offer a complete ventilation-system package, others provide individual components. In general, any well-designed, properly-installed system will provide improved air quality. However, for hypersensitive people, some equipment and some installations can be problematic.

Capacity

One of the first steps in ventilation-system design is to determine the capacity needed. The best guidelines currently suggest that a general ventilation system should be able to provide a continuous air-exchange rate of either 15 cubic feet per minute (cfm) per person or $^1/_3$ of an air change per hour (ACH), whichever is greater. If the average occupancy of a house is 4 people, then 60 cfm (4 x 15) of continuous ventilation should be sufficient.

To determine ACH, you first need to calculate the volume of the house. A 1,200

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[232] National Center for Appropriate Technology (NCAT), *Heat Recovery Ventilation for Housing* (Butte, MT: NCAT, n.d.). GPO-061-000-00631-1.

sq. ft. house with 8' high ceilings will contain 9,600 cu. ft. (1,200 x 8). One-third of an air change per hour would be 3,200 cu. ft. per hour (9,600 ÷ 3). This translates into 53.3 cfm (3,200 ÷ 60) of continuous capacity.

Sometimes it's advantageous to oversize a ventilation system. For example, a system may be sized for the needs of three occupants, but what happens when there are a dozen family members over for Thanksgiving dinner? The solution can be as simple as installing a higher-capacity system and running it on slow speed when there are only a few people at home, then high speed when company arrives.

Many ventilation systems are designed for intermittent operation. For example, suppose a neighbor's wood smoke is a problem at night during the winter months. You may choose to only operate your ventilation system for 8 hours a day when the outdoor air is clear. In such a case, the capacity of the system should be sized to overventilate when it's running. If this is done, the average 24-hour rate should meet the above recommendations. Of course, if a house is unoccupied during the day—when people are at work or school—the average ventilation rate can be reduced accordingly. These factors should all be taken into account when determining the equipment capacity.

The 15 cfm and $^{1}/_{3}$ ACH figures were arrived at by placing a person inside a closed room (made of fairly healthy materials) and exchanging the air in the room at different rates. Average people off the street were asked to stick their head in the room and report how fresh it smelled. For 80% of the people, an exchange rate of 15 cfm or $^{1}/_{3}$ ACH was enough for the room to smell fresh. At lower ventilation rates, many people said the room seemed stuffy. Their reactions were not to pollutants typically found in houses because the room was made of fairly healthy materials but, instead, to the metabolic by-products released by the person sitting in the room. So, these guidelines are considered a body-odor standard, not a health standard.

If a house is built, furnished, and maintained with healthy materials, then 15 cfm or $^{1}/_{3}$ ACH will be sufficient for most people. If unhealthy materials are used, it can be very difficult to guess at what rate is sufficient, simply because so many different pollutants are possible, and they occur at such varying concentrations. So, because the air inside each house is different, it's virtually impossible to state a universal rate for all unhealthy houses, but in some cases it could easily be 60 cfm per person or $1^{1}/_{2}$ ACH—or more. Of course, ventilating at a high rate can have drawbacks. For example, it will mean higher heating/cooling bills, and it can make a house excessively dry in the winter. A high-powered ventilation system will also be expensive to install and to operate—and it will be noisy.

One study looked at how much air exchange average houses, without mechanical ventilation systems, actually got.[233] It found that 90% had an average "natural" ventilation rate less than $^{1}/_{3}$ ACH for at least a full month. Seventy percent of the houses averaged below $^{1}/_{3}$ ACH for the entire heating season. Based on this study, it's obvious that most houses need mechanical ventilation.

Controls

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233 "Natural Ventilation in Ordinary Leaky Houses," *Energy Design Update* (June 1991):11.

There are many different controls that can be used with ventilation systems. No single control is ideal for all situations—all have advantages and disadvantages. Fairly simple controls include no control (the ventilation system runs 24 hours per day, every day), an on-off switch, and a variable-speed controller. Low-cost, spring-wound crank timers are popular, as are the fancier electronic timers that can turn a fan on or off at specific times of day. There are also controls that can turn a ventilation fan on when the relative humidity gets too high, or when the carbon-dioxide concentration rises above a certain level. Most ventilation-equipment suppliers offer a variety of different controls.

Distribution

Exhaust air is air that's leaving a house. It's often called *stale air* because it's been contaminated by people, activities, or materials inside the house. The outdoor air that enters a house is either called *make-up air* (because it makes up for what was exhausted), or *intake air*. It's also often called *fresh air* even though it may be contaminated with outdoor air pollutants.

It's always a good idea to pull intake air from a clean outdoor location. For example, don't have the fresh-air intake near a garage door because it will pull exhaust gases indoors. And don't put it too near the stale-air exhaust, or a clothes-dryer exhaust, or a chimney, or stale, contaminated air will be pulled back indoors.

Inside the house, fresh air is often introduced into bedrooms, living rooms, and family rooms because that's where people spend the most time. Stale air is often exhausted from service rooms like kitchens, utility rooms, and bathrooms because they are typically more contaminated. This results in an exchange of air through all of the rooms. Actually, there are as many variations to ventilation-system layout as there are different floor plans.

Costs

The cost of ventilation varies widely. For example, a cheap bathroom exhaust fan might cost only $25 to purchase, while a high-quality, energy-efficient, quiet version will be over $100. A top-of-the-line heat-recovery ventilator could be in the $1,000 range, plus installation.

Operating costs also vary, but they typically aren't exorbitant. For example, a 50-cfm bath fan running two hours a day costs less than $15 per year to operate in most parts of the U.S. This cost is determined by the local electricity rate and the cost of heating or cooling the incoming make-up air.

Because heat-recovery ventilators conserve energy, they can be more cost-effective than other ventilation strategies—but only in some climates. For example, the operating cost of 80 cfm of continuous ventilation in Minneapolis might be $188 a year without heat-recovery or $86 with heat-recovery. The annual savings of $102 (188 - 86) could easily make the extra cost of a heat-recovery ventilator worthwhile in this cold climate. On the other hand, in Los Angeles the annual operating cost might be $82 without heat-recovery or $54 with heat-recovery. Saving only $28 (82 - 54) a year probably wouldn't make a heat-recovery ventilator cost-effective in Southern

California.[234]

The cost of ventilation isn't exorbitant, and it's definitely something that most houses need. In a 1998 report, it was determined that the total cost (annualized equipment cost plus operating cost) of a whole-house ventilation system in most parts of the U.S. could be in the $200 range per year.[235] These costs were based on a fairly simple system. There are also more elaborate (and more expensive) systems that offer various advantages, but the fact is that ventilation does not need to be expensive. And if you build a tight, energy-efficient house, your overall energy savings will generally be more than the cost of ventilation—so you will be dollars ahead.

Equipment Location

Ventilation equipment takes up a certain amount of space, and while an attic or crawl space might seem like a good, out-of-the-way location, they should only be considered if they are easily accessible. This is because ventilation equipment requires regular maintenance in the form of cleaning and lubrication. Over a washer/dryer in a utility room is often a good location, as is a heated basement.

Ducts

Generally, metal ducts are preferred, but plastic-lined flexible ducts are often acceptable. Some ducts will need to be insulated for energy-efficiency, or to prevent condensation.

If ventilation is considered early in the planning process, the actual location of the ducts can be coordinated with the framing to minimize interference. Ductwork is covered in more depth in the next chapter.

Noise

One of the most common consumer complaints about ventilation systems is noise. Manufacturers' installation literature often addresses this with suggestions such as hanging ventilation equipment from rubber straps to minimize vibration noise. Many manufacturers are now offering much quieter fans.[236]

Air noise is more pronounced with the high-powered ventilators required in unhealthy houses, than with the low-capacity units typically used in healthy houses. Sometimes, ducts are lined with a sound-absorptive material to reduce noise, but these materials can outgas and shed fibers into the airstream, or become home to

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234 John Bower, *Understanding Ventilation: How to design, select, and install residential ventilation systems* (Bloomington, IN: The Healthy House Institute, 1995): 184.

235 Judy A Robertson and others, *Recommended Ventilation Strategies for Energy-Efficient Production Homes* (Berkeley, CA: Lawrence Berkeley National Laboratory, December 1998). LBNL-30378.

236 Andrew Shapiro, "Quiet bathroom fans," *Journal of Light Construction* (June 1996): 35-40.

microorganisms.[237]

Deliberate Holes

Mechanical ventilation usually requires that some holes be placed in a house. In many instances, only one or two holes are needed—for a fresh-air intake or a stale-air exhaust. But in tight houses, more holes might be necessary with some ventilation strategies. For example, in a loose house, a central-exhaust system might have a single exhaust port, and rely on fresh air entering through all the random holes in the house. But in a tight house, there aren't many random holes. So, devices called *through-the-wall vents* are often used to provide a way for fresh air to enter.[238] Most can also be used as stale air exhausts when a house is pressurized.

Building a tight house, then poking some holes in it might seem rather silly, but it actually makes a great deal of sense. When air enters a depressurized house through random holes, it can bring pollutants such as radon and insulation indoors with it. The air enters in an uncontrolled manner—wherever there happens to be a gap or crack in the structure. But when you have a tight house, and through-the-wall vents are installed in specific rooms, the air enters those rooms without the pollutants associated with air entering random holes. Plus, you can place the vents exactly where you want fresh air—not in random locations. Suppliers of through-the-wall vents include **National HVAC Products**, **American Aldes Corp.**, and **Therma-Stor Products.** There are also similar vents, called Trickle Ventilators (**Titon, Inc.**), that are made to mount in a window sash. They can look very unobtrusive, and some can be closed when not needed.

To minimize a variety of pollution and moisture-related problems, it's always better to have air both enter and leave a house through deliberate holes in a tight house than through random holes in a loose house.

Local Ventilation Equipment

Much of the local ventilation equipment stocked by building-supply centers is of low quality, inefficient, and noisy. Fortunately, several manufacturers offer durable, better-than-average equipment at only a modest increase in cost.

Local ventilation fans should always be ducted to the outdoors—never into an attic or crawl space. One of the purposes of these devices is to expel moisture, moisture that can cause damage in an attic or crawl space as well as in the living space. It's not unusual for the roof decking to become black with mold—within a year of operation—when a kitchen range hood is ducted into an attic.[239]

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237 John Gregerson, "Reducing the frequency of HVAC noise," *Building Design & Construction* (April 1993): 59-62.

238 Nadav Malin, "Fresh air supply for exhaust-only ventilation," *Environmental Building News* (March/April 1993): 13-14.

239 William Lotz, "Moisture problems: Five case studies," *Journal of Light Construction* (February 1991): 34-35.

Exhaust Fans

One of the most significant advances in exhaust fans has been the *low-sone* fan. A sone is a unit of sound measurement, and a low-sone fan is very quiet when compared to a typical vibrating, rumbling, squealing bath fan. The quietest units can hardly be heard, even when you're in the same room. At $^1/_2$ Sone, and consuming only 14 watts, one of the quietest and most energy-efficient 70 cfm fans is made by **Panasonic**. Other quiet-fan manufacturers include **Broan Mfg. Co., Inc.**, **Nutone, Inc.**, **Penn Ventilator, Inc.**, and **Reversomatic Htg. & Mfg. Ltd.** (Most of these companies also produce other fans besides the quiet models.)

The majority of these exhaust fans mount in the ceiling of the room they are meant to serve, but **Tamarack Technologies, Inc.** has a unique Preventilator fan that mounts on the outside of an exterior wall. The Preventilator makes for a very quiet installation—because it is outside the house—and it has a motorized cover that closes for energy efficiency when the fan is not running. **Fantech, Inc.** has exhaust fans that mount on exterior walls or roofs to get the noise out of the living space. **Ventex Systems Corp.** markets a unique toilet that has a built in ventilating fan to clear a bathroom of odors quickly. They also offer a retrofit kit for adapting their exhaust system to existing toilets. Mail-order suppliers of quiet fans include **American Aldes Corp.**, **EFI** and **Shelter Supply.**

Fifty cfm is the minimum capacity for an exhaust fan in a small bathroom. Seventy to one-hundred cfm is better for most installations, but very large bathrooms can require even greater capacity.

Kitchen Exhausts

An overhead range hood does not, contrary to popular belief, suck pollutants up off the stovetop. Instead, the pollutants and moisture generated during cooking rise (simply because warm air rises naturally) up into the collection hood, then the fan blows them outdoors. For overhead exhaust hoods, 150-250 cfm is usually adequate capacity.

The downdraft exhausts used with some stoves must be much more powerful because they need to overcome the natural buoyancy of the warm air. They often need over 500 cfm of capacity to suck the odors and moisture downward and exhaust them from the kitchen. This is a great deal of exhaust capacity, and it can depressurize a house to a significant degree—causing potentially serious pollution problems such as backdrafting in chimneys. Also, the 500 cfm of make-up air that enters the house when the fan is running can be very cold in the winter.

Most kitchen range hoods are quite loud, but there is a simple way to reduce the noise. Remote-mounted kitchen fans are designed to mount on a roof or outside on an exterior wall. They are then connected to the hood by a length of sheet-metal duct. Manufacturers of exterior-mounted range-hood fans include **Broan Mfg. Co., Inc.**, **Nutone**, **Reversomatic Htg. & Mfg. Ltd.** and **Viking Range Corp.**

Small, Single-Room Heat-Recovery Ventilators

To ventilate a single room in an energy-efficient manner, two companies offer small, compact heat-recovery ventilators. (Heat-recovery ventilators are discussed in depth later.) The window-mounted units produced by **Stirling Technology, Inc.** and

Thermax look similar to window air conditioners, but they are designed to provide fresh air and exhaust stale air in an energy-efficient manner.

General Ventilation Equipment

General ventilation systems are either installed as stand-alone systems, or in conjunction with a forced-air heating/cooling system. Neither approach is ideal for all situations—there are advantages and disadvantages to each.

Exhaust Ventilators

With a little ingenuity, almost any type of fan can be used to create a whole-house exhaust-ventilation system. But a few companies have developed systems that take most of the guesswork out of the design process.

American Aldes Corp., **Broan Mfg. Co., Inc.**, **Fantech, Inc.**, **Reversomatic Htg. & Mfg. Ltd.**, and **Therma-Stor Products** all offer multi-port ventilators. Each of these is basically a "fan in a box" with a single exhaust outlet that is ducted to the outdoors and several inlets that pull air from various rooms of the house. In addition, **National HVAC Products** (Aereco) and **American Aldes Corp.** both have packaged systems that contains a fan, through-the-wall inlets, and controls, in a well-thought-out package.

Supply Ventilators

General ventilation systems that pressurize houses aren't common, but they do have some advantages in some climates. While any type of fan can be adapted for use in such a system, there are a couple of companies who offer equipment that slightly pressurizes a house. **Tjernlund Products, Inc.** has a Fresh Air In-Forcer which consists of a small cabinet, a fan, and a timer. **American Aldes Corp.** has a Blending Ventilator that brings in outdoor air, mixes it with a certain amount of indoor air (to moderate the temperature) then distributes it into the living space.

Balanced Ventilators

A balanced ventilation system can easily be created using any two fans of equal capacity and some ductwork. **Kanaflakt, Inc.**, offers a balance ventilator that tempers the incoming air by mixing it with a certain amount of exhaust air. While this reintroduces some of the pollutants back into the living space that were on their way outdoors, it can be a viable ventilation strategy in some situations when the higher cost of a more-expensive heat-recovery ventilator (see below) isn't feasible. **Nutech Energy Systems, Inc.** has a FreshVent which is also a balanced ventilator that brings in a certain amount of fresh air and mixes it with some exhaust air before distributing the tempered mixture into the living space. They also have a Ventmax balanced ventilator that can operate in a low-speed recirculate mode when outdoor air isn't needed, or on a high-speed ventilation mode when outdoor air is desired. **Venmar Ventilation** has a Construct Air Exchanger that is also a balanced ventilator.

Heat-Recovery Ventilators

The majority of the balanced ventilation systems on the market are heat-recovery ventilators (HRVs). Most HRVs consist of an insulated cabinet, a heat-recovery core, two fans, some ductwork, and a control. But not all HRVs are created equal. They have different types of cores, they are made from different materials, they handle moisture differently, and some are more efficient than others. Units that transfer moisture between the incoming and outgoing airstreams are called energy-recovery ventilators (ERVs).

HRV manufacturers include **American Aldes Corp.**, **Air For Life, Inc.** (Boss Aire), **Broan Mfg. Co., Inc.** (Guardian), **Carrier Corp.**, **Venmar Ventilation** (Van EE), **Des Champs Laboratories, Inc.** (E-Z Vent), **Duro-Dyne Corp.** (Durovex), **Eneready Products Ltd.**, **Honeywell, Inc.** (Perfect Window), **Kanaflakt, Inc.** (Enviro), **Lennox Industries**, **Mitsubishi Electric** (Lossnay), **Nutech Energy Systems, Inc.** (Lifebreath), **Nutone, Inc.**, **Raydot, Inc.** (Safe Aire), **Research Products Corp.** (PerfectAire), **Stirling Technology, Inc.** (Recouperator, whole-house or window units), **Tamarack Technologies, Inc.** (NewAire), and **Thermax**.

Cores

There are several different types of heat-recovery cores. *Flat-plate cores* are the most common. They consist of several thin plates spaced about an 1/8" apart. The plates are connected at the ends and edges so the fresh airstream and stale airstream can move through the alternating spaces without contaminating each other. *Crossflow* flat-plate cores, which have the airstreams moving at 90° to each other, are the most widely available. *Counterflow* flat-plate cores have the airstreams moving in opposite directions.

Rotary cores have a special wheel that rotates between the fresh and stale airstreams. *Heat-pipe cores* are not widely used. They consist of sealed tubes filled with a refrigerant that transfers heat from one airstream to the other.

Flat-plate cores can be made of plastic, aluminum, or specially treated paper. All rotary cores are plastic, and heat-pipe cores are made of metal.

Some cores can be removed from the cabinet. This is a good idea, because a removable core can be taken outdoors and occasionally washed off with a garden hose. Cleaning non-removable cores can sometimes be very difficult.

Leakage

Ideally, there should be no leakage between the fresh and stale airstreams. However, in reality, there is usually some leakage. Obviously, it's desirable to obtain a model with minimal leakage between airstreams. Cross-leakage rates have been reported as low as 0% and as high as 40%.[240] In general, rotary-core models have higher cross-leakage rates.

Efficiency

Efficiency also varies.[241] [242] Some units are advertised as being over 90% efficient. However, test results from independent laboratories are often lower than a

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240 "Heat Recovery Ventilators," *Consumer Reports* (October 1985): 596-599.

241 *Ibid*.

242 William A. Shurcliff, *Air-to-Air Heat Exchangers* (Andover, MA: Brick House Publishing, 1982).

manufacturer's advertising claims. Efficiency depends on the particular design of the unit, indoor and outdoor temperature, humidity, and fan speed. Therefore, efficiency ratings for the same unit can vary, depending on how the testing was done.

If a unit with an efficiency of 80% is used when the outdoor air temperature is 0°F and the indoor temperature is 70°F, then the 10° air will be warmed up to 58° (10 + {[70 - 10] x 80%}) as it passes through the core. The 70° air releases its heat and drops in temperature to 12° (70 - 58) by the time it reaches the outdoors. Of course, the 58° air will still need to be warmed up by the heating system, but the cost will be considerably less than if a window was opened and 10° air was used for ventilation.

Independently tested efficiencies and leakage rates for most HRVs are available in the *Certified Home Ventilating Products Directory*,[243] which is available from the **Home Ventilating Institute**.

Fans

All HRVs have one or two small fans to move air through them. If a fan motor is within the fresh airstream, it can be a minor problem for some hypersensitive people. This is because, as a motor warms up during use, oil, synthetic materials, or lacquers heat up and volatilize, sending minor odors into the fresh airstream. Some HRVs have the motor located in the stale airstream, where this minor outgassing will be blown toward the outdoors.

Moisture

Because the temperature and relative humidity of the airstreams change as they pass the core of an HRV, water can condense in the core. When this happens, the moisture drips into a pan inside the cabinet, then it passes down a drain which must be connected to a plumbing drain. A $^3/_4$" drain is usually sufficient. If the drip pan is not allowed to drain freely, it can harbor mold growth.

Rotary cores, and flat-plate cores made of treated-paper, are designed to transfer moisture from one airstream to the other. This can be advantageous in the summer in a hot humid climate where you want to bring in fresh air, but not excessive humidity. Some pollutants (such as formaldehyde) can be transferred through these cores along with the moisture, but the amount is not significant.[244]

Defrosting

If the outdoor winter temperature is low enough, the moisture that condenses inside an HRV can freeze, blocking the flow of air through the core.[245] If this is a

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243 Home Ventilating Institute, *Certified Home Ventilating Products Directory* (Arlington Heights, IL: Home Ventilating Institute, July 1999). Publication #HVI 911.

244 W.J. Fisk and others, *Formaldehyde and tracer gas transfer between airstreams in enthalpy-type air-to-air heat exchangers* (Berkeley, CA: Lawrence Berkeley Laboratory, July 1984). #LBL-18149.

245 W.J. Fisk and others, *Freezing in residential air-to-air heat exchangers: An experimental study* (Berkeley, CA: Lawrence Berkeley Laboratory, September 1983). #LBL-16783 UC-38.

potential occurrence with a particular model, or in a particular climate, the HRV should have defrosting capability. Some manufacturers simply use a small electric heater to warm up the interior of the cabinet whenever frost forms—one company uses a light bulb. Other units have a small motor-driven damper that allows warm house air to periodically circulate through the core to defrost it.

Materials

Most HRV cabinets are insulated. This is necessary to prevent condensation either on the inside or on the exterior of the cabinet itself. At one time, some companies used raw fiberglass insulation, but most are now using a foil-faced insulation to prevent contamination of the air stream.

In order to prevent air from leaking out of the cabinet, or around the edges of the core, gaskets are used in various places. Occasionally a sensitive person will be bothered by the odor of a synthetic gasket but, with care, gaskets can usually be covered with aluminum-foil tape, and still flex enough to form a tight seal.

Miscellaneous Equipment

With a packaged piece of ventilation equipment, very little design expertise or guesswork is necessary to plan an installation and actually install the equipment. But there are instances where special circumstances call for a unique design. In these cases, a number of manufacturers offer multi-purpose fans that can be used in a wide variety of ventilation applications.

In-line fans are designed to have a section of round duct connected to each end. They are usually of high quality and are long-lasting. Suppliers include **American Aldes Corp.**, **Fan America, Inc.**, and **Fantech, Inc.** Other multi-purpose fan suppliers include **Grainger, Inc.** and **Penn Ventilator, Inc.**

Therma-Stor Products offers a nice piece of well-designed ventilation equipment that combines more than one function. (The system approach again!) They have a whole-house dehumidifier (Sierra) that can be used in conjunction with a central ventilation strategy. And their "Ultra Aire Air Purifying Dehumidifier" is a combination piece of equipment that can bring in fresh outdoor air, filter it, then distribute fresh, filtered, and dehumidified air into the living space. This device works particularly well in hot humid climates where the outdoor air contains a great deal of moisture. **American Aldes Corp.** also has a whole-house dehumidifier.

A great deal of water can evaporate from indoor swimming pools into the air, thus requiring a significant amount of ventilation to get rid of the moisture. **Nutech Energy Systems, Inc.** has larger heat-recovery ventilators suitable for indoor swimming pool applications. **Crispaire** has a special heat-pump device that will dehumidify the air and use the heat obtained through condensation to heat the water in the pool. This will save energy and minimize the amount of ventilation required.

Combining Ventilation with Heating/Cooling

Ventilation equipment is often installed in conjunction with a heating/cooling system.[246] This is only possible with a forced-air heating/cooling system. It is not possible with heating/cooling equipment that doesn't use ductwork, such as a forced-hot-water boiler. There are both advantages and disadvantages to combining the two systems.

A general ventilation system moves a fairly small volume of air, usually 50-200 cfm, through small-diameter ducts, compared to a forced-air heating/cooling system which might move over 1,000 cfm through larger-diameter ducts. When heating/cooling and ventilation are separate, independently operating systems, two sets of ductwork are needed. This increases the installation cost. Combining the two systems means you only need a single system of ductwork.

If you interconnect the two systems and only run the ventilation fan, it won't be able to push the air through the entire system of larger heating/cooling ducts. So, when ventilation and heating/cooling are combined, both fans must usually operate at the same time. In a typical installation, a low-powered ventilator fan blows fresh air into the ductwork just ahead of the furnace/air conditioner, where it mixes with air coming from the living space. This mixture of fresh air and house air is then heated or cooled, and blown into the living space by the larger fan. A combined system means more air movement, and more noise, than would be experienced if only a low-powered ventilation fan were running.

A significant advantage to combining heating/cooling and ventilation is that you can use a single better-than-average filter to clean both airstreams. When the systems operate independently, you may need two filters: one for the incoming fresh air to remove outdoor pollutants such as pollen, and a second filter to remove pollutants, such as house dust, that are generated within the living space.

In a combined system, during mild weather when neither heating nor cooling are necessary, ventilation will still require both fans to be running, one of which is fairly powerful. This means a higher operating cost. A few high-efficiency furnaces are fitted with energy-efficient *ECM motors* which can significantly reduce the operating cost compared to standard furnace motors. They are often recommended when ventilation and heating/cooling are combined into a single system, particularly when the heating/cooling fan is to run continuously. Because they have a higher up-front cost, ECM motors aren't common, but they can be cost-effective over the life of a motor.[247] [248] In fact, if a furnace motor runs continuously, an ECM motor can pay for itself in one year.[249] They can be retrofitted to make an existing system more energy-efficient. ECM motors are variable speed, brushless, DC, permanent-magnet motors that can change speed at any time during

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246 Bruce Sullivan, "Using heating ducts for ventilation," *Journal of Light Construction* (September 1993): 51.

247 Canada Mortgage and Housing Corp. (CMHC), *Barriers to the use of energy efficient residential ventilation devices* (Ottawa, ON, Canada: CMHC, June 1992).

248 Canada Mortgage and Housing Corp. (CMHC), *Efficient and effective residential air handling devices* (Ottawa, ON, Canada: CMHC, March 1993).

249 Joan Gregerson, "High-efficiency residential blower motor replacements: Capturing a lost opportunity" Dallas, TX: *Proceedings of the 12th Annual International Energy Efficient Building Conference*, February 23-26, 1994): B49-B60.

operation. They are currently manufactured by Emerson Motor Co. and General Electric Motors and are available through major forced-air heating/cooling equipment manufacturers.

Ventilating Furnaces

Nutech Energy Systems, Inc. has a Clean Air Furnace that is specifically designed to combine forced-air heating/cooling and ventilation. It basically consists of a metal air-handler cabinet, a heat-recovery-ventilator core, and a hot-water heating coil. During operation air is circulated from the living space through the hot-water heating coil (or an air-conditioning coil) then the conditioned air is returned back into the living space. At the same time, a portion of the air coming from the living space is sent through the heat-recovery core toward the outdoors, and fresh outdoor air is brought in through the heat-recovery core and sent indoors. Hot water from a conventional water heater is circulated into the hot-water heating coil to provide warmth. This system can also be combined with a better-than-average air filter.

Fresh-Air Ducts

A simple way for a forced-air heating/cooling system to provide ventilation air is to connect a duct between the main return air duct of the forced-air heating/cooling system and the outdoors. Whenever the forced-air heating/cooling system's fan is running, the return-air duct will be under negative pressure, thus it will pull in a certain amount of outdoor air, which will mix with the house air and be distributed into the living space. This setup will slightly pressurize the house—unless another fan is used somewhere else to exhaust air simultaneously from the living space. This certainly has a low installation cost, but it has disadvantages. For example, you will get the most outdoor air being pulled in during seasons when the fan runs the most (the cold of winter, or the heat of summer), so the house can be overventilated when it is the most expensive to heat or cool the incoming air. And, in the off seasons, when the forced-air heating/cooling system's fan isn't running much, you don't get much ventilation air. Plus, with this approach, if too much cold outdoor air is brought in during the winter, it can "shock" the hot heat-exchanger in a furnace, possibly resulting in cracking or damage. However, a fresh-air duct can work well if excessive amounts of cold air are not involved.

American Aldes Corp. has a Make-Up Air Kit designed for just this purpose. It is usually used in conjunction with one of their central exhaust ventilators. **Duro-Dyne Corp.** has a spring-loaded damper that can be mounted in the duct running between the outdoors and the return-air duct. It can be combined with their Dyna-Fresh controller which will automatically turn on the furnace/air-conditioner fan at regular intervals so you can have fresh air during seasons when the fan wouldn't normally be running.

Lipidex Corp. has a very nice timer available called the AirCycler that can be used in these systems to automatically turn on the fan if it has been idle for a certain time period.[250] So, in the spring and fall, when you don't often need heating or cooling, the AirCycler will automatically turn the fan on to bring in fresh air on a regular basis.

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[250] Armin Rudd, "Air distribution fan and outside air damper recycling control," *Heating and Air Conditioning and Refrigeration News* (July 5, 1999): 45.

Summary

As with any mechanical device, ventilation equipment must be installed correctly if it is to function as it was intended to function. Generally, this means following the manufacturer's directions carefully. Most manufacturers offer technical advice over the telephone so an installation can proceed smoothly. A complete in-depth discussion of all aspects of ventilation is beyond the scope of this book. For much more in-depth information about residential ventilation, and a more-complete listing of manufacturers, see *Understanding Ventilation* by John Bower.

Our bodies are very complicated biological machines in which various organs interact. Houses are not quite as complicated but, just as the leg bone is connected to the thigh bone, ventilation is connected to airtightness. In fact, heating/cooling, moisture, ventilation, airtightness, healthfulness, and energy efficiency are all interrelated and should be considered together. Because a state-of-the-art house must be viewed as a system, and because of the interdependence of all the components, few chapters of this book stand alone. It is especially important that this chapter be read in conjunction with *Chapter 7, Heating and cooling* and *Chapter 9, Tight construction*.

7. Heating and Cooling

This chapter will discuss the various advantages and disadvantages of heating and cooling systems, and how those systems can affect the health of the occupants. For optimal indoor air quality, the selection of heating/cooling equipment should be coordinated with the choice of ventilation equipment, air filtration, and how tightly the house is constructed. The heating/cooling system is an important part of a house, yet it is often all-but-ignored in many house designs. In addition, many heating/cooling systems are neglected after installation, so they receive little maintenance. It's no wonder they can contribute to poor indoor air quality. In commercial installations, researchers have traced half of the indoor air quality problems to poorly functioning heating/cooling systems,[251] and most residential equipment is probably no better.

General Considerations

Because it is often the most complicated subsystem of a house, a heating/cooling system is subject to a number of disadvantages. Some are considered minor—and not usually problematic—but others can be quite serious.

Fuel Storage

When liquid fuels leak into the living space, they soak into, and contaminate, various building materials. Spills can be difficult to clean up completely. This also happens with gaseous fuel leaks, but the long-term contamination generally isn't as serious. Fuel leaks can be the result of an overflowing or damaged storage tank, loose or damaged fittings in piping or tubing, damage to the heating equipment, *etc*. A fuel-oil leak can expose occupants in the living space to various VOCs such as xylene and naphthalene for over a week[252] and other compounds for much longer periods.

Symptoms of exposure to natural gas (methane) and LP gas (propane) are very common among sensitive people, and they can range from a stuffed-up head to asthma, hyperactivity, confusion, and loss of consciousness.[253] These symptoms can occur with low-level exposures that are considered acceptable by the gas industry. Even the small amounts of combustion by-products given off by a gas pilot light can result in symptoms. The methyl mercaptan often used to give natural gas its disagreeable odor can be bothersome to sensitive people.[254] The only way of providing relief to people who are extremely sensitive to natural gas or propane, and their combustion by-products, is to

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251 "An HVAC systems approach to IAQ," *Indoor Air Quality Update* (February 1991): 1-9.

252 Marjorie Kaplan and others, "Residential releases of number 2 fuel oil: A contributor to indoor air pollution," *American Journal of Public Health* 83 (January 1993): 84-88.

253 Randolph, *An Alternative Approach*, 56.

254 "Natural Gas Appliances," *Everything Natural* (March/April 1987): 3.

remove all gas-fired appliances and all gas piping from the house. In some cases, ducts can be contaminated enough by gas, or combustion by-products, that sensitive individuals have had to replace them. Propane/natural-gas alarms are available from **AIM Safe-Air Products** (Dual Combustable Detector), **BRK Brands, Inc.** (MPG120 Gas Alarm), **M.T.I. Industries, Inc.** (Safe-T-Alert), and **North American Detectors** (American Sensors).

Fuel oil has also been implicated in ill health. This can be due to combustion by-products entering the living space during the heating season, to leaking fuel oil, or to residual odors in the off-season. Theron Randolph. MD describes what happened to one sensitive woman who entered an oil-heated hunting lodge. "She began to cough and wheeze within a few minutes after entering the building, and became unconscious."[255]

To minimize indoor pollution, fuel-storage tanks are best located outdoors or underground. If an oil-storage tank, for example, must be located in a basement, it is important that the fill pipe and vent pipe are both run to the outdoors, and that all fittings are well-sealed.

If firewood is stored indoors, it can contaminate the living space with mold spores, pollen, and wood dust, and it can add moisture to the indoor air. In addition, some sensitive people are bothered by the natural odor of raw wood.

The indoor air pollution associated with fuel storage can certainly contaminate a house, but the combustion by-products generated when fuels burn are a much more common problem.

Combustion By-Products

When a fuel burns, combustion by-products are always generated. The specific pollutants released depend on the type of fuel and the efficiency with which it burns. Some combustion by-products are relatively benign (*e.g.* water vapor and carbon dioxide), some are moderately dangerous (*e.g.* nitrogen and sulfur compounds) but one in particular can be deadly—carbon monoxide. According to Dr. Randolph, "Clinical susceptibility to gas, oil and coal—including their combustion products and related derivatives—is a common unsuspected cause of chronic symptoms."[256]

Children living in homes heated with wood have a much greater chance of developing respiratory symptoms than children in homes without wood heat.[257] One study found that 84% of children in wood-heated homes experienced at least one severe symptom of acute respiratory illness during the heating season, compared to only 3% in other homes. Symptoms included a history of coughing at night, coughing on most days, or occasional wheezing apart from colds. Allergies were present in 19.4% of the children

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255 Randolph, *An Alternative Approach*, 53.

256 Theron G. Randolph, *Human Ecology and Susceptibility to the Chemical Environment* (Springfield, IL: Charles C. Thomas, 1962), 106.

257 J. Scott Osborne III and Richard Honicky, "Health effects of heating with woodburning stoves: A prospective study of chronic symptoms of respiratory disease in young children" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 1, Human Health, Comfort and Performance*, 1990): 447-452.

in wood-heated homes but in only 3.2% in the control group.[258] These symptoms are early manifestations of respiratory-tract injury, and because young children are generally confined to the house more than either adults or older children—especially in the winter—it seems logical that they would be the first to exhibit symptoms. Prolonged exposure could certainly have an effect on occupants of all ages.

Every year a few hundred people die in North American houses due to carbon-monoxide poisoning. According to the **Consumer Product Safety Commission** in 1993 there were 214 non-fire-related deaths in the U.S. due to CO poisoning, and in 1995 there were 5,900 non-fire-related CO injuries.[259] The majority of these deaths and injuries involved space heaters and furnaces. Actually, millions of individuals are exposed to low-level, non-lethal concentrations of this invisible and odorless gas. This low-level exposure can easily result in flu-like symptoms—headache, nausea, dizziness, vomiting, weakness, *etc*. In fact, one study found that neary 24% of a group of people reporting they had the flu, were actually suffering low-level carbon monoxide poisoning.[260] Although carbon monoxide is the most serious combustion by-product, lesser quantities of formaldehyde, particulate matter, volatile organic compounds, and polynuclear aromatic hydrocarbons can also be produced.[261]

As an indoor air pollution source, burning wood is responsible for a wide variety of contaminants.[262] The effects of particulates, nitrogen dioxide, sulfur dioxide, and carbon monoxide are well documented, but there are over 200 pollutants in wood smoke whose names are not-easily recognized, some of which are carcinogenic: benz(a) anthracene, chrysene, benzofluoranthene, *etc*.[263] Wood stoves add up to 200 times more

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258 Richard E. Honicky, Scott Osborne III, and C. Amechi Akpom, "Symptoms of Respiratory Illness in Young Children and the Use of Wood-Burning Stoves in Indoor Heating," *Pediatrics* 75 (March 1985): 587-593.

259 Lydia Gibson, "How safe are your houses?," *Professional Builder* (February 1998): 71-74.

260 Michael C. Dolan and others, "Carboxyhemoglobin Levels in Patients with Flu-like Symptoms," *Annals of Emergency Medicine* 16 (July 1987): 782-786.

261 D. Moschandreas and others, "Emission Rates from Unvented Gas Appliances," *Environment International* 12 (1986): 247-253.

262 Tauseef Quraishi and John Todd, "Effects of domestic wood burning on indoor air quality—an overview" (Berlin: *Proceedings of the 4th International Conference on Indoor Air Quality & Climate, Vol. 1, Volatile Organic Compounds, Combustion Gases, Particles and Fibers, Microbiological Agents*, 1987): 489-492.

263 John D. Spengler and Martin A. Cohen, Emissions from Indoor Combustion Sources, in *Indoor Air and Human Health*, by Richard B. Gammage & Stephen V. Kaye (Chelsea, MI: Lewis Publishers, 1985): 267-268.

particulate matter to the air than other heating methods.[264] Burning pressure-treated lumber in a wood stove has led to arsenic poisoning, rashes, muscle cramps, seizures, and loss of consciousness.[265]

One study found Cesium-137, an isotope resulting from nuclear fission, in a number of samples of wood ash.[266] It's believed that trees can harbor residue from nuclear fallout released by weapon testing that was done between 1945 and 1975. When these trees are cut down and burned, the ash remains slightly radioactive. Some of the radiation can also go up the chimney. Some 1.4 million tons of ash are generated each year in the U.S. from burning wood, some of it with over 100 times the radioactivity that can legally be released by nuclear power plants.[267]

In a Wisconsin study, polycyclic aromatic hydrocarbons (PAHs), which are carcinogens released by combustion, were up to 46 times higher indoors when wood was being burned than during non-wood-burning periods.[268] Sadly, it isn't unusual to go into a house in the summer and smell the odor of wood smoke on the furnishings—an odor that was absorbed months earlier, during the heating season. This lingering odor means burning wood in the winter can have an effect on health all year long.

Symptoms of exposure to combustion by-products are quite varied, sometimes minor, but sometimes severe. As with exposures to many pollutants, minor exposures over long periods can result in ill health in later years that has no readily discernible cause. Among hypersensitive people, negative health effects related to combustion fuels and combustion by-products are almost universal.

Malfunctioning Chimneys

There should be *no* combustion by-products indoors in a healthy house. Even something as seemingly innocuous as water vapor can build up and lead to mold growth. Most people would never consider building a fire in the middle of the living room floor (even if there was no danger of burning down the house), because they know that smoke isn't good to breath. But when fuels are burned indoors in furnaces, water heaters, boilers, and stoves, we are often doing just that. Because chimneys often function poorly, these heating devices can deposit combustion by-products directly into the living space.

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[264] "Ban Ordered on Wood Fires in Smoggy Reno," *Nontoxic and Natural News* (January/February 1986): 1.

[265] H.A. Peters and others, "Seasonal arsenic exposure from burning chromium-copper-arsenate-treated wood," *JAMA* 251 (1984): 2392-2396.

[266] "Wood burning threatens radiation contamination," *Indoor Air Review* (June 1992): 9.

[267] "Radioactivity on your lawn?," *Safe Home Digest* (May/June 1992): 2.

[268] J.M. Daisey, J.D. Spengler, and P. Kaarakka, "A comparison of the organic chemical composition of indoor aerosols during woodburning and non-woodburning periods" (Berlin: *Proceedings of the 4th International Conference on Indoor Air Quality & Climate, Vol. 1, Volatile Organic Compounds, Combustion Gases, Particles and Fibers, Microbiological Agents*, 1987): 215-219.

Traditionally, chimneys have been made of brick or stone. Some still are, but most chimneys today are metal. Gas water heaters, oil furnaces, and wood stoves are routinely connected to some type of chimney which is *supposed* to direct the combustion by-products outdoors.

A chimney can certainly malfunction because of damage, or blockage. For example, an old deteriorating chimney may be too leaky to work correctly, and it isn't unusual for an animal to build a nest inside a chimney, or to get stuck inside and die. Obviously, regular chimney cleaning and maintenance is always important. But the following discussion is about a problem that's common with clean chimneys that are in good shape.

When air moves down a chimney, instead of up, it is called *backdrafting*. When this occurs, combustion by-products can't rise up the chimney, like they are supposed to, so they enter the living space instead. This can be very serious. Fortunately, total backdrafting isn't extremely common—but it does occur much more often than people realize.

Spillage is a common condition where the combustion by-products don't rise up the chimney fast enough, and some spill into the living space. A small amount of spillage is actually considered normal with many combustion devices. "Normal" spillage occurs when a combustion device (*e.g.* a water heater or furnace) first starts up. Ideally, it only takes a short time after startup for a chimney to warm up and for a draft to form, but during this short time, combustion by-products spill into the living space around the base of the chimney. In theory, these spilled combustion by-products are then sucked into the chimney and expelled. But, some can remain in the living space and be distributed throughout the house.

Chimneys often function or malfunction because of air-pressure differences. When everything is working correctly, hot combustion by-products rise up a chimney because warm air rises. This upward movement of air is associated with an upward pressure, and it is possible to measure a small difference in air pressure between the inside and the outside of a chimney with a sensitive pressure gauge. The negative pressure in a chimney that results from the upward movement of warm air is called the *draft*.

If something causes air to leave the living space (*e.g.* natural, accidental, or controlled ventilation), it will have an effect on the air pressure in the house. If this effect is great enough, it will influence the draft in the chimney. For example, when a clothes dryer is running, it blows about 150 cfm of air outdoors. This depressurizes the house slightly and results in 150 cfm entering somewhere else—perhaps by coming down the chimney. After all, a chimney is simply a hole in the house, and the incoming air will enter wherever it can. When air comes down a chimney, you can have backdrafting or spillage.

Backdrafting and spillage are more of a problem in tight houses, and most houses built in recent years are more tightly constructed than houses used to be. The seriousness actually depends on two factors—house tightness, and how much air is exhausted. A 700-cfm kitchen-range exhaust is almost guaranteed to cause backdrafting or spillage in most of today's houses—unless a deliberate pathway exists for 700 cfm of make-up air to enter. One problem with that much make-up air entering through a single deliberate opening is that it will be very cold in the winter so, in most cases, large deliberate make-up air openings are not being installed.

Anything that causes enough of an air-pressure difference in a house can be responsible for poor chimney function. This includes all forms of natural, accidental, and controlled ventilation. Chimneys can even compete with each other. It isn't unusual for a roaring wood fire to exhaust enough air up its chimney to cause backdrafting or spillage in another chimney in another part of the house—perhaps one serving a natural gas furnace or water heater.

The chimneys that are the most problematic are those that have most of their height outside the insulated part of a house. For example, a masonry chimney that is attached to the outside of a house is more susceptible to backdrafting and spillage than a chimney that rises up through the center part of a house. This is because, to function well, a chimney must be warm, and if a chimney is outside the insulated envelope of the house, it will be quite cold in the winter. Such a chimney can certainly be warmed up by the combustion by-products, but there can be spillage or backdrafting until it is warm enough to function correctly.

The backdrafting and spillage problem is very real—and very common. Experts suggest that a chimney can malfunction at one time or another in as many as 50-80% of North-American homes. If a chimney is malfunctioning, it's important to have the situation evaluated by a professional.

Solutions to Chimney Problems

Some of the newer heating devices that have been developed in recent years eliminate the problems associated with poor chimney function. Usually referred to as *direct-vent* devices, many are very energy-efficient (direct-vent natural-gas furnaces typically have efficiencies over 95%), and they utilize *sealed combustion chambers*. Here's how they work. During operation, air is pulled from the outdoors, through a sealed plastic pipe, into a sealed combustion chamber, where it mixes with the fuel, and is burned. Most of the heat is then extracted from the combustion by-products inside a sealed heat-exchanger. Then the cooled combustion by-products (which are too cool to rise up a chimney naturally) are blown outdoors by a fan through a second sealed plastic pipe. The entire combustion process is totally sealed, and there is no way combustion by-products can enter the living space—unless something is damaged. (In the event of damage, a small pressure-sensitive switch will prevent the unit from operating.) Of course, when something is said to be totally sealed, the key word is "totally," and very few things are "totally" anything. So, while sealed-combustion appliances are *very well* sealed, they may not be 100% sealed. For example, there may be some very tiny leaks—leaks that are almost insignificant—but leaks nevertheless. Or there may be some very minor leakage through a condensate drain. For the vast majority of people, and even for most sensitive people, these types of leaks will not cause any problems. The only way to insure that they do not cause problems for individuals who are extremely hypersensitive to combustion by-products would be to locate the appliances in a sealed mechanical room, or outdoors (see below).

Some higher-efficiency heating devices have a plastic exhaust pipe, but do not use a plastic air-intake pipe (they pull air from the living space, rather than from the outdoors). They are definitely better than devices that rely on conventional chimneys, but they have been found to spill some combustion by-products into the living space—

especially in tight homes.[269] The best units have both an intake pipe and an exhaust pipe. The plastic pipes are cool (there is no hot air blown through them) and are subject to little outgassing.

There are ways to minimize backdrafting and spillage with heating devices that rely on a chimneys to expel the combustion by-products from the house. First of all, a very-well-sealed room can be built around the heating device to isolate it from the rest of the house. The room should have every possible crack and crevice sealed shut, and it should have a tight-fitting, weather-stripped, access door. When the door is closed, there should only be two pathways for air to get into or out of the room—the chimney will be the way out, and there should be a dedicated way for air to get from the outdoors into the room. This is called the combustion-air supply, and it's required by various building codes when a combustion device is located in an enclosed space.[270] If there is any ductwork inside the room, it should be very well sealed so the air inside the ducts isn't contaminated by air in the room. All gaps around places where ducts or pipes pass through the walls (or floor, or ceiling), must be well-sealed. In effect, what is being created is a sealed-combustion system, whereby outdoor is drawn into a sealed room, then into an unsealed combustion chamber, where it mixes with the fuel and is burned. The hot combustion by-products then rise out of the unsealed combustion chamber, into the chimney and leave the house. If there is some spillage on startup, it won't be of concern because it cannot escape the sealed room and get into the living space. And the air pressure in the sealed room is not affected by air pressures in the rest of the house. This is a lot of work, and in new construction it's generally much easier to install a high-efficiency, direct-vent, sealed-combustion device in the first place.

A heating device can also be placed completely outside the house in a small, insulated shed. Well-sealed heating ducts or pipes are run from the shed into the living space. As long as everything is protected from freezing temperatures, and the ducts aren't leaky, this can be a viable way of separating the combustion process from the air in the living space but, again, installing a high-efficiency, direct-vent, sealed-combustion device in the first place is considerably easier. In an existing situation, one solution can be to install a combustion-air fan that supplies a certain amount of outdoor air to the room containing the combustion appliances. One brand, called a "Combustion Air Inforcer," is available from **Tjernlund Products, Inc.** This company also offers power venting systems that are designed to blow combustion by-products outdoors. The *Journal of Light Construction* ran a good article in late 1999 on installing make-up air for combustion appliances.[271]

A heating device in a garage may seem like it's well-separated from the living

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269 Peter Moffatt, Sheltaire Scientific, Ltd. *House Depressurization Tolerance of Draft-Induced Gas-Fired Appliances* (Ottawa, ON, Canada: Canada Mortgage and Housing Corp., 1991).

270 John Siegenthaler, "Mechanical room ventilation," *Journal of Light Construction* (September 1996): 56-58.

271 Carl Saunders, "Makeup air for combustion equipment," *Journal of Light Construction* (December 1999): 33-40.

space—and if precautionary steps are taken during construction, it can be—but most garages have a number of random holes that can allow combustion by-products, resulting from poor chimney function, to be pulled from the garage into the living space. This is especially true if the ductwork in the garage is leaky. For additional information about combustion by-products, see *Chapter 25, An in-depth evaluation of six common pollutants*.

Fried Dust

Hot surfaces are generated inside heating devices, and a few sensitive people report symptoms related to various metals when they are heated.[272] This isn't very common, but for these individuals, even metal cookware can be a problem—especially if made of aluminum. However, there is another heat-related problem—if dust falls on a hot surface in a heating system, and it inevitably will, it will burn. This is popularly called *fried dust*[273] but is also known as *carbonized dust* and it can give off a tiny amount of combustion by-products. When dust containing synthetic particles from carpeting, for example, is burned, tiny amounts of phosgene and hydrogen-cyanide gases are released.[274] Phosgene is a nerve gas and hydrogen cyanide is used in gas chambers. Even if there are no synthetic materials in a house, dust can be composed of a wide variety of compounds, and none of their combustion products are good to have in the indoor air. Even if all of the dust burns, as a heater cycles on an off the first few times in the heating season, additional dust will settle on the hot surfaces, so this can be an ongoing occurrence.[275]

Although fried dust is not a significant pollution source, hypersensitive people are often bothered by it. Higher temperatures are responsible for more toxic compounds being formed than are lower temperatures.[276] Fortunately, the fried-dust problem can be minimized by preventing dust from reaching surfaces over 250°F. There are two ways to do this: filter the air to remove as much dust as possible, or use a heating method that operates at a temperature below 250°F.

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272 Casimir M. Nikel, "Residential Space Heating," *The Human Ecologist* #15/16 (March 1982): 6-8.

273 Guy O. Pfeiffer and Casimir M. Nikel, *The Household Environment and Chronic Illness* (Springfield, IL: Charles C. Thomas, 1980): 69.

274 Sidney J. Heiman, "Petrochemicals and Plastic Synthetic Gases," in *Clinical Ecology*, ed. Lawrence Dickey (Springfield, IL: Charles C. Thomas, 1976): 273-274.

275 Brian Krafthefer and Dave MacPhaul, "Ultrafine particle emission from baseboard and other resistance-type heaters" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 3, Characteristics of Indoor Air*, 1990): 659-664

276 Esko Sammaljarvi and Taisto Raunemaa, "Aerosol and Reactive gas effects by electric heating units" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 3, Characteristics of Indoor Air*, 1990): 653-658.

Electricity

Electricity is generated in several different ways. The burning of coal to run electric generators is a fairly polluting industry. The hydro-electric power generated at dams is considerably cleaner, but thousands of acres of productive or recreational land is sometimes lost in the creation of a reservoir. And, of course, nuclear generating stations are not without their environmental risks. Yet, electricity is responsible for little indoor air pollution when used to heat houses.

The use of electricity does, however, produce invisible electromagnetic fields (EMFs). In houses, EMFs can be strong near electric heating elements, water pumps, and fan motors. Because some negative health effects have been associated with strong fields, the use of electricity to heat houses has come under attack in recent years. Fortunately, electromagnetic fields generally diminish in strength as you move away from the source. So, usually, the EMFs given off by pumps, motors, and heating elements will be reduced to a fairly low level a couple of feet away. Even with electric baseboard heaters that are actually within the living space, the EMFs tend to be restricted to a relatively small area. With careful thought, houses can be designed to minimize occupant exposure to any high-strength fields.

Because electrical devices are a necessary part of most heating/cooling equipment, the primary way of reducing one's risk is to locate heating/cooling equipment in a place where you spend little time. In fact, heating/cooling equipment is often located in a basement or garage. This is generally far enough from the occupied space so that the EMFs are at a low level in places where the occupants spend the most time. However, magnetic fields can travel through walls, so you should consider what is on the opposite side of the wall from the heating/cooling equipment. For example, a furnace against a wall in a garage may be separated from the headboard of a bed by just a few inches of drywall and insulation—and magnetic fields can extend right through the wall. EMFs are discussed in more depth in *Chapter 23, Electrical systems*.

Ductwork

The ducts used in forced-air heating/cooling systems (and with ventilation systems) are themselves a much bigger problem than was believed just a few years ago. This is partially because of the use of new materials, but more significantly because of duct leakage.

Duct Materials

Traditionally, ducts have been made out of galvanized metal, which is relatively inert. Sometimes new galvanized ducts have a residual oil film on them, left over from the manufacturing process, that can bother some sensitive people. The oil is easily washed off with water containing TSP (tri-sodium phosphate, a cleaner often sold in paint and hardware stores) or a tolerated detergent, then rinsed. Because zinc has some anti-fungal qualities, the zinc coating actually deters mold growth.[277]

Some heating/cooling systems utilize ductwork that is cast inside a concrete floor

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[277] Alex Wilson and Nadav Malin, "The IAQ challenge: Protecting the indoor environment," *Environmental Building News* (May/June 1996): 1.

slab. In the past, these ducts were often made of asbestos cement. Although asbestos-cement products don't always release fibers, if the ducts become cracked, broken, or abraded, they can introduce asbestos fibers into the airstream. Sealed, rigid, plastic ducts are a much better solution under a concrete slab, but minor outgassing from the plastic could be a problem, especially for hypersensitive people. **General Plastics** makes such a system called Black Max.

Today, flexible plastic ducts have become quite popular because they are cheaper and easier to install than rigid, metal ducts. They can be subject to a small amount of outgassing, especially when warmed by the heating equipment, but outgassing usually isn't a significant problem. The plastic that is facing the airstream in flexible ducts is usually mylar (a polyester). Foil-lined flexible plastic ducts are also readily available, usually by special order. One manufacturer is **Hart & Cooley**. Unfortunately, foil-lined ducts have a thin mylar coating inside them, so there is no advantage to using them instead of conventional flexible ducts for hypersensitive people who are bothered by mylar.

Another popular material today is called *duct board*. It is a semi-rigid fiberglass product with aluminum foil on one side. The glass fibers are held together with a formaldehyde-based resin. When installed, the foil is on the outside and the fiberglass is on the inside—exposed to the air stream. This is, without a doubt, one of the worst possible uses of fiberglass in the entire construction industry. In this application, glass fibers and formaldehyde—both of which are suspected carcinogens—can be released directly into air the occupants will breathe. Cases have been reported where the glass fibers have eroded, contaminating the airstream, possibly due to air turbulence.[278] A study by **Johns-Manville Corp.** (a manufacturer of duct board) acknowledges that there's some erosion of fibers into the airstream (2-3 times the background level), but the study doesn't consider it a significant amount.[279] Some duct-board manufacturers have recently begun offering products that have a surface coating over the fiberglass. This means considerable less fiberglass is exposed to the airstream, but it doesn't eliminate the problem because there is exposed fiberglass at the interior corners, and wherever the material has been cut.

In one study, new duct board was found to support fungal growth when the air inside it had a high relative humidity, and when the material was wet or dirty even more fungal growth was detected.[280] If duct board becomes contaminated with microbial

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[278] Karl Raab, *Updating Health Standards for Residential Construction* (Ottawa, ON, Canada: Canada Mortgage and Housing Corp., December 1982).

[279] R.R. Gamboa, B.P. Gallagher, and K.R. Matthews, "Data on glass fiber contribution to the supply airstream from fiberglass duct liner and fiberglass duct board" *Paper presented to ASHRAE's Engineering Solutions to Indoor Air Problems Conference,* 1988.

[280] K.K. Foarde, "Susceptibility of fiberglass duct lining to fungal (penicillium chrysogenum) growth," *Inside EPA* (Fall/Winter 1995): 15.

growth, the **EPA** recommends that it be removed and replaced.[281] This is because cleaning is impossible, and it certainly negates any cost savings from installing the material in the first place. One household was exposed to so many glass fibers emitted from an air conditioning system they were forced to abandon their home. A family member and the dog developed cancer, possibly as a result of this exposure.[282]

Another problem with duct board has to do with relative humidity, and the fact that ducts are often run through unconditioned spaces, like attics or crawl spaces. This means that, in cold climates in the winter, the exterior of the duct board will be cold. The house air (which is circulating through the ducts) will have a certain relative humidity. This air will penetrate the insulation on the interior of the duct board, where it will come in contact with the cold foil on the exterior. The result can be condensation, and an ideal environment for microbial growth.

In order to save money, it's very common in houses to move heating/cooling air through building cavities. Stud spaces, and the spaces between floor joists, are often used to convey air from the living space to a forced-air furnace or air conditioner. This is not recommended because of the possibility of contaminating the airstream with contaminants outgassed or released from the various building materials. The air you breathe passes through the ducts, so they should be as uncontaminated as possible.

Leakage

The ducts in most houses are incredibly leaky. It isn't unusual to find that 25-40% of the system's capacity is leaking into or out of various gaps and cracks between the different components of a duct system.[283] In one house, 50% of the return air was being pulled from the attic through duct leaks. The owner found that he couldn't run the air conditioner during the day because it didn't have enough capacity to cool all the hot attic air passing through the system.[284]

An average duct-leakage rate is probably between 10% and 15% but, because duct leaks are under pressures 10-20 times higher than the rest of the building, they can be responsible for doubling or tripling the infiltration rate of the entire house.[285] This typically happens when you want it the least—during the hottest and coldest times of the year. The house pressures generated because of duct leakage can also cause radon and

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281 "The effectiveness of antimicrobial surface treatments," *Inside IAQ* (Spring/Summer 1997): 5.

282 Harold W. Newball and Sami A. Brahim, "Respiratory Response to Domestic Fibrous Glass Exposure," *Environmental Research* 12 (1976): 201-207.

283 "About the importance of duct cleaning," *Solplan Review* (March 1998): 15.

284 Brian Coyne, "A million miles of ducts: Duct sealing update," *Home Energy* (March/April 1992): 14-20.

285 Michael Uniacke and John Proctor, "Getting the most from mechanical cooling," *Journal of Light Construction* (August 1993): 18-22.

other soil gases to be pulled indoors, or backdrafting of chimneys.[286]

Duct leakage is one of the most significant causes of the pressure imbalances that lead to accidental ventilation in houses (see *Chapter 6, Ventilation*). Sometimes, the affect of duct leakage on indoor air quality is easy to analyze, but most of the time it's complex and takes specific diagnostic equipment—and someone specially trained to analyze pressure changes in houses—to fully comprehend the implications. Here are three easy-to-understand scenarios.

In one particular house, a significant amount of air leaks *out of* supply ducts located in a crawl space. Because a crawl space is outside the living space, this has the same effect as blowing air directly outdoors. As a result, the living space becomes depressurized. This depressurization can lead to backdrafting or spillage in a susceptible chimney.

In another house, a significant amount of air leaks *into* return ducts located in an attic. Over time, loose-fill insulation is pulled into the leaks and blown throughout the living space. The homeowners periodically clean up the dust without realizing that they have been exposed to a great deal of particulate air pollution.

In a third house, air leaking *out of* supply ducts in an attic leads to depressurization of the living space. The depressurization is worse in the basement because of air leaking *into* return ducts located there. The basement depressurization leads to radon and residues of termite chemicals being sucked indoors.

In a survey of houses where the termiticide chlordane was used in the soil, 95% of the houses with ducts in the crawl space had chlordane in the living space, while 83% of the houses with ducts in the attic had no detectable level of chlordane in the living space.[287] Sealing the ducts significantly reduced the occupants exposure to pesticides.

In another survey, 80% of the houses tested had serious duct leakage, yet most of the problems could be fixed for less than $200.[288] The biggest duct leaks tend to occur where building cavities are used to convey air. But there can also be significant leaks between each and every elbow, fitting, and straight or flexible component of a duct system. If plumbing systems were this leaky, houses would have water squirting out everywhere.

There are ways to analyze duct systems under pressure to determine how leaky they are. It's beyond the scope of this book to explain the procedures involved, but there was a very good series of articles on the subject in the September/October 1993 issue of *Home Energy* magazine.[289] **The Energy Conservatory** has a Duct Blaster that can be

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[286] "Surprising field observations on forced air distribution systems," *Energy Design Update* (January 1990): 5-9.

[287] Thomas Lillie and Edward Barnes, "Airborne termiticide levels in houses on United States Air Force installations (Berlin: *Proceedings of the 4th International Conference on Indoor Air Quality & Climate, Vol. 1, Volatile Organic Compounds, Combustion Gases, Particles and Fibers, Microbiological Agents*, 1987): 200-205.

[288] Jeff Tiller, "Put a stop to MAD-Air and leaky ducts," *Southface Journal of Energy and Building Technology* (Winter 1990): 12-13.

[289] "Diagnosing Ducts," *Home Energy* (September/October 1993): 26-65.

used to pressurize a duct system in order to analyze its tightness and determine where the leaks are. For contractors, there is an excellent course being taught by **Advanced Energy** that details both theory and repair procedures. The course also covers related issues like chimney function and backdrafting. Other organizations around the country are beginning to offer similar courses. The U.S. Department of Energy has published *Improving the Efficiency of your duct system* —a very good booklet for consumers dealing with issues related to duct leakage.[290]

In the past, if duct-sealing was done at all, a fabric-backed duct tape was wrapped around some of the joints. More recently, aluminum-foil duct tape has been used. Neither type of tape is recommended any longer because, in many instances, tapes just don't adhere for very long. In many cases, duct tape begins to fall off after only a few months. While it's possible to replace the tape periodically, in most installations many of the ducts are inaccessible once a house is finished. Duct tape works best with brand new, perfectly clean metal ducts.

Today, people who have studied the many problems caused by duct leakage recommend *duct-sealing mastics*.[291] These products are about the consistency of mashed potatoes and, if applied carefully to all the seams and joints in a duct system, they result in long-term sealing. Duct-sealing mastics can be applied with a putty knife, stiff brush, or your hand. Water-based versions are recommended to minimize indoor air pollution. RCD #6 (**RCD Corp.**) and Kingco 11-600 (**Kingco Adhesives**) have been recommended for chemically sensitive people but, as with all of these products, they require a certain period of time to outgas and become odor free. Other water-based duct-sealing-mastic manufacturers include **Foster Products Corp.** (Safetee, Duct-Fas), **Hardcast, Inc.** (several products), **Mon-Eco Industries, Inc.** (Eco-EZ), **RectorSeal Corp.** (Air-Lock), and **McGill AirSeal Corp.** (Unimastic).

Besides ducts, the air handler of a forced-air heating/cooling system can also be leaky. Some of the larger leaks—particularly those where the air handler connects to the ducts—can be sealed with mastic. However, there are usually some small leaks around access covers, particularly if they aren't gasketed. For this reason, it is not a good idea to locate forced-air heating/cooling system air handlers in spaces where the air quality is compromised. For example, don't locate the air handler in a garage, attic, crawl space or damp basement. The best location is within the living space. To minimize noise complaints, the air handler can be located in a small insulated mechanical room. If an air handler must be located in a garage, for example, the access cover can be sealed with duct tape. However, the tape will need to be removed and replaced every time the cover needs to be opened.

Duct Insulation

It's necessary to insulate ducts for two reasons: energy efficiency, and to prevent condensation (sweating) which could lead to mold growth. Ducts run through crawl

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[290] U.S. Department of Energy (DOE), *Improving the Efficiency of your duct system* (Washington, DC: DOE, April 1994). #DOE/EE-0015.

[291] Bruce Sullivan, "Making Mastic Stick," *Journal of Light Construction* (December 1992): 38.

spaces or attics are outside the living space, so they are insulated for energy efficiency—especially in harsh climates. Condensation occurs when warm humid air comes in contact with a cold surface. In the winter, the air inside ducts is often warm and humid, but in an air-conditioned house in the summer, the air outside the ducts (if they are in an attic, for example) is warm and humid. So, condensation sometimes occurs on the inside, sometimes on the outside. Both scenarios can be minimized with properly installed insulation, but the possibility can't be eliminated completely. For example, if ducts are run in unheated spaces, and the system is run intermittently, there is the possibility of condensation (and fungal growth) inside the ducts when the system is off.[292] So, it's best to run ducts within conditioned spaces.

Fiberglass-batt insulation is often applied to the outside of metal ducts. In some cases a semi-rigid fiberglass is glued to the *inside*, but this is not recommended because of the possibility of the fiberglass contaminating the airstream. If metal ducts are well-sealed (preferably with a duct-sealing mastic) before the insulation is wrapped around them, then the fiberglass cannot contaminate the airstream. In most cases, a plastic or aluminum foil is wrapped around the outside of the fiberglass to protect it. The plastic or foil should be well sealed to minimize any condensation problems, or the release of fibers.

With the duct board mentioned above, the insulation is an integral part of the product. When warm, humid air moves inside duct board that is located in a cold attic or crawl space, the moisture can travel easily through the fiberglass, and condense on the inside of the foil facing, which is cold—leading to contamination by a variety of microorganisms.

Flexible plastic ducting is widely available with an integral layer of fiberglass wrapped around it, and an integral plastic sleeve around the fiberglass. This product does not result in insulation contaminating the airstream—as long as all end connections and fittings are properly sealed.

It isn't unusual to find older ductwork (or water piping) insulated with asbestos. If the asbestos is deteriorating, the easiest solution may be to seal it with a product specifically designed for the purpose. Sometimes, very careful removal is necessary. See *Chapter 25, An in-depth evaluation of six common pollutants* for more information about asbestos.

Cleaning

Ducts can get extremely dirty. This generally happens because of two reasons: 1) the ducts are leaky, and pollutants get sucked into them from dusty, contaminated attics, crawl spaces, and building cavities, and 2) pollutants from the living space are pulled through the entire duct system because of inefficient filtration. Well-sealed ducts in a forced-air heating/cooling system fitted with a high-efficiency filter can often pass a white glove test as long as two years after installation.[293]

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292 M.J. Jantunen and others, "Does moisture condensation in air ducts promote fungal growth?" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 2, Characteristics of Indoor Air*, 1990): 73-78.

293 Roger Thurmond, Personal communication.

A Canadian study recommended that if supply ducts are dirty, they could be contaminating the indoor air, so duct cleaning is probably a good idea, and if return ducts, the air-handler fan, and the coil are dirty, the dust could be affecting performance and should be cleaned.[294]

In a typical forced-air system with leaky ducts and an inefficient filter, the ducts are usually contaminated with a wide variety of particulates and microorganisms—all directly exposed to the air being breathed by the occupants.

Whether the cleaning of ducts actually results in improved indoor air quality is still being debated. While the heating/cooling system's performance is often better after cleaning, it is more difficult to say if the indoor air is cleaner.[295] [296] This is because there are often other factors that contribute to indoor air quality, such as indoor pollutant sources, occupant activities, and outdoor air quality. Metal ducts can generally be cleaned fairly well, but with duct board, which is lined with porous fiberglass, thorough cleaning is impossible. One study found that microbial contamination of duct board returned to precleaning levels within 6 weeks.[297]

The **EPA** suggests that you should consider having your ducts cleaned if there is substantial visible mold growth inside the ducts or other components of the heating/cooling system, if the ducts are infested with vermin, insects, or rodents, or if the ducts are clogged with excessive amounts of dust or debris, or if there are actually particles being released into the air.[298] They also point out that there is no evidence that cleaning ducts will result in improved health for the occupants. Still, it makes sense that you would want the air you are going to breathe to be passing through clean ducts.

Many cities now have businesses that specialize in duct-cleaning. They typically have large truck-mounted vacuums connected to long hoses that are run indoors. Sometimes they agitate the ducts, or use rotating brushes or air hoses, to loosen the accumulated debris, then the powerful vacuum draws the pollutants out into the truck.[299] Vacuuming alone isn't nearly as effective as mechanically agitating the ducts with a

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[294] "Need and Effectiveness of Duct Cleaning in Houses," *Energy Design Update* (December 1994): 7-8.

[295] "Field study on residential air duct cleaning," *Inside IAQ* (Spring/Summer 1997): 6-7.

[296] "Results of a pilot study to evaluate the effectiveness of cleaning residential heating and air conditioning systems and the impact on IAQ and system performance," *Inside IAQ* (Spring/Summer 1998): 18.

[297] "Investigation of contact vacuuming for remediation of fungally contaminated duct materials," *Inside IAQ* (Spring/Summer 1998): 17.

[298] "Should you have the air ducts in your home cleaned?," (Washington, DC: EPA, October 1997). #EPA-402-K-97-002.

[299] Laurie Benda, "Duct Cleaning: Air Quality and Economic Returns," *INvironment* (August 1992): 2-7.

brush, but brush/vacuuming can cost up to 4 times as much money.[300] Be sure no small pets are loose during this process because the vacuum can be powerful enough to pull them into it. This type of cleaning is usually sufficient to remove the majority of contaminants, but a few hypersensitive people have found it necessary to dismantle their duct system and thoroughly clean the residual pollutants wedged in small cracks and crevices.

Some duct cleaners like to spray a cleaning chemical, sealer, encapsulant, or disinfectant inside the ducts. These are *not* recommended, because they can be pollutant sources themselves.[301] At a meeting of the Office of Management and Budget where anti-microbial duct compounds were discussed, one government source said "There's a lot of skepticism about whether or not air ducts and systems can be disinfected at all, and whether the chemicals used have side effects greater than the original problem."[302] Some sensitive people have had success in dealing with mold in ductwork by having it cleaned with Zephiran (available through local pharmacies, or by mail from **N.E.E.D.S.**) diluted 1 oz. to a gallon of water.[303]

Humidity Control

People feel comfortable when the relative humidity is within a certain range. If the humidity is too low, your sinuses and throat can dry out. If the humidity is too high, a room can feel stuffy, and biological contaminants can thrive. So we often add, or remove, humidity to make our living spaces more comfortable—and healthy.

In general, as far as health is concerned, too dry is better than too humid. People don't usually complain of dryness until the relative humidity indoors is less than 30%. In one study, test subjects didn't describe discomfort after exposed to 9% relative humidity for 72 hours.[304] In another study, at 10% relative humidity, most subjects responded that it was either "dry" or "comfortably dry."[305] If the air is relatively clean, there can be less eye irritation and the sensation of dryness, so a lower relative humidity can be more tolerable in a less polluted house.

Humidification

Many houses are dry indoors during the winter. This is generally due to

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300 Iain S. Walker, "What does duct cleaning do?," *Home Energy* (March/April 2000): 13-14.

301 "Cleaning ducts the safe way," *Journal of Light Construction* (October 1989): 25.

302 "Antimicrobial Debate Falls into Black Hole," *Indoor Air Review* (June 1992): 1.

303 Mary Oetzel, "Selecting and installing a heating system," *The Human Ecologist* (Summer 1990): 1.

304 Ib Anderson and others, "Human response to 72-hour exposure to dry air," *Environmental Health* 29 (1974): 319-324.

305 Ib Anderson and others, "Human perception of humidity under four controlled conditions," *Archives of Environmental Health* 26 (1973): 22-27.

overventilation. In other words, an excessive amount of dry outdoor air is being exchanged for the more humid indoor air. This is often a problem in the coldest part of the winter because the house is being overventilated continually by stack effect, and occasionally by wind. Houses with combustion-fired forced-air heating are more susceptible to overventilation because leaky ducts and chimneys contribute to accidental ventilation whenever the furnace is running. Leaky, poorly insulated houses have more of this natural and accidental ventilation than tight energy-efficient houses—especially when the outdoor temperature is at its lowest.

Tight houses, built (incorrectly) without mechanical ventilation, can have excessively high humidities indoors during the winter due to *insufficient* ventilation. In a new house, when tight construction is combined with a correctly sized mechanical ventilator, indoor humidity levels tend to be comfortable—yet not high enough to encourage biological growth—without requiring humidification.

In existing overventilated houses that need additional humidity, the use of a humidifier often causes more problems than it solves. This is because many humidifiers (both portable models, and central units) have a reservoir of standing water that can easily harbor a great deal of biological growth.[306] A film or scum present on any part of a humidifier can indicate bacteria or fungi.[307] Periodic cleaning is always recommended, but it is often ineffective, or only marginally so. In one study, cleaning with a disinfectant was not enough—sterilization in an autoclave was required to completely disinfect a humidifier.[308] After unsuccessful weekly cleanings, building inspector Jeff May disconnected his own humidifier because the water was "virtually indistinguishable from pond scum."[309]

If the water used in a humidifier contains minerals, some humidifiers can spew those minerals into the air. In fact, 90% of the dissolved minerals can be dispersed into the indoor environment where they can settle on furnishings as a white dust, or they can be inhaled into the lungs. The mist can include impurities such as lead, aluminum, asbestos, and dissolved gases.[310] Occasionally, water from a boiler is run into a central humidifier. This should never be done because boiler water can contain corrosion-

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306 "Humidifiers cause microbial contamination in office building," *Indoor Air Quality Update* (February 1993): 11-13.

307 Consumer Product Safety Commission (CPSC), *Safety alert: Dirty humidifiers may cause health problems* (Washington, DC: CPSC, December 1988).

308 A. Van Assendelft and others, "Humidifier-associated extrinsic allergic alveolitis," *Scandinavian Journal of Work Environments and Health* 5 (1979): 35-41.

309 Jeffry May, "Moisture problems: From case studies and home inspections" (Washington, DC: *Proceedings of the Bugs, Mold, and Rot Workshop Sponsored by the Building Thermal Envelope Coordinating Council of the National Institute of Building Sciences*, May 20-21, 1991): 49-55.

310 "Humidifiers increase indoor pollutants," *The Human Ecologist* #40 (Winter 1988): 26.

preventing chemicals, which can be spewed into the air.[311]

Even if no water reservoir is present, central humidifiers attached to forced-air heating systems can be problematic. During operation, they blow very humid air into the duct system. This moisture-laden air eventually enters the living space where it is quickly diluted by the dry room air. But problems occur inside the duct system when the moisture condenses on cool surfaces (uninsulated ducts) or finds its way into seams and gaps between sections of old leaky ducts and moistens the dust that has settled there. The result is mold, or other biological growth, inside the duct system.

Most portable humidifiers contain various plastic and rubber parts or motors that can outgas enough to bother some sensitive people. Portable ultrasonic humidifiers have a reservoir, so they can harbor microbial growth. While the ultrasonic vibrations tend to kill the microorganisms, they can still spew bits and pieces of dead mold and bacteria into the air,[312] and allergic people are bothered by allergens even when they are dead. Ultrasonic humidifiers also spew minerals into the air, but this can be minimized by using distilled water in them. Some manufacturers use a demineralization cartridge to remove any minerals from the water before it is dispersed, or an air filter to remove the minerals before they are blown into the room.[313]

Portable warm-mist humidifiers and steam humidifiers can heat the water enough to kill any microorganisms but, again, because allergic people react to particular proteins, they can be bothered by the dead microbes. These humidifiers generally don't spew minerals into the air.

Cool-mist humidifiers are the worst of both worlds. They have reservoirs that can harbor living microorganisms, and they spew minerals into the air. Many of these units have a rotating wheel or drum that moves through the water reservoir, then the wheel passes by a fan that blows mist into the air. You can at least avoid the minerals by using distilled water in them.

It is generally better to address the problem of overventilation by tightening the house, than to use a humidifier and risk polluting the dry air. But if you must humidify, the **EPA** has the following recommendations for minimizing health problems with humidifiers.[314] Empty the tank and refill the water in portable humidifiers daily, use water with low mineral content, clean portable humidifiers every third day, follow the manufacturer's directions for cleaning whole-house humidifiers, keep steam humidifiers out of the reach of children, do not allow the relative humidity to rise over 50%, do not allow absorbent materials around the humidifier (carpet, drapes, *etc.*) to become wet, follow the manufacturer's directions for maintaining or replacing humidifier parts, and clean the humidifier at the end of the season.

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311 John Andrews, "Clearing the air about humidifiers," *Custom Builder* (September/October 1992): 104-107.

312 "Ultrasonic humidifiers," *Consumer Reports* (November 1985): 679-683.

313 George Brandsberg, "Breathing Easy," *Practical Homeowner* (November 1989): 76.

314 Environmental Protection Agency (EPA), *Indoor Air Facts No. 8: Use and Care of Home Humidifiers* (Washington, DC: EPA, February 1991).

There is one particular type of humidifier used in forced-air heating/cooling systems that has no reservoir—the flow-through evaporative humidifier. They have plates (usually expanded metal or fiberglass) that water runs through, then the excess water runs down the drain. Air is blown past the plates, where it picks up moisture, transfers the moisture into the duct system, then into the living space. These humidifiers don't spew out minerals and, because there is no reservoir, there is no microbial growth, so they tend to be the healthiest types.[315] Of course, using any humidifier can result in excessive moisture and mold growth somewhere inside the duct system. A disadvantage to flow-through types is the fact that a certain amount of water runs down the drain and is simply wasted. Manufacturers of flow-through evaporative humidifiers include **Carrier Corp.**, **General Filters, Inc.**, **Research Products Corp.** (Aprilaire), and **Skuttle Mfg. Co.**

Dehumidification

In hot, humid climates *too much* indoor moisture can be a problem in the summer. And high indoor humidities can be pushed even higher by too much ventilation. Consider the case where the temperature inside a house actually went up whenever the central-air-conditioning system was running. This was caused because massive amounts of hot attic air were being sucked into leaky ducts—resulting in far more heat and humidity entering the living space than the air conditioner was designed to handle.

In most cases, the indoor relative humidity is held in check in the summer by a well-designed air-conditioning system. But in some cases an air conditioner isn't enough, and dehumidifiers are necessary. Portable dehumidifiers are readily available at department and appliance stores. They should be emptied regularly when water fills their reservoir because it could lead to biological growth. Better yet, they should be connected to a floor drain, so there is no reservoir of water. **Therma-Stor Products** manufacturers a high-capacity central dehumidifier (Sierra) that is very energy-efficient.

A central dehumidifier can be used as a large stand-alone unit, or it can be installed as a part of a forced-air heating/cooling system to dehumidify all the air in the house, or it can be used in conjunction with a mechanical ventilation system to dehumidify the incoming air before it's distributed throughout the living space. The "Ultra-Aire Air Purifying Dehumidifier" from **Therma-Stor Products** is a whole-house unit that combines several functions—fresh air, filtration, and dehumidification). They also have a Sierra free-standing portable dehumidifier.

Cooling Methods

There are a variety of ways to cool a house. In the past, fans were commonly used to create a cooling breeze. Air conditioners have the ability to both lower the air temperature and reduce indoor humidity levels. In some parts of the country, swamp coolers are used to cool the living space.

Air conditioners are often recommended for allergy patients. The primary reason

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[315] John Spengler, Harriet Burge, and H. Jenny Su, "Biological agents and the home environment," (Washington, DC: *Proceedings of the Bugs, Mold, and Rot Workshop Sponsored by the Building Thermal Envelope Coordinating Council of the National Institute of Building Sciences*, May 20-21, 1991): 11-18.

has to do with the fact that windows are usually closed when an air conditioner is running, thus outdoor allergens, such as mold spores and pollen, tend to remain outdoors. Of course, there could still be some outdoor air entering the house because of natural, accidental, or controlled ventilation—but not as much as when windows are wide open. Air conditioning also helps allergy sufferers by reducing the indoor relative humidity needed by biological contaminates such as mold and dust mites. Lowered humidity also makes it physically easier to breathe for those with heart or chronic respiratory problems.

Fans

A variety of different kinds of fans can be used to cool people during warm weather. This works because the movement of air across bare skin evaporates perspiration. The act of evaporation requires heat, which is pulled from the body, thus lowering skin temperature.

Fans can be economical to purchase and operate, but they have a few drawbacks as far as health is concerned. Allergic individuals should be aware that a fan can stir up particulate pollutants that may not normally be airborne. For example, if house dust (which typically contains a wide variety of allergens) is sitting on a window sill or table top, it isn't airborne, so you won't be able to inhale it, but if a fan blows it into the air, you can inhale it quickly. Secondly, if a fan pulls outdoor air into a house—as with a window fan—the incoming air will be unfiltered and could contain a variety of outdoor allergens that you might not otherwise have been exposed to. Thirdly, some hypersensitive people are bothered by the minor odors given off by a warm fan motor.

Whole-house cooling fans are often permanently mounted in the ceiling of the uppermost floor in a house where they blow the rising warm air outdoors. These often work quite well to cool a house, but they have lost favor as air conditioning has become popular. Manufacturers include **Nutone** and **Tamarack Technologies, Inc.** One of the models from **Tamarack Technologies, Inc.** (HV1000 Whole House Cooler) has a motorized and gasketed cover that can be closed for energy efficiency during the winter when the fan is not being used. This is one of the quietest and most energy efficient whole-house fans available.

Central Air Conditioners

Central air conditioners consist of a metal cabinet and a fan, which are together called an *air handler*. The cabinet also contains a radiator-like *coil* that is connected by two insulated copper lines to an outdoor unit which contains a *compressor*. The air handler is connected to the living space by two sets of ductwork: *supply ducts*, which blow air into the living space, and *return ducts* that pull air from the living space.

During operation, the compressor cools a refrigerant, such as Freon, and pumps it through the insulated copper lines into the coil. At the same time air is pulled from the living space by the fan, the air moves past the coil and is cooled, then the cooled air is blown back into the living space. In the process of cooling the house air, the refrigerant gets warm and is continually circulated back to the compressor to be recooled.

Central air conditioners also contain a fairly inefficient filter. Its purpose is to remove large particles of dust that could otherwise build up on the coil and block the airflow through it, and also to protect the bearings in the fan motor.

There are a variety of components in all central air conditioners that can be problematic for some hypersensitive people: plastic parts, plastic-jacketed wiring, and air filters all outgas a tiny amount. Electric motors can also outgas as they get warm, and they can give off a small amount of ozone. (Some resourceful contractors have remounted the fan motor outside the air-handler cabinet, so it is outside the airstream, but this is generally difficult to do.) These are usually insignificant sources of pollution and should not pose a problem for most people who are in good health. However, there are some areas of concern that are potentially more serious.

Cabinet Insulation

All air-handler cabinets are insulated. This is done for energy efficiency, to prevent condensation, and to minimize noise. At one time, all manufacturers used exposed fiberglass insulation that had several drawbacks: it shed tiny fiberglass fibers into the airstream as it aged, it was held together with a formaldehyde-based resin that outgassed a small amount of formaldehyde into the airstream, and its porous surface could become contaminated with mold which would release spores into the airstream.

Some sensitive people have removed the insulation from their air handlers, but this should not be done unless you first speak to a manufacturer's technical representative because it could void the warranty. Removing the insulation is not a simple process. It typically involves dismantling the air handler and scraping the insulation from the walls. The insulation is usually glued in place, and a noxious solvent is often required to get rid of all the fibers and glue that remain after scraping. If removal isn't feasible, the duct-sealing mastics discussed earlier can be used to seal any exposed fiberglass insulation. Fortunately, many manufacturers are now using a foil-faced insulation which minimizes airstream contamination. Still, the foil-faced insulation is not always sealed very well at the edges.

Mold Growth

Wherever there is water, there can be mold growth. When humid air passes through the cooling coil, moisture from the air condenses on the coil and falls down into a drip pan, then it runs down into a plumbing or floor drain. This is how air conditioners lower the humidity in the air. Drip pans are often installed improperly so they don't drain well. If they are tilted in such a way that water remains standing, it can be a good place for mold to grow. In such a situation, the drip pan should be repaired or adjusted to drain quickly. If mold is growing in an air conditioner, there can be a burst of mold spores blown into the living space when the fan is first turned on, then fewer spores will be released after the unit has been running for a while.[316]

In one Canadian office building where workers complained of eye irritation, lethargy, headaches, and nausea, the problem was traced to the drip pan under the cooling coil. The pan had a liner of porous insulation, and the drain itself was above the bottom of the pan, so it held water for extended periods of time. A lab analysis found many types of fungi, including some toxigenic species. When the pan was reworked, the health

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316 Diane Gilroy, *Allergy Action Guide: How to Fight Allergies and Win* (Emmaus, PA: Rodale Press, 1986): 21.

complaints ceased.[317]

If mold growth is a continual problem in a drip pan, sprinkling a layer or borax in the pan might help. Another possible solution would be to line the pan with copper, because it is toxic to many microorganisms. Copper foil can be obtained through some craft and hobby stores. Some roofing suppliers have copper flashing that can be used. But the best solution is to design the drip pan so it drains freely and quickly.

When an air-conditioner fan shuts off, a small amount of water can remain clinging to the coil itself. If temperature and humidity conditions are just right, this can become a home to mold. But there is a solution. Many air-conditioners have a switch that allows the fan to run continuously—even when cooling isn't needed, and the compressor is off. It's often called a recirculate switch, and if it's left on, when the cooling cycle shuts off, the fan will continue running and dry out the coil. This can also help to dry out a problematic drip pan.

When service technicians clean air-conditioning coils they usually use a very acidic or a very caustic cleaning solution. **BBJ Environmental Solutions, Inc.** has a BBJ Micro Coil Clean cleaner with specialized surfactants that is pH balanced, so it won't damage the coil. It contains no solvents, has a mild odor, and rinses off well. However, very sensitive people should test it for tolerability prior to use. This can be done by spraying it on something and rinsing it off, to see if they can detect any residual odor.

Clammy Feeling

As homeowners have become more and more concerned about saving energy, air-conditioner manufacturers have increased the efficiency of their products. A high-SEER (**S**easonal **E**nergy **E**fficiency **R**ating) air conditioner is more energy efficient than a low-SEER model. However, high SEER models often have more cooling ability than dehumidifying capability.[318] They can work very well at lowering the air temperature, but less condensation takes place in the coil, so the indoor relative humidity can remain high. This can result in a house that feels clammy. The high humidity in the living space can also lead to mold growth.

In engineering terminology, the lowering of air temperature is called the *sensible load*, and the lowering of humidity is called the *latent load*. To minimize under-dehumidification, air conditioning equipment should be sized and selected carefully with the proper balance between sensible capacity and latent capacity for a particular application.

Refrigerant Leaks

Sensitive people often become concerned about refrigerant leaks contaminating the air passing through a central air conditioner. While this is a closed system, there is still the remote possibility of a leak developing and the house being contaminated with refrigerant. Refrigerants have been implicated in health problems in sensitive people, and

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[317] Gail Melson, "When Drain Pans Don't Drain," *INvironment* 2 (Winter 1994): 2-6.

[318] Jeffery Tiller, "Humidity and high SEER—A conflict?," *Southface Journal of Energy and Building Technology* (Spring 1989): 8-10.

on a larger scale, they have been responsible for damaging the ozone layer in the upper atmosphere. One function of the ozone layer is to protect us from harmful radiation from the sun. Without it, skin cancer rates will increase.

Refrigerant leaks are certainly possible, but they are not common. If such a leak does occur, it will be noticed fairly quickly because the air conditioner will begin to lose its cooling capacity.

Advantages

Besides the advantages listed above for allergic individuals, and their ability to make a house cooler and more comfortable, one of the most significant advantages to a central forced-air air-conditioning system is that it can be fitted with a better-than-average air filter to remove pollutants from the indoor air. To get the most advantage from such a filter, the air-handler fan should run continuously.

It's also possible to combine a cooling system and a ventilation system so they function together. This has both advantages and disadvantages, as discussed in *Chapter 6, Ventilation*. As a rule, there are no significant health-related differences between central air conditioners produced by different manufacturers.

Hydronic Cooling

Although they are not common, there are central cooling systems that do not use fans to blow cool air around the house. These *hydronic cooling systems* use a *chiller* to lower the temperature of water, then they pump the cooled water from the chiller to radiators located in various rooms of a house. The radiators function like the coil in a central air conditioner—as warm room air passes near and through the radiators, it becomes cooler. Having absorbed some of the room's heat, the water in the radiator warms up and is circulated back to the chiller to be recooled. Moisture will condense on the cool radiators, so they are manufactured with a drip pan under them which must be connected to a drain.

This approach to cooling differs from central air conditioning in several respects. It does not use a fan (it relies on natural air currents in the room to circulate air through the radiators) so it is quiet. While there is no fan, there is a pump located near the chiller that must be maintained. Because there is no ductwork, there is no filter, so dust can settle on the coils which require periodic cleaning.

Hydronic cooling systems can usually be used for heating as well as cooling, simply by running hot water from a boiler through them in the winter, but the converse is not true—not all hot-water systems can be used for hydronic cooling. **Edwards Engineering Corp.** has a hydronic cooling/heating system that is designed to be mounted out of the way, up near the ceiling, as a valance.

Individual Room Air Conditioners

For cooling a single room, or a very well insulated house, a small-capacity air conditioner is all that is necessary. These all typically contain plastic parts and insulation that can outgas slightly, as can some of the electrical or mechanical components.

In general, the health advantages and disadvantages of individual room air conditioners are similar to central units. For example, they have water condensing in them which can lead to mold growth if the unit doesn't drain properly and dry out completely. (They can often be dried out by running the fan continuously—just like a central unit.) But they don't have the advantage of being able to be fitted with a better-than-average filter.

Window Air Conditioners

The most common individual room air conditioners are window units. These usually have a drain in the back for automatic water removal. Some are designed to bring in a certain amount of outdoor air, so they can provide some degree of ventilation. But they often have exposed fiberglass insulation in them which can be a good medium for growing mold. As far as health is concerned, most manufacturers produce similar products.

Mini-Split Air Conditioners

Mini-split air conditioners are a cross between a window unit and a central unit. They have an outdoor compressor (like a central air conditioner) and a separate indoor unit, that are connected together by an electrical wire and two refrigerant lines.[319] [320] [321] The indoor unit, which is usually mounted high up on a wall indoors, can be located virtually anywhere in a house—it doesn't need to be located on an exterior wall. The only requirement is that it be within 30'-50' (depending on the model) of the outdoor unit.

Mini-split air conditioners have a drip pan which can either be drained outdoors or to a plumbing drain. They cannot bring in outdoor air, and they have very inefficient filters. They have plastic cases, and are insulated with a fairly inert foam insulation, but outgassing is generally minimal because chemically sensitive people often tolerate them. These units tend to be quieter, more compact, and less offensive than window air conditioners—but more expensive.

Manufacturers include **EMI Corp.**, **Friedrich Air Conditioning Co.**, **Mitsubishi Electric** (Mr. Slim), and **Sanyo Air Conditioning Products.** Some companies make both wall units and ceiling units as well as models that will fit into a dropped ceiling grid. Some models have a single outdoor unit and a single indoor unit, while others have up to four indoor units which can be located in different rooms. The individual units range in capacity from 9,000 BTU/hour up to 48,000 BTU/hour.

Swamp Coolers

In some parts of the country, evaporative coolers, also known as "swamp coolers," are used to supply cool air to a house.[322] They operate by pulling hot outdoor air through a water-soaked filter. As the water evaporates, heat is released, and the air is cooled. The cool air is then blown into the living space. This can be an economical

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[319] V. Elaine Gilmore, "Split Coolers," *Popular Science* (July 1988): 76-77.

[320] J.D. Ned Nisson, "Ductless HVAC Simplifies Installation," *Journal of Light Construction* (February 1992): 40-41.

[321] "Ductless Heating and Cooling—Zoning with the Mini-Splits," *Energy Design Update* (September 1991): 6-14.

[322] "Keeping Cool Without Air Conditioning," *Home* (July 1982): 62-67.

method of providing cool air, but it's not necessarily a healthful solution—the water can become a breeding ground for microorganisms such as *Legionella* bacteria and mold.

Heating Methods

There are several different strategies available for heating a house, and several fuel choices. Each strategy, and fuel, has advantages and disadvantages from both a technical standpoint and from a health perspective. Very sensitive people should select a system with care because according to one authority, "Cumulative experience has indicated that none of the systems…is tolerable to every chemically susceptible person."[323]

Heat is transferred by three different methods: conduction, convection, and radiation. Conduction involves the transfer of heat through solid objects. When you actually touch a heater, you will feel its warmth by conduction. This method of heat transfer is important in insulated walls where heat flow is not desired. Convection involves heat transfer by fluids. Air and water are both fluids, so this is the way heat is transferred in forced-air and forced-hot-water heating systems. Radiation involves the transfer of energy from a heater directly to an object. This energy is in the form of infrared waves, and it's technically not heat itself. As soon as the energy strikes a surface, it is transformed into heat. The heat the earth receives from the sun comes to us by way of radiant energy. The warmth felt by someone standing in front of a hot stove is also a result of radiant energy.

Central Heating

As with cooling strategies, no central heating system is perfect. All of the different approaches have advantages and disadvantages. Forced-air systems are probably the most common, but in some parts of the country, forced-hot-water systems are popular. Although not as widely used, radiant floors and ceilings also have their adherents.

When selecting a heating system, you should consider equipment and installation costs, operating costs, noise, maintenance requirements, whether the system can be coupled with a ventilation system, and of course, health issues. There are a number of sources for general information on system selection.[324] [325] If everything else is equal, chemically sensitive individuals tend to be more bothered by heaters than by air conditioners because the heat causes slightly more outgassing of things such as insulation, motors, plastic-jacketed wiring, *etc*.

Forced Air

Forced-air heating systems and central air-conditioning systems have similar components: a cabinet containing a fan (the air handler), a heating device (sometimes this is a heating coil), a filter, return ducts, and supply ducts. During operation, the fan pulls

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[323] Nikel, "Residential Space Heating."

[324] Baron Fowler, "Selecting a Heating System," *Solplan Review* (July 1996): 3-7.

[325] Bonneville Power Administration (BPA), *Electric Heating Options* (Portland, OR: BPA, June 1988). #DOE/BP-870.

air from the living space, through the return ducts, through the filter, across the heating device, then it blows the warmed air through the supply ducts, back into the living space.

There are several health concerns with forced-air heating systems that are similar to central air conditioners (see the discussion of cabinet insulation, electric motors, filters, plastic components, *etc*. under the heading *Central air conditioners* above). However, there don't seem to be significant health-related differences between different manufacturers of similar pieces of equipment. For example, sealed-combustion gas furnaces are fairly similar from a health perspective.

As with central air conditioning, the most significant advantage to forced-air heating is the fact that it can be fitted with a better-than-average air filter. (This will work most effectively if the air-handler fan is running continuously.) It can also be interconnected with a general ventilation system. In many cases, forced-air heating and central air conditioning are combined into a single system, so they share the same ducts, air handler, *etc*.

The heat in a forced-air heating system can be derived from electricity or a combustion fuel. Electric furnaces have a resistance wire, similar to that found in a toaster, that gets very hot when the electricity is turned on by the thermostat. Electric furnaces tend to be less costly to purchase than other furnaces, and while they certainly provide warmth, they can be very expensive to operate in cold climates. The resistance wire can get quite hot, resulting in fried dust.

A forced-air heat pump is basically a central air conditioner that has the capacity to operate backwards in the winter. During the summer, a heat pump works just like a central air conditioner, pulling heat from the house and moving it through the refrigerant lines into the compressor outdoors. In the winter a heat pump works in reverse, it extracts heat from the outdoor air (even in the winter, there is a certain amount of heat in the outdoor air), moves the heat through the compressor, through the refrigerant lines, and into the coil in the air handler.

Heat pumps are more energy-efficient than electric furnaces, but they often have the same type of resistance wires as used in electric furnaces—for back-up heat. This is necessary because heat pumps lose their efficiency as the outdoor temperature drops (loss of efficiency usually takes place below about 35°F). In mild climates the resistance wires may never be needed, but they will be activated regularly in cold climates during the coldest hours. This means a lower average energy efficiency.

The coil in a heat pump operates at a low enough temperature that fried dust isn't a problem. But the resistance wires can produce fried dust when they're operating during the colder winter months. Because they don't use combustion fuels, electric furnaces and heat pumps are often recommended for sensitive people. They are readily available from a variety of manufacturers, including **Amana Heating and Air Conditioning**, **Carrier Corp.**, **Lennox Industries**, **Rheem Manufacturing**, **Trane Co.**, and others. There don't seem to be significant health-related differences between different manufacturers' models.

Because the outdoor air temperature varies considerably during the year, it's difficult to design a heat pump that's energy-efficient at all temperatures. Geothermal heat pumps have been developed to improve on the drawbacks of extracting heat from the outdoor air.[326] They can be more energy efficient than conventional heat pumps because they pull heat from the earth itself and, besides heating the air, some can also provide you with hot water.[327]. They can be expensive to install, but some electric utilities have incentive programs to cover a portion of the cost.[328] There are two types: water-source heat pumps and ground-source heat pumps.

With water-source heat pumps, heat can be extracted from underground water, so a well may be required to bring water up from the ground. This water is usually at a constant temperature, so the heat pump can be designed to operate efficiently at that specific temperature. This makes a water source heat pump more energy-efficient, and less dependent on the resistance wires. A difficulty with these units is disposing of the water that was taken from the ground. Some municipalities will not allow it to be returned by way of a second well because of the possibility of contaminating the ground water, and it should not be put into a sanitary sewer. If the water cannot be deposited in a drainage ditch or storm sewer, a very large drainage field will need to be constructed to dispose of it. This field will be in addition to any required septic field, because the amount of water would easily overload a septic system.

Geothermal heat pumps are also available that extract heat from the soil itself, rather than either water or air, by using a closed-loop system. A loop of plastic piping is buried in the yard around the house (or it can be placed in the bottom of a pond) to provide a heat source for the furnace. The depth of the piping is selected to provide a uniform soil temperature that will allow the heat pump to operate efficiently during the entire year. In many cases, resistance heating wires are still required for back-up. There are a number of manufacturers of geothermal heat pumps[329] including: **Carrier Corp.**, **Climate Master**, **FHP Manufacturing, Inc.**, and **Water Furnace International Inc.**

The primary drawback to combustion-fired forced-air furnaces has to do with poor chimney function. Fuel leaks can also occur, but they aren't as common as backdrafting and spillage. However, high-efficiency, natural gas (or propane), direct-vent, sealed-combustion furnaces are now widely available. These furnaces are often tolerated by sensitive people simply because the combustion by-products can't get into the living space. Most major furnace manufacturers (including **Amana Heating and Air Conditioning**, **Carrier Corp.**, **Lennox Industries**, **Rheem Manufacturing**, **Trane Co.**, and others) offer these furnaces, which are usually over 90% efficient, and there don't seem to be any major health-related differences between them. Currently only one manufacturer (**Dornback Furnace Division**) offers a sealed-combustion oil furnace. Although they cost more than low-efficiency furnaces, high-efficiency furnaces have low

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[326] Rachel Freifelder, "Ground-source heat pumps: Earth as heat source and heat sink," *Home Energy* (November/December 1990): 32-38.

[327] Jim Soden, "Ground-source heat pumps," *Journal of Light Construction* (December 1994): 33-37.

[328] "Government, industry push geothermal," *Journal of Light Construction* (January 1994): 8.

[329] Dan McLeister, "Ground-source heat pumps rising," *Professional Builder* (February 1997): 153.

enough operating costs to pay for the extra up-front cost.[330]

Some of the early high-efficiency gas furnaces had serious problems with internal corrosion. These furnaces are called "condensing furnaces" because water vapor (a combustion by-product) can condense inside them. When the water combines with some indoor air pollutants (in particular, chlorine from household cleaners) hydrochloric acid is formed, and it can lead to corrosion. Many early furnaces corroded internally, but today, the problem has been solved by using corrosion-resistant stainless steel, ceramic, and plastic components. In addition, outdoor air, rather than contaminated indoor air, is generally used for combustion. These devices use a plastic exhaust pipe which is resistant to corrosion, and a plastic intake pipe, to avoid chlorine-contaminated indoor air. So, corrosion is no longer a problem.[331] However, one of the early types of plastic that was used for intake and exhaust pipes has been found to be problematic and has been the subject of a massive recall by the **Consumer Product Safety Commission**.[332] The type of plastic, HTPV, has the name Plexvent, Plexvent II, or Ultravent stamped on the side, and was manufactured between 1987 and 1993. It is subject to a slow deterioration, and can eventually crack and leak carbon monoxide into the living space. Fortunately, other types of plastic don't deteriorate.

Some higher-efficiency gas furnaces have a sealed plastic exhaust pipe, but no sealed air-intake pipe. These units pull combustion air from the living space. They are much better than furnaces that rely on conventional chimneys, but on occasion, they can spill small amounts of combustion by-products into the living space.

Because of the hot surfaces inside all combustion-fired furnaces, some fried dust can be generated. This, as well as plastic parts, motors, insulation, *etc*., can bother some hypersensitive people.

For existing combustion-fired heating systems that are experiencing poor chimney function, it is best to analyze precisely what is causing the problem before trying to fix it. **Field Controls** has several powered venting devices for oil- or gas-fired equipment that can remedy such a situation. **Tjernlund Products, Inc.** also has power-venting fans that can be used with conventional gas or oil furnaces, boilers, or water heaters. **Exhausto, Inc.** produces chimney fans that sit on top of a chimney to suck combustion by-products up and out of the house. It should be remembered that when using these powered exhaust devices, makeup air will enter the house somewhere to make up for the air being exhausted. This makeup air could come down another chimney. In other words, you could solve a backdrafting problem in one chimney, yet cause a problem in another chimney. So, these devices should only be used after a situation has been thoroughly evaluated.

Some manufacturers are offering hybrid hot-water/forced-air heating systems. In

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330 Henry Kurth and Nicolas Hall, "Furnace replacement: The high-efficiency payoff," *Home Energy* (May/June 1990): 19-23.

331 J.D. Ned Nisson, "Rocky road to efficient furnaces," *Journal of Light Construction* (March 1990): 39-40.

332 Dan McLeister, "Safety Agency Issues Pipe Recall," *Professional Builder* (June 1998): 101.

these units, water is heated in a boiler or a conventional water heater (which could be fueled by electricity or a combustion fuel), then pumped through a coil inside the air handler of a forced air heating system.[333] [334] The advantage of this approach for very sensitive people is the fact that the hot-water coil temperature is too low to produce fried dust. Some systems combine water heating for domestic use, water heating for a radiant system, and water heating for a forced-air system.[335] [336] Manufactures of combo systems include **Apollo HydroHeat and Cooling**, **First Co.**, and **Lennox Industries, Inc.** (Complete Heat).

Nutech Energy Systems, Inc. has a combo system in their Clean Air Furnace that is specifically designed to combine forced-air heating/cooling and ventilation. It basically consists of a metal air-handler cabinet with fan, a heat-recovery-ventilator core, and a hot-water heating coil. During operation air is circulated from the living space through the hot-water heating coil (or an air-conditioning coil) then the conditioned air is returned back into the living space. At the same time, a portion of the air coming from the living space is sent through the heat-recovery core toward the outdoors, and fresh outdoor air is brought in through the heat-recovery core and sent indoors. Hot water from a conventional water heater is circulated into the hot-water heating coil to provide warmth. This system can also be combined with a better-than-average air filter.

Forced-Hot-Water

With a forced-hot-water heating system, water is heated in a boiler, then distributed through pipes to radiators in various rooms of the house, where the heat is released into the air. Room air circulates around the radiators and moves through the room on natural air currents.

Many older buildings have large cast-iron radiators as a part of a hot-water system. Some of these systems don't have a pump to move the water. Instead, the hot water rises from a basement boiler, up through pipes to radiators on upper floors, then the water cools, and drops back to the boiler through another set of pipes. All of this is based on the principle that warm fluids rise, and cool fluids fall. The pipes on many of these older systems are insulated with asbestos. This insulation was still being manufactured as recently as 1972.[337] Modern hot water systems use pumps to distribute the water because it's easier to control and results in more even and comfortable heat. Modern radiators are sleek, efficient, and unobtrusive when compared to the old cast-iron models. Many have

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333 J.D. Ned Nisson, "Heating space and water with a single unit," *Journal of Light Construction* (October 1990): 41-43.

334 "'Combo' space and domestic hot water heating systems," *Solplan Review* (September 1994): 9.

335 Richard Groff, "Mixing forced-air and boiler heat," *Fine Homebuilding* (December 1993/January 1994): 84-87.

336 Rick Groff, "Hydro-Air Heating Options," *Journal of Light Construction* (November 1997): 37-40.

337 CPSC, *Asbestos in the Home*, 8.

baked-on finishes that outgas very little when warm.

A house with an existing hot-water heating system can be difficult to air condition—unless the radiators are specifically designed for hydronic cooling. If you have hydronic heating and it isn't suitable for hydronic cooling, air conditioning ducts will need to be run throughout the house—an expensive and difficult process in an existing structure. It's also possible to install mini-split air conditioners for cooling. In either case, separate heating and cooling systems are much more expensive to install than a single system that combines both heating and cooling.

Hot-water systems generally operate at low enough temperatures so they do not generate fried dust, making them well tolerated by sensitive people. But, because there is no fan, air filtration is not possible. Mold growth is only likely if a pipe develops a leak.

Hot water systems generally have one or more air release valves to let air escape from the pipes or radiators. These will vent a small amount of water vapor occasionally. This venting usually doesn't cause any negative health problems, but if the water has had any chemicals added to it, small amounts can be released into the living space. Chemicals, such as diethylaminoethanol (DEAE) are sometimes added to boiler water to control lime buildup and they can be bothersome to sensitive people.[338] The solution is to only use water with no chemicals.

An electric boiler can be used to eliminate the possibility of combustion by-products entering the living space, but electric boilers can be expensive to operate. A number of companies produce energy-efficient, direct-vent, sealed-combustion, natural-gas (or propane) boilers. They include **Burnham Corp.**, **GlowCore A.C. Inc.**, **HydroTherm**, and **Weil-McLain.** In addition, **Burnham Corp.** offers oil-fired sealed-combustion boilers and electric boilers.

To get the boiler out of the living space, **Energy Kinetics** offers a gas-fired Freedom model that is designed to sit outdoors. It is often used for swimming pools, but can also be used for heating a home. **Central Boiler, Inc.** has several sizes of outdoor wood-fired boilers. The piping between an outdoor boiler and the house must be well insulated. **Edwards Engineering Corp.** has a Tetco line of geothermal heat pumps that are designed to use in place of a conventional boiler to supply hot water for space heating or potable use. They can also supply cool water for hydronic cooling.

Radiant Floors and Ceilings

With this method of heating, the entire floor or ceiling is used as a heating panel. In most radiant-floor systems, a pump moves hot water from a boiler through tubing in the floor—where it releases its heat—then back through the boiler to be reheated.[339] [340] The tubing can be embedded in a concrete slab or attached to the underside of a wood

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338 James Miller, "An unsafe heating chemical in a safe office," *The Human Ecologist* (Winter 1991): 16-17.

339 John Siegenthaler, "Hydronic Radiant-Floor Heating," *Fine Homebuilding* (October/November 1996): 58-63.

340 John Siegenthaler, "Radiant Slab Techniques," *Journal of Light Construction* (August 1992): 21-24.

floor system. In radiant-ceiling systems, and some floor systems, electric wires are used to provide the heat. The wires are typically embedded in a drywall or plaster ceiling, or under ceramic floor tile. Some electric radiant systems generate high electromagnetic fields throughout a room, but others are designed to minimize electromagnetic fields.

With radiant heating, heat is transferred from a warm surface, via infrared energy, to objects (and people) in a room. Thus, radiant heating is said to heat objects, not air. With radiant heating, people can be quite comfortable even when the air temperature is lower. So, utility bills with radiant heating can be lower than with forced-air heating (if the fuel cost, and heating efficiency is similar)—but actual savings are difficult to document.[341] [342]

With radiant floors or ceilings, nothing is visible in the living space, so there are no restrictions as to where furniture can be placed, the system is very quiet, and dust isn't blown around the room. Even when they are well-insulated, unheated concrete floor slabs can feel cool to the touch, but radiant floor slabs are warm and comfortable to walk on, so they are especially popular in bathrooms, where bare feet are common. Radiant heating can also be used to melt snow from sidewalks and driveways.

Many people claim that radiant heating is more comfortable and healthful than forced-air heating. While the physics of making a human body comfortable are rather complex, there are reasons why radiant heating can be more comfortable.[343] And people who have radiantly heated floors generally like them a lot. Whether or not radiant heating is actually healthier is a different matter. Yes, we, as a species, have evolved over hundreds of thousands of years under the radiant heat of the sun, and many people prefer radiant heating, but there is little evidence that a body warmed by radiant energy is actually healthier than one warmed by hot air.

Disadvantages? Radiant systems can have a high installation cost. With radiant ceilings, you can have a warm head, but cold feet. Radiant floors must be designed so they are not too warm, and the designer must take into consideration whether or not a floor will be covered with carpeting (which acts as insulation). A radiantly heated concrete slab will respond slowly to a change in the thermostat's setting because it takes so long to warm up the slab.[344] Ventilation and air conditioning can't be combined with radiant heat, so they must be separate systems.[345] In the past, water leaks were not unusual, but the tubing used today is much more durable and resistant to leakage. But if a leak does occur inside a concrete slab, it can be difficult to repair.

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[341] "Radiant floor heating verses forced air heating—Comfort and energy performance," *Energy Design Update* (June 1991): 9-10.

[342] J.D. Ned Nisson, "Radiant Heat: Cozy But Does It Save Energy?," *Journal of Light Construction* (November 1991): 48-49.

[343] "Comfort and Energy Savings with Fast-Acting Radiant Ceiling Panels," *Energy Design Update* (July 1994): 5-6.

[344] Richard Kadulski, "Radiant Heating," *Solplan Review* (March 1996): 4.

[345] Don Vandervort, "Hot to trot," *Builder* (January 1993): 214-216.

A radiant heater can sometimes accelerate the outgassing of furnishings.[346] This is because furnishings can get warmer with radiant heat than they would with another form of heating. In addition, the materials actually making up a radiant floor or ceiling will be warmer and subject to increased outgassing. For this reason, materials should be chosen carefully. For example, a radiantly heated ceramic-tile floor would be fairly inert, but a plywood subfloor covered with synthetic carpeting could be problematic. Some very sensitive people can be bothered by the small amount of outgassing from a radiant ceiling because of warmed drywall, joint compound, and paint.

Hydronic radiant floor heating system manufacturers include **Maxxon Corp.** (Infloor) and **Wrisbo Co.** And **Heatway** has both hydronic systems and electric systems. The magnetic field strength from their electric system generates a low 4 mG. magnetic field 1" above the floor. (The field strength will be even less at a greater distance above the floor.) There is an SunTouch electric radiant flooring system designed for use under ceramic tile that also generates a low 4 mG. magnetic field 1" above the tile. It is made by **Bask Technologies LLC**. By comparison, there is an radiant electric system made by **NuHeat Industries Ltd.** with a magnetic field strength that ranges from 25-300 mG. at 1.2" above the floor. Some companies claim that they have never measured the magnetic fields surrounding their electric radiant flooring systems.

Solar Heating

Solar heating involves relatively low temperatures, so it should not result in fried dust. It can be a viable, healthy way to warm a house. However, unless a solar-heating strategy is well-thought-out, it can end up being unhealthy.

Active solar heating involves a mechanical system of some type. This typically requires considerable advanced planning to insure that the heating system and the house interact and work together properly—as a system. Active systems use air, water, or some other liquid, to transfer heat from a rooftop collector, into a heat-storage area, then into the living space.

Greenhouses are sometimes used to store excess heat until it is needed to warm the living space. Sensitive people should be very cautious about having a greenhouse filled with plants attached to the living space because the soil can be a haven for mold. Some people are so sensitive to mold they can’t tolerate a single house plant, much less a greenhouse full of plants, pollen, and mold. Commonly used gardening chemicals such as fertilizers and pesticides can also be problematic.

The rock-heat-storage systems used in some solar designs can introduce radon into the living space, and there is at least one report that related ill health to mold spores escaping from such a rock bed.[347] Even if a rock storage area is designed to be dry, a plumbing leak could easily contaminate it enough to result in mold growth. Cleaning a rock-storage area is often impossible. If termite-control chemicals ever find their way into such an area, they could easily contaminate the entire house.

Some active solar systems use a closed loop of water (or another fluid, if freezing

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[346] Nikel, “Residential Space Heating.”

[347] Forrest Wilson, “Doctors For Building,” *Technology Review* (May/June 1986): 49-58.

conditions are likely) that is heated by the sun and then piped through the house. If anti-freeze is used to transfer the heat, a leak could soak into the structure and be difficult to clean up completely. All active systems use piping or ductwork, temperature sensors, and electrical motors to run fans or pumps. Motors can be a minor source of air pollution for sensitive people because they outgas slightly when they warm up during operation. The lubricating oil is often the culprit, but electrical lacquers and insulations have also been implicated.

Passive solar designs are simple and easy-to-maintain because they require little-or-no equipment. Instead, the window size and placement, and the roof overhang, control how much sunlight enters the house at different times of the year. A properly designed overhang will totally block the sun in summer, yet allow full penetration in winter. A poorly designed house, with too many south-facing windows, can overheat during the day and get too cold at night.

Passive-solar heating is generally non-polluting—but not always. Some people have noticed that synthetic draperies, carpeting, and other furnishings are more odorous when warmed by the sun. Of course, if these products are not subject to outgassing (*e.g.* 100%-cotton curtains and upholstery materials), there should be no outgassing. However, natural materials can degrade in the sunlight and contribute to house dust.

Ceramic-tile and concrete floors are often used in passive-solar designs to store excess heat. This heat is then automatically released during the evening when the outside temperature drops. There are a handful people who report that concrete warmed by the sun is subject to a small degree of outgassing, but fortunately this is not a common reaction, and it's generally due to contaminates that have been spilled on the concrete, or odorous sealers. Passive solar heating is often used in superinsulated house designs because it can be an inexpensive way to heat a house and it requires no operating system —it just works automatically and doesn't break down.

There are many healthy solar heating installations. Because the design of these systems can be quite varied, all the possibilities cannot be adequately covered, but if the designer is aware of the general principles covered in this book, it should be relatively easy to circumvent any potential problem areas. As a rule, passive systems tend to be less problematic than active systems.

A solar heating system only works when the sun is shining, and no matter how large the storage system, some form of back-up heating is usually necessary. With both active and passive systems, insulation is of prime importance—to keep the cost of back-up heating low, and to keep the heating-equipment size small. An uninsulated house needs a large solar system and a large back-up system, but a well-insulated house only needs a small solar system and a small back-up system.

Individual Room Heaters

Sometimes a central heating system isn't what is needed. For example, an individual room heater may be all that is necessary for a room addition when a central system can't be easily extended. In warm climates, and in some very well insulated houses in cold climates, heating requirements can be so low that a central system simply isn't cost-effective.

Electric baseboard heaters are widely available. Although not as common, electric heaters are also made to mount out-of-the-way, near the ceiling. Most electric heaters are easy to install and relatively inexpensive to purchase, but they can be costly to operate. Individual combustion-fired heaters are a little more difficult to install, and they are often more economical to operate, but tend to cost more to purchase.

Many individual heaters are convection heaters, that is, they circulate heat by convection. Cool air near the floor is pulled toward the heater, where it is warmed, then the warm air rises naturally and circulates through the room. Individual heaters can also be designed to heat primarily through radiation instead of convection.

Some individual heaters have fans, others rely on natural air currents in a room to distribute the warmed air. Most don't have filters, and those that do have inefficient ones.

Electric Convection Heaters

Most standard electric heaters are convective heaters, and they operate in much the same way as a toaster. Electricity is run through a special wire, the resistance of the wire causes it to get hot, and it heats the air surrounding it. This results in fried dust and an odor some sensitive people find disagreeable or offensive.

Some brand new electric heaters release a bothersome odor when they are first turned on. This can be due to traces of oil on new parts, or to fresh paint on the case. These odors can usually be baked off by leaving the heaters turned on high for a few hours to a few days. For sensitive people, this should not be done inside their living space. It can be done outdoors or in a garage as long as the heaters are wired properly and there is no danger of fire.

Even after all the initial odors have baked off, most electric heaters are capable of producing fried dust. But if an electric heater is designed to operate on 220 volts, and it is only hooked up to 110 volts, it will not get as hot and it will be more tolerable to sensitive people who are bothered by fried dust. Of course, there will need to be more heaters installed in a given room to allow for the diminished heating ability.

A less-common baseboard heater is the hydronic type. These are, in effect, self-contained hot-water heaters. Outwardly, they look similar to other electric heaters but they contain a hermetically sealed copper tube filled with water (or another fluid, such as antifreeze or oil). This tube has an internal electric heating wire. The advantage over the more common electric heaters is the fact that they operate at about 200°F, which is too low to produce fried dust. A number of portable heaters of this type are sold through department stores. Some are filled with oil, rather than water, which shouldn't be a problem as long as they don't leak.

The Softheat brand of hydronic baseboard heaters, manufactured by **Cadet Manufacturing Co.**, is widely recommended for sensitive people. In fact, these heaters (which were previously manufactured by Intertherm Co.) are the most-often-tolerated heaters for sensitive individuals. They are available as either portable heaters with a 110-volt power cord, or as heaters that are permanently installed and connected directly into the house wiring system. Softheat heaters have a baked-on powder-type paint that has virtually no odor. **Berko Electric** has very similar hydronic baseboard heaters. They are coated with a conventional paint, and they are available in 110-volt portable units, or to be permanently connected directly to the house wiring system.

Over time, the inside of any electric heater can collect dust, so they should be cleaned periodically with a vacuum and stiff brush. Some heating elements are fitted with aluminum fins to increase their surface area and transfer heat to the air quickly. Though not common, a few hypersensitive individuals are bothered by heated aluminum. For them, it would be important to avoid heaters with aluminum parts.

Occasionally in healthy-house construction, a house will be ready for finishing the drywall or plaster, and then painting, during cold weather—but before the heating system has been installed. Most builders simply bring in unvented portable propane heaters. While most of the combustion by-products will dissipate before the house is occupied, sensitive people are often concerned about residual pollution that can get absorbed into the structure. There are a few of solutions. **Fostoria Industries, Inc.** has industrial-grade, portable electric heaters that can be used to temporarily warm a house. Their larger sizes are designed for three-phase power, but they also have 34,000 and 51,000 BTU models that will operate on 240-volt, single-phase power. **Allmand Bros. Inc.** manufactures large, wheeled, portable gas-fired heaters designed to deliver warm air that is free of combustion by-products. They have enclosed burners and are rated at 1,000,000 BTUs per hour at a maximum of 5,600 cfm. As a third alternative, it may be possible to temporarily hook up a used furnace to a chimney and warm the house.

Electric Radiant Heaters

Some individual heaters are specifically designed to transfer heat by radiation, not convention. There are advantages and disadvantages to this strategy (see *Radiant floors and ceilings* above). Because radiant energy only moves in a straight line, and not around or behind objects, a piece of furniture could easily block the energy from reaching across an entire room. For this reason, the placement of radiant heaters is more critical than with other individual heaters. Sometimes they are placed on or near the ceiling, but this can be unattractive if not planned well.

Radiant heaters usually have either stainless steel, steel with a baked-enamel finish, or aluminum parts. Some have exposed fiberglass insulation on the back side. One type uses a metal heating element fused to a glass or ceramic plate. They have been used successfully with many chemically sensitive people,[348] but they should be chosen with care because they have sometimes been implicated in causing symptoms in some individuals—even after several days of outgassing.[349] This could be due to the synthetic material used to bond the heating element to the plate.

Individual radiant heater manufacturers include **Radiant Electric Heat, Inc.** and **SSHC, Inc.** (Enerjoy brand). There are a variety of styles available, including baseboard heaters, cove models that mount at the top of a wall near the ceiling, ceiling units, and portable heaters.

Combustion-Fired Heaters

Individual combustion-fired heaters include kerosene space heaters, wood stoves, and fireplaces—in short, any type of individual heater that has a flame. The most serious health drawback to these devices involves combustion by-products entering the living

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[348] Suzanne and Ed Randegger, “Ceramic Radiant Heat: a safe, clean, & cozy alternative,” *Environ* #13 (1992): 29-30.

[349] Don L. Jewett, “Product Information, Heaters,” *The Human Ecologist* #15/16 (March 1982): 17.

space. Combustion-fired heaters typically transfer heat by both convection and radiation. If the surface temperature of the heater is fairly high, it can give off more radiant energy than a lower-temperature device—but more fried dust.

The only devices in this category that should be considered in a healthy house are those having totally-sealed combustion chambers, and there are now many direct-vent, sealed-combustion, natural-gas (or propane) fireplaces on the market.[350] These have well-sealed glass doors, and they do not draw any air from the living space.[351] All the air they need for combustion comes through an intake pipe from the outdoors, and all the combustion by-products are expelled to the outdoors through an exhaust pipe. These two pipes are typically run out the back of the unit through a sidewall, but they can also be run up inside a chimney. (While a chimney isn't really needed, it can be installed for aesthetic reasons, and sealed off so only the two pipes are inside it.) Most fireplace manufacturers now offer one or more sealed-combustion direct-vent models.[352] As was discussed earlier, these devices may not be *100% totally* sealed, but they tend to be *very well* sealed, so they are often used by sensitive people.

Direct-vent, sealed-combustion fireplaces are made in a wide variety of styles. Suppliers include **Central Boiler**, **Heatilator, Inc.**, **Heat-N-Glo**, **Lennox Industries**, **Miles Industries, Inc.**, **Selkirk**, **Superior Fireplace Co.**, and **Vermont Castings-Majestic Products Co.** Some models come with a handy infrared remote controller (like a TV), so you can sit back across the room and click on the fire.[353] When installed in small, well-insulated homes or apartments, these fireplaces can be operated by a thermostat to satisfy a great deal of the heating requirements.[354]

Direct-vent, sealed-combustion, natural-gas (or propane) space heaters are available from **Empire Comfort Systems** (Empire Wall Furnace), **Miles Industries, Inc.** (Thermotrend), and **Monitor Products, Inc.** In addition, **Monitor Products, Inc.** has kerosene-fired sealed-combustion space heaters.

Burning wood is usually not a very clean process, so it results in outdoor pollution that can be brought back indoors by natural, accidental, or controlled ventilation. Outdoor pollution can be minimized in a variety of ways. For example, if wood-burning devices are as energy-efficient as possible, they will be less polluting. EPA-certified stoves have lower emissions than older, non-certified stoves. This is accomplished by using catalytic combustors, or a variety of design features such as baffles, secondary combustion

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350 Sharon O'Malley, "Gas Fireplaces," *Building Products* (Fall 1996): 52-54.

351 John Wagner, "Direct-vent fireplaces ignite market," *Custom Builder* (May/June 1995): 100-101.

352 Dan McLeister, "Direct-vent fireplaces get standard," *Professional Builder* (October 1996): 79.

353 Jeff Ward, "Today's fireplaces are not just blowing smoke," *Custom Builder* (November/December 1992): 26-31.

354 "Fireplace efficiency," *Solplan Review* (November 1996): 3-5.

chambers, or the introduction of secondary air.[355] Furthermore, only seasoned hardwoods should be burned, not resinous softwoods. Chemically treated lumber and non-wood products such as plastic, should never be burned because of the highly toxic gases given off. Stoves that burn manufactured wood pellets can burn relatively cleanly, but they are expensive to purchase.[356]

To minimize the chance of combustion by-products entering the living space, all wood-burning heaters should be fitted with combustion air ducts to provide outdoor air rather than indoor air for combustion, and tight-fitting doors. "The Ultimate Seal" airtight fireplace doors are available from **Wilkening Fireplace Co.** They also have a "Clear View" combustion-air inlet that is designed to bring outdoor air into the fireplace while moving air across the inside of the glass doors to eliminate smoke accumulation on the glass.

Open fireplaces are not only indoor polluters, they also rob a house of heat because, during cold weather, the chimney can act like a continually running exhaust. One study found that the overall energy consumption of a house can increase by 30% if the house has an open fireplace.[357] This heat loss can be minimized by closing off the chimney with a tight-sealing damper when it is not in use.

Newer, tighter, more energy-efficient wood stoves and fireplaces produce less pollution than many older models, but they all must be opened in order to load them with wood. When the door is opened for loading, stoking, or ash removal, pollutants can enter the room. If a wood stove is improperly operated or installed, it can be even more polluting. Open fireplaces introduce considerably more pollutants into the living space than closed stoves—particularly when the fire dies down and there is little or no draft in the chimney. This is actually the most dangerous period, because glowing coals produce a great deal of carbon monoxide.

During periods of moderate outdoor temperatures, when a wood burning appliance is operated intermittently, it will be less efficient (and more polluting) than if it were operated continuously at a consistently high temperature.

Although they are generally not recommended in healthy houses, there is one wood-burner that is a good compromise. The **Vermont Castings-Majestic Products Co.** is now making a Pure-Energy balanced-flue, sealed-combustion, direct-vent, wood-burning fireplace. When it is being loaded with wood, the doors are opened into the living space, so some pollutants can be released into the house, but once the doors are closed, the unit is totally sealed.

For those who insist on having a wood-fueled fireplace, there is a book titled *The Fireplace in the House as a System*, that discusses how to install an operate such a device

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355 Environmental Protection Agency (EPA), *Buying an EPA-certified woodstove* (Washington, DC: EPA, February 1990).

356 Alex Wilson, "Pellet Stoves: Wood burning that's better for the environment, *Environmental Building News* (September/October 1992): 6-7.

357 "The energy cost of an open fireplace," *Energy Design Update* (July 1992): 9.

so there will be a minimum amount of combustion products entering the living space.[358] It is available from **Gulland Associates**.

Unvented Space Heaters

Unvented combustion appliances that burn natural gas, propane, alcohol, or kerosene spew combustion by-products directly into the living space. They are routinely sold in many parts of the country but, at the same time, they are banned in several states.[359] From a health standpoint, unvented combustion appliances should never be used in any house. Even when they are relatively clean-burning, they can introduce a great deal of water vapor into the living space—enough to cause a mold problem. In order to avoid excessive indoor air contamination, manufacturers who produce unvented gas space heaters recommend that small appliances be used, and that they only be operated for short periods of time. But in many cases larger units are installed that are used for space heating.[360] This can be dangerous.

Unvented kerosene heaters, in particular, have been shown to emit not only the well known pollutants such as carbon monoxide, carbon dioxide, nitrogen dioxide, *etc*. but also mutagenic pollutants such as polycyclic aromatic hydrocarbons.[361] These compounds can cause damage to people at the chromosomal level that will show up in later generations. Emissions also include pentachlorophenol, which is associated with many serious negative health effects. **Canada Mortgage and Housing Corp.**, Canada's leading housing-research organization, does not consider unvented appliances suitable for Canadian housing.[362]

These "cimneyless" heaters have been compared to the idea of a drainless sink.[363] We can easily see that a sink that dumps drain water on the floor is not a good idea. Well, heaters that dump combustion by-products into the living space are an even worse idea. Actually, with an unvented combustion appliance, the entire house become the chimney, so you are living inside a chimney.[364]

Simply opening a door to another room will not provide adequate ventilation for

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358 "Review: The Fireplace in the House as a System," *Solplan Review* (March 1998) 17-18.

359 Isaac Turiel, *Indoor Air and Human Health* (Stanford, CA: Stanford University Press, 1985): 66.

360 Ted Cushman, "Vent-free gas heaters—How safe?," *Journal of Light Construction* (July 1997): 53-58.

361 Gregory W. Traynor, "Selected Organic Pollutant Emissions from Unvented Kerosene Heaters" (Minneapolis, MN: , *Proceedings of the 79th Annual meeting of the Air Pollution Control Association*, 1986). Paper #86-52.5.

362 "Unvented gas fireplaces," *Solplan Review* (November 1997): 12-13.

363 "Unvented gas space heaters: Drainless sinks?," *Home Energy* (September/ October 1996).

364 Charles Wardell, "A Heated Debate," Popular Science (March 2000): 79-81.

an unvented heater. It will only mean that two rooms will be contaminated rather than one. Opening windows defeats their purpose—it just means they will need to run for longer periods of time to keep up with the increased heat loss.

Unvented space heaters are often used on construction sites to keep a building, and the workers, warm in the winter before the construction is being completed. For example, they are often used to warm a space while concrete cures. As an alternative **Allmand Bros. Inc.** manufactures large, wheeled, portable heaters to deliver warm air that is free of combustion by-products. They are rated at 1,000,000 BTUs per hour at a maximum of 5,600 cfm.

Individual-Room Heat Pumps

Many of the manufacturers of window air conditioners and mini-split system air conditioners (see above) also offer similar units that are heat pumps. Mini-split systems tend to be well-designed and quiet, and they allow you to heat and cool a room with a single device. Most have resistance heaters in them that are activated when the outdoor temperature is very low. The resistance heaters can be responsible for fried dust.

Summary

Selecting a heating/cooling system involves many decisions that are related to other decisions about ventilation, airtightness, filtration, insulation, climate, occupant sensitivity and, not least of all, cost. All these factors interact so they must be considered together in order to arrive at the best equipment for a particular situation.

8. Air Filtration

The purpose of an air filter is to remove pollutants from the air. All filters do this to some extent, but some do a better job than others. While filters are great inventions, people often ask more of a filter than it's capable of doing. For example, they may (unsuccessfully) try to use an air filter to clean up the air in a very polluted house without first implementing the healthy-house design principles of Elimination and Separation. Or they may not realize that filtration can't be substituted for ventilation because it cannot create oxygen, and it cannot remove excess moisture from the air. Filters always work best when combined with other strategies for improving indoor air quality.[365]

There is a great deal of hype in advertising about air filters. As a result, many people are being sold more filtration capacity than they need, while others are sold gimmicks that do very little to clean the air.[366] For most people, in most situations, a medium-efficiency filter is all that's necessary as long as a house is built with low-tox materials[367] but some very sensitive people may need state-of the art filtration.

It should be remembered that all filters require maintenance. This may involve changing a disposable type filter regularly, or periodically cleaning a reusable type. Manufacturers generally have cleaning or replacement recommendations, but all houses are different, so your particular situation may require more frequent maintenance. **Blue Earth Research** has a Furnace Filter Monitor that can remind you when to change your forced-air heating/air-conditioning filter. It is based on the principle that the air pressure difference from one side of a filter to the other changes as a filter gets clogged. This unit has an indicator light that flashes when the air-pressure difference changes by a specific amount. The pressure difference is preset to a specific level, but it is adjustable, so it can be set to the filter manufacturer's recommendations. This device cannot be used with electrostatic precipitators or other types of filters that don't experience a pressure change as they become loaded.

Filter Locations

There are several ways filters can be used in houses. Each has advantages and disadvantages. To obtain the most effectiveness, it's best to minimize indoor pollutant sources first, then use a filter to remove pollutants that can't be minimized by other

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365 "Why doesn't my air purifier help my allergies?," *Residential and Institutional Hygiene* (January 1990): 2.

366 Karl Raab, "Low Technology Strategies for Residential Indoor air Quality (Stockholm, Sweden: *Proceedings of the 3rd International Conference on Indoor Air Quality & Climate, Vol. 5, Technical Solutions to Providing Adequate Indoor Air Quality and Thermal Comfort*, 1984): 159-164.

367 Karl Raab, *Upgrading Residential Forced Air Filtration* (Ottawa, ON, Canada: Canada Mortgage and Housing Corp., May 1982).

means.[368]

First of all, a filter can be used with a ventilation system to remove pollutants from the outdoor air before it's brought indoors. This works well in a tight house, but in a loose house there will some incoming air that won't be filtered—that entering through random holes. Filtering incoming air makes a lot of sense, but most residential ventilation systems have low-powered fans that aren't designed to push or pull air through a filter having very much resistance to airflow. So, a ventilation system and a filter must be selected together.

The most common use of a filter in a residence is in conjunction with a forced-air heating/cooling system. As the air handler fan pulls air from the living space, it pulls the air through the filter, then (after heating or cooling the air) it blows the filtered air back into the living space. In a loose house, polluted outdoor air will enter through random holes, mix with the indoor air, then be filtered as it passes through the air handler. The occupants will be exposed to the outdoor pollutants as they mix with the indoor air, but the overall levels in the house will be lower than if no filter were used. This approach works best if the air-handler fan runs continuously, not just when heating or cooling are called for[369] but fans use electricity, and this can add to your energy bills. So, when running a forced-air heating/cooling fan continuously, it makes sense to use an energy-efficient motor.

If a forced-air heating/cooling system and a ventilation system are combined to operate together, the same filter can be used to remove pollutants from the outdoor air being brought in by the ventilation system, as well as the indoor air being circulated by the heating/cooling system's air handler.[370] This is generally the most effective way of filtering the air in a house—especially if the house is tightly constructed and all the outdoor air enters through the ventilation system. But it can also be expensive because it involves several pieces of equipment that must work together. This approach is also most effective if the air-handler fan runs continuously.[371]

Portable filters are also widely available, and they are typically sized to remove pollutants from the air in a single room. They also work best if run continuously. To prevent the room's air from being contaminated by the rest of the house, the door should be kept closed, and the air in the room should not be circulated throughout the rest of the house by a forced-air heating/cooling system. This might necessitate closing off the

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368 Harold Nelson, "Recommendations for the use of residential air-cleaning devices in the treatment of allergic respiratory disease," *Journal of Allergy and Clinical Immunology* 82 (1988): 661-669.

369 C.J. Weschler and others, "The effect of Building Fan Operation on Indoor-Outdoor Dust Relationships," *Air Pollution Control Association Journal* 33 (January 1983): 624.

370 Gary Mayk, "Furnace Add-Ons That Clean the Air," *Journal of Light Construction* (October 1989): 24-26.

371 Oboe Engineering Ltd., *Medium Efficiency Filtration: Improved Filters for Residential Forced Air Systems*, (Ottawa, ON, Canada: Canada Mortgage and Housing Corp., September 1986).

heating/cooling registers in that room. Of course, this will mean the room will need its own heater or air conditioner, and perhaps its own ventilation system. As a rule, small desktop filters are not large enough to remove enough pollutants to be worth the trouble.[372]

As has been mentioned, running a forced-air heating/cooling fan continuously can result in a high operating cost due to the electricity needed to operate the fan 24 hours a day. A few high-efficiency furnaces are fitted with energy-efficient *ECM motors* which can significantly reduce the operating cost compared to standard motors, so ECM motors are often recommended when a forced-air heating/cooling fan is run continuously. Because they have a higher up-front cost, ECM motors aren't common, but they can be cost-effective over the life of the motor. In fact, if a fan motor runs continuously, an ECM motor can pay for itself in one year. They can be retrofitted to make an existing system more energy-efficient. ECM motors are variable speed, brushless, DC, permanent-magnet motors that can change speed at any time during operation. They are currently manufactured by Emerson Motor Co. and General Electric Motors and are available through major forced-air heating/cooling equipment manufacturers.

Filtration Strategies

While there are thousands of different air pollutants that have been identified, from a filtration standpoint they can be placed in two broad categories: particulates (tiny particles) and gases.

As a rule, a particulate filter won't remove gases, and a gas filter won't remove particulates. So, if you want to remove both particulates and gases from the indoor air, you need two kinds of filters. Many manufactures offer combination filters that contain both a gas filter and a particulate filter in a single package.

The cost of filters varies considerably.[373] Some are expensive to install but never need replacing. Others must be changed regularly, and some have an electrical requirement, thus there is a routine operating expense. So, your choice of a filter will depend on what you want to remove, how efficient you want the filter to be, how much maintenance you are willing to perform, and what you want to spend.[374]

Particulate Filters

Particulate filters, like their name implies, remove particulates from the air. They will not remove gases, like formaldehyde. Mold, pollen, dust, asbestos, viruses, *etc*. are all particulates found inside houses, and they certainly bother a lot of people. Selecting a particulate filter is not always easy, because particulates come in a wide variety of sizes.

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[372] "Air Cleaners," *Consumer Reports* (January 1985): 7-11.

[373] Environmental Protection Agency (EPA), *Residential Air-Cleaning Devices: A Summary of Available Information* (Washington, DC: EPA, February 1992). #EPA 400/1-90-002.

[374] Dennis Creech, Mike Barcik, and Steve Byers, "Clearing the Air: Filters for Residential Forced-Air Systems," *Home Energy* (July/August 1996): 14-18.

The basic measuring unit with particulate filters is the micron. A micron is a very small unit (1 micron = 0.000039 inch). The point of a straight pin is about 75 microns across. Particles smaller than 10 microns are almost impossible to see with the unaided eye. However, many particulate pollutants are larger than 10 microns and are relatively easy to remove. While it is often desirable to remove smaller particles, they are more difficult to capture. Our respiratory system can filter out particulates down to 3-5 microns, mostly through the lining of the nose and windpipe. Smaller particulates travel into the lungs where they can become trapped and result in damage and disease.[375]

Particulates in smoke are quite small—ranging in size from 0.01 up to 1.0 micron. Some components of house dust can be just as small. Animal dander is typically 0.5 to 10.0 microns in size. Pollen grains can be quite large in comparison, usually over 10.0 microns. Mold spores can be as small as 1.0 micron, and viruses are tiny at only 0.01 micron across.

Mechanical particulate filters are the most common particulate filters. They remove particulates by trapping them on a filter material, somewhat like a coffee filter works. The term mechanical does not imply that these filters have any moving parts, it simply means they are not electronic. Sometimes particulates also stick or adhere to the filter if it has been treated with an oil or *tackifier*.[376]

Particulate-filter efficiency can be measured in several different ways, something that leads to a great deal of confusion. The *weight-arrestance test* and the *atmospheric-spot-dust test* are the most common, and both are described in a technical paper called ASHRAE Standard 52–76.[377] Almost any filter performs well on a weight-arrestance test, so results from an atmospheric-spot-dust test are generally much more useful.

Standard Furnace Filters

Usually made of fiberglass or polyester in a cardboard frame, standard, inexpensive, 1"-thick furnace filters are mechanical particulate filters. They are only capable of removing very large particulates, so they are called coarse mechanical particulate filters. Their primary purpose is to protect the air-handler's fan motor, and minimize the amount of dust on the heating/cooling coil. They are rightly called *furnace* filters (or air-conditioning filters) and, because they do little to remove the pollutants that bother people, they shouldn't be considered "people" filters. They rate impressively on an arrestance test—as high as 80% efficient—but that test means very little. These filters are only 3-5% efficient on a spot-dust test. There are many different manufacturers of these types of filters and they are widely available from hardware stores and heating-equipment

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375 Richard Kadulski, "Clean Air: Getting the Most Out of Filters," *Solplan Review* (December/January 1991): 3-6.

376 Paul Borders, "Evaluating Filters—Our Tools for Cleaning the Air," *Indoor Air Review* (September 1994): 33-34.

377 American Society of Heating, Refrigerating and Air-Conditioning Engineers, *ASHRAE Standard 52–76 (1976), Method of Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter* (Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1976).

suppliers.

Electrostatic Air Filters

An electrostatic air filter is a reasonable upgrade from a standard furnace filter. These filters are usually 1" thick, and they rely primarily on static electricity to capture particulates but, secondarily, they also mechanically capture some particles.[378] They are typically made of various kinds of plastic. Sometimes the static charge is generated by the movement of air through the filter, but some filters are permanently charged with *electrets*. Some can be cleaned and reused but others must be replaced when they get dirty.

When dust passes through an electrostatic air filter, it receives a static charge, which causes it to cling to the oppositely charged filter, much like static electricity causes oppositely charged pieces of clothing to cling together. These filters are typically 10-15% efficient on a spot-dust test—roughly three times as good as standard furnace filters. They are not particularly efficient at removing particulates below 6 microns in size, but they are fairly good with larger particles such as ragweed pollen, and larger mold spores.

3M (Filtrete brand), **Air Kontrol**, **Allerx**, **Allermed** (Permastatic II), and **Permatron Corp.** (Dust Eater) all offer electrostatic air filters in several standard sizes. They can easily be used to replace a standard furnace filter, and they are routinely available at building-supply stores and through mail-order catalogs.

Newtron Products Co. has several models of electrostatic air filters. The Watchdog has a built-in carbon-monoxide detector; other models contain activated carbon. The Remind-Air has a unique insert that whistles when the filter starts becoming clogged—to remind homeowners that it is time to clean it.

Electrostatic Precipitators

Electronic air cleaners are more correctly called electrostatic precipitators. Unlike electrostatic air filters, these devices must be connected to a house's electrical system. When passing through an electrostatic precipitator, particulates in the airstream are given a negative electrical charge by high-voltage wires, then they are attracted to positively charged collector plates. After a while, the collector plates get full of dust and must be cleaned—by removing the filter from the cabinet and washing it off (usually in a dishwasher).

Electrostatic precipitators are typically advertised as being 95-99% efficient (on a spot-dust test) at removing particulates. While this certainly sounds good, it can be misleading. In one test, an electrostatic precipitator was found to have an initial efficiency of 80%, but the efficiency dropped to 50% after 20 hours of use and was only 20% efficient after 40 hours of use.[379] The efficiency drops off as the collector plates fill up so, if you are asking the filter to remove a great deal of dust from the air, you should be prepared to clean it frequently.

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378 Roy Sandberg, "Electrostatic Media Air Filtration: An Excellent Alternative," *Indoor Air Review* (March 1992): 18-19.

379 J. Gordon King, "Air For Living," *Respiratory Care* 18 (March/April 1973): 160-164.

These filters have various advantages and disadvantages.[380] For example, they can be more efficient at capturing smaller particulates than some of the common larger ones like plant pollens. They can spark internally, something that causes small particulates to be released back into the airstream—and they produce a small amount of ozone. Some manufacturers offer a thin, optional, activated-carbon filter that causes the ozone to be catalyzed into harmless oxygen. Some units can be modified slightly by a technician to produce less ozone, but they become less efficient as a result. While an electrostatic precipitator never needs replacing, it must be cleaned regularly—in some cases as often as every week, or every few days. **Honeywell, Inc.** offers a Model W8600F electronic indicator that can be programmed to remind you to clean your electrostatic precipitator as often as every 10 days, or as long as every 180 days.

In spite of the drawbacks, electrostatic precipitators can improve the air quality significantly over a standard furnace filter. They are often used by people with allergies to dust, mold, and pollen and they are readily available through local heating-equipment suppliers. Manufacturers include **Carrier Corp.**, **White-Rodgers** (Electro-Air), **Honeywell, Inc.**, **Lennox Industries**, and **Trion, Inc.** Electrostatic precipitators are several inches thick and are usually installed in a special metal housing in a furnace/air conditioner's duct system. Because of the way they are constructed, they have almost no resistance to airflow.

The above devices are sometimes called *dual-stage* electrostatic precipitators. This is because there is a charging stage and a separate collecting stage. There is also something called a *single-stage* electrostatic precipitator or a *dynamic air cleaner*. It uses a much lower voltage and has the charging and collecting areas combined. These units have the advantage of producing little or no ozone, and they are typically 1-inch thick, so they can be used as a replacement for a standard furnace filter. They work by causing a fiberglass filter panel to take on a static charge, thus it attracts oppositely charged dust particles. So, they are somewhat of a cross between a conventional (dual-stage) electrostatic precipitator and an electrostatic air filter, and their efficiency falls somewhere in between. When the fiberglass filter panel becomes dirty it must be replaced. These are manufactured by **Environmental Dynamics Group**.

Medium-Efficiency Filters

There are many different types of mechanical filters that are capable of removing particulates of various sizes. They must be very dense to capture very small particulates, and this makes it harder for air to move through them. In order to minimize this inherent resistance to airflow, they are usually manufactured with a great deal of surface area. Some are made in a pleated configuration that makes them look like an accordion. Sometimes they are called extended-surface filters.

There are a number of manufacturers who make very efficient mechanical filters, but the most efficient are used primarily in commercial and industrial applications. However, several in the 25-45% efficiency range (on a spot-dust test) are readily available for residential use. These are considered medium-efficiency filters, and they do a very good job of capturing the mold and pollen particles that plague many allergic individuals. Medium-efficiency filters are several inches thick, and are generally installed

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380 *Ibid*.

in a special housing in a duct system. They are quite effective at trapping particulates down to about 0.5 microns. The filter itself usually needs to be changed annually.

Residential medium-efficiency filter manufacturers include **Carrier Corp.**, **General Filters Inc.**, **Honeywell, Inc.**, **Lennox Industries**, and **Research Products Corp.** (Space-Gard). (**Honeywell, Inc.** makes one model with a housing that can be fitted with either a medium-efficiency filter or with an electrostatic precipitator. This allows you to change the type of filter without the labor of installing a new housing.) **E.L. Foust Co., Inc.**, a mail-order company specializing in the needs of sensitive people, also offers medium-efficiency filters. **Air Kontrol** manufactures them, under the Dust Patroller brand, that can be fitted with different types of media, one of which is impregnated with activated carbon.

Farr Co. has 20/20 and 30/30 pleated filters that are 1-2" thick. Though not as efficient as the ones above, they are somewhat more efficient than a standard furnace filter, and they do not require a special housing to be installed. They are often available through local heating/cooling equipment suppliers.

Also designed to be a substitute for a standard furnace filter, **Air Kontrol, Inc.** has a 1"-thick, pleated, medium-efficiency filter that is coated with an anti-microbial and is called a H.E.L.P.A. It is coupled with an electrostatic filter, and the combination yields fairly good efficiency. However, the electrostatic filter *must* be cleaned every 30-60 days. If it is not, the build-up of dust on the filter can cause clogging and excessive resistance to airflow. This can result in damage to the heating/cooling system.

Nutech Energy Systems, Inc. has a TFP (**T**urbulent **F**low **P**recipitator) air cleaner that is in the 80-90% efficiency range. It uses a fairly new technology by capturing particulates on a material similar to a standard furnace filter, but without having the air pass through the material. A TFP is designed to create *turbulent* airflow inside the unit, because this type of airflow causes particulates to *precipitate* (or be hurled) onto interior surfaces. By changing the direction of the air moving through the unit, particulates cling to the internal surfaces, which are made up of disposable collector filters. This results in high efficiency with over 3-4 years of maintenance-free operation, and with minimal restriction of the air flow. TFP air cleaners are also available from **American Aldes Corp.** and **Nutone.**

HEPA Filters

The most efficient particulate filters are called HEPA (**H**igh **E**fficiency **P**articulate **A**ccumulator) filters. These were originally developed during World War II by the Atomic Energy Commission to filter radioactive plutonium dust out of laboratory air. They are often used in medical and electronics labs where special “clean rooms” are necessary. HEPA filters typically remove over 95% of the particulates in the air. In fact, some have an efficiency of 99.999% at removing particles larger than 0.3 microns. They generally last 1-5 years before replacement is necessary. HEPAs are the most efficient particulate filters available, but for many residential applications they are overkill. While it is certainly desirable to remove all particulates from the air, the particulates most bothersome to allergy sufferers can usually be removed easily with a medium-efficiency filter.

Besides their high cost, a big problem with HEPA filters is that the fans used in most residential heating/cooling systems, and in ventilation systems, aren’t powerful enough to move air through them—these filters simply have too much resistance to airflow. There are, however, some companies that make packaged HEPA systems that contain their own fan to overcome the resistance of the HEPA. (See *Packaged filter systems* below.)

Adsorption Filters

In order to remove gases from the air, the process of adsorption (spelled with a D) is used. Adsorption filters work because of the fact that gaseous contaminants will adhere to certain surfaces. Cigarette smoke and mercury vapor cling to walls and ceilings because of adsorption. There are a variety of materials that are used in adsorption filters (*e.g.* zeolites, soda lime, silica gel), but activated carbon and activated alumina are the most common.

The life of an adsorption filter will depend on the air flow rate, the concentration of pollutants, and the amount of adsorption material present. As contaminated air moves through the filter, gas molecules adhere to surfaces of the adsorption material itself. Eventually, the surfaces become full and there is no more room for additional gas molecules to adhere. At that point the filter must be replaced. Adsorption filters are designed to remove gases, not particulates. If particulate removal is desired, a particulate filter can be combined with an adsorption filter.

In a situation where the concentration of gases in the air is variable, an adsorption filter will capture the gases when the concentration is high, then slowly release them into the airstream when the concentration is low.[381]

Because there can be a lot of air resistance with an adsorption filter, manufacturers often configure their filters to have more surface area so a powerful fan isn't necessary. In commercial applications, the adsorption material is often placed in trays with metal screen on the bottom. Several of these trays are inserted in an accordion-shaped cabinet to conserve space. Filters of this type are rarely used in residential situations because of the extra cost and engineering involved—but they are available. Manufacturers of multiple-tray adsorption filters include **Barnebey & Sutcliffe**, **Farr Company**, and **RSE, Inc.** These companies also usually offer adsorption materials in bulk. While multiple-tray adsorption filters can be very efficient at gas removal, most heating contractors are unfamiliar with them.

Activated Carbon

Activated carbon (also called activated charcoal) is the most widely used adsorption material. It is extremely porous and each granule has a tremendously large surface area. Activated carbon is made by the controlled oxidation of coconut shells, hardwoods, coal, *etc*. The material made from coconut shells is often better tolerated by sensitive people.

Activated carbon works very well at capturing a wide variety of high-molecular-weight gases such as benzene, toluene, ethers, acetone, *etc*. However, it does not work nearly as well with low-molecular-weight gases such as formaldehyde. If ozone comes in contact with activated carbon it will not adhere to the filter. Instead, the ozone undergoes

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[381] Mary Ellen Fise, "Indoor Air Quality: A Consumer Protection Issue," *Otolaryngol Head Neck Surgery* 106 (1992): 665-668.

a chemical reaction and is catalyzed into oxygen.

Many activated-carbon filters are comprised of granules approximately $^1/_8$" across. Other filter manufacturers glue an activated-carbon powder to a low-efficiency particulate filter. Either strategy can work, but to be truly effective, a filter needs a great deal of carbon. An ounce of carbon powder on an inexpensive filter will become expended very quickly. Some commercial filters contain 20-40 pounds of carbon.

Activated carbon can be specially treated to better remove specific gases. For example, while regular activated carbon isn't particularly effective at capturing formaldehyde, a treated carbon is readily available that is designed specifically to capture formaldehyde. Special carbons are also available to adsorb mercury vapor, ethylene, and hydrogen sulfide.

Several manufacturers produce thin (1") filters containing activated carbon: **Aero Hygenics, Inc.** (Hygi-flo), **Air Kontrol** (Odor Kontroller), **Barnebey & Sutcliffe** (Dacor, Pur Air Combo), **Columbus Industries** (Polysorb brand), and **Permatron Corp.** (Dust Plus). The **E.L. Foust Co.** is a retail, mail-order source for 1" filters (and thicker models) containing activated carbon. Thin filters are not as effective as multiple-tray adsorption filters,[382] but they are considerably less expensive, and they can easily be installed in residential forced-air heating/cooling systems. The Odor Kontroller line of 1" filters from **Air Kontrol** is available with either activated carbon, zeolite, or Purafil (see below), for different applications.

Activated Alumina

Activated alumina impregnated with potassium permanganate is another common adsorption material. It works well with low-molecular-weight gases—like formaldehyde. This material not only adsorbs gases, it also reacts with them and destroys them by oxidation. Sometimes an activated-carbon filter is combined with a filter containing special impregnated carbon or activated alumina for maximum gas removal. If this is done, it is important to place the activated carbon filter "upwind" from the alumina filter or else hydrochloric acid could be formed if chlorinated hydrocarbons are present in the air.[383] Manufacturers of activated alumina include **Purafil Corp.** (Purafil) and **Carus Chemical Co.** (Carusorb). Most filter manufacturers who offer activated-carbon filters also offer activated alumina, or a carbon/alumina mix, in bulk, as an option.

Packaged Filter Systems

In most applications, there are two kinds of pollutants in the air—gases and particulates—so it is desirable to have two kinds of filtration. Several companies have developed packaged systems that do just that. Some are made specifically for use with forced-air heating/cooling systems, but most are adaptable to a variety of applications.

Allermed Corp. offers a whole-house air filtration system for hypersensitive

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382 Christopher Muller, "A Comparison of Packed-Bed and partial-Bypass Gas-Phase Filters," *Indoor Air Review* (January 1993): 15.

383 "What You Should Know About Air Filtration," *The Human Ecologist* #23/24 (Fall/Winter 1983/84): 6-7.

individuals—a CS-2000 filtration package that can be used in conjunction with a forced-air furnace/air conditioner or with its own system of ducts as a stand-alone central filtration system. This unit consists of an insulated cabinet, a built-in high-efficiency fan motor, a prefilter, 40 pounds of adsorption material (several different products are available), and either a 90–95% or a 99% HEPA final filter. The company can modify this system to meet the specific needs of hypersensitive people. In one situation, they used organically raised cotton for gasketing.

General Filters Inc. has an AC-2 Air Purifier with a $4^1/_2$"-thick housing that mounts in the return-air duct of a forced-air heating/cooling system. It contains nearly $4^1/_2$ pounds of activated carbon inside a series of 18 tubes that minimize the resistance to airflow. This unit can be used alone or in conjunction with one of the company's medium-efficiency filters (see above).

Nutech Energy Systems, Inc. offers a Scrubber filter system designed for use in conjunction with an HRV central ventilation system. The standard model consists of a metal cabinet with eight slots containing a 1" prefilter, six 1" polyester filters impregnated with activated carbon, and a 2" pleated filter. As an option, either an electrostatic precipitator or an electrostatic air filter can be substituted for one of the carbon filters, or other more-efficient filters can be used. The amount of air resistance depends on the specific filters selected. Because this unit does not contain its own internal fan, the airflow is dependent on the particular ventilation system with which it is used. When coupled with a Nutech HRV capable of delivering 170 cfm, a Scrubber containing eight filters could have enough resistance to reduce the airflow by about a third.

Pure Air Systems, Inc. produces a 600HS that contains a prefilter, a 2" activated-carbon filter, and a 99%+ HEPA filter, all housed in a metal cabinet. Instead of the HEPA, the company's 600 OdorAdsorber contains a 16"-thick activated-carbon (or activated-alumina) filter for optimum gas removal. Either unit can be fitted with a single-speed or an optional two-speed, $^1/_3$-hp. fan capable of delivering 600 cfm. For higher-capacity situations, a 2,000-cfm model is available. Designed primarily for use in conjunction with a forced-air furnace/air conditioner, these filters can also be used as stand-alone whole-house recirculating units, or adapted for use with a fresh-air ventilation system.

Raydot, Inc. has a Purepak filter module that can be added to its heat-recovery ventilators to clean the outdoor air before it reaches the living space. A Purepak consists of an insulated metal cabinet with a pleated activated-carbon prefilter and a HEPA filter. It does not have its own fan, so it will result in a decreased airflow capacity when used with an HRV.

Therma-Stor Products has an "Ultra-Aire Purifying Dehumidifier" that consists of a metal cabinet, a built-in fan, and a whole-house dehumidifier. There are two options for the high-efficiency filter: either a 30%-efficient filter or a 95%-efficient pleated filter. This unit is rated to remove up to 100 pints of water a day. During operation, a certain amount of the airflow is pulled in from the outdoors, then it is filtered and dehumidified before distributing it to the house. It can be installed as a stand-alone unit or as a part of a forced-air heating/cooling system. This unit work particularly well in houses that have humidity problems, such as those in hot humid climates.

If you don't plan to use a pre-designed package filter, it is usually necessary to consult with someone knowledgeable about designing such an installation. Some filter suppliers or local heating/cooling contractors may be able to provide this service. Because some air filters restrict the flow of air to a certain extent, too many filters—or the wrong type of filter—can result in inadequate air moving through the system. This can mean insufficient hot (or cool) air reaching the living space. It can also mean overheating and damage to a fan's motor or an air-conditioner's compressor. Sometimes it's necessary to increase the capacity of the fan or the horsepower of the motor in order to compensate for the resistance of air cleaning equipment.

Portable Filters

There are many manufacturers now producing portable air filters of various types. For best performance, only room-sized models are recommended—desk-sized filters are generally to small to be of much benefit. Larger, more powerful models will clean the air faster, and more thoroughly, than moderately sized models. Size, efficiency, appearance, filtration strategy, *etc*., all have an effect on cost. These air filters can contain low-to-medium-efficiency particulate pre-filters, high-efficiency particulate filters (often HEPAs), activated carbon, impregnated alumina, or any combination.

Before deciding on a particular model, look over the product literature from several manufacturers first to become familiar with the various features. There are many manufacturers and mail-order suppliers of portable room sized air purifiers: **Aireox Research Corp.**, **Allergy Relief Shop, Inc.**, **Allerx**, **American Environmental Health Foundation, Inc.**, **Allermed Corp.**, **Austin Air**, **Befit Enterprises Ltd.**, **E.L. Foust Co., Inc.**, **Honeywell Inc.** (Enviracare), **The Living Source**, **N.E.E.D.S.**, **Nigra Enterprises**, and **Ozark Water Services and Environmental Services**.

Other Air-Cleaning Strategies

There are a variety of miscellaneous air-cleaning strategies that have been recommended at various times. Most have limited value when compared to the four healthy-house design principles of Elimination, Separation, Ventilation and Filtration. Some strategies are not recommended at all. However, there are situations where others have proved useful.

Air Fresheners

There are many different brands and types of air fresheners on the market. Some have been mounted inside a furnace cabinet or as a part of the general ventilating system. More commonly, they are used in rooms, on desktops, or in automobiles. Most tend to bother sensitive people—sometimes seriously. Introducing "the pleasing scent of lemons," or other aromas, into the air is actually contributing to indoor-air pollution because you are removing nothing from the air and, instead, are actually adding something—a fragrance. This may cover up, or mask, undesirable odors—but it doesn't remove them. One study found that air fresheners caused symptoms in test mice such as increases in sensory and pulmonary irritation, decreases in airflow velocity, and abnormalities of behavior.[384] In general, air fresheners are not recommended in healthy houses.

Some carpet fresheners consist of a fine powder with a fragrance added. They are designed to be sprinkled on the carpet to mask odors. It's been shown that the powder can remain airborne (and be inhaled) for up to 24 hours after application.[385] Vacuuming also redistributes the powder into the air. Fine powders can be inhaled deeply into the lungs, where they can lodge and cause damage. In some cases, powders can also abrade and damage carpet and rug fibers. These products are not recommended.

Negative-Ion Generators

Negative-ion generators are not air filters, but they can sometimes contribute to cleaner indoor air. They operate by spewing out electrons. The electrons attach themselves to particulates in the air and cause them to become negatively charged. These charged particles (ions) then attach themselves to various positively charged surfaces. If the negative-ion generator has a "downwind" particle filter, the charged particles will attach themselves to that filter. If the ions are simply spewed out into the room (as many are), the charged particles will attach themselves to walls and furnishings. Eventually some of the particulates lose their charge, detach themselves from the walls and furnishings, and re-enter the air. In the meantime, they can contribute to dirty walls.

Simply having negative ions in the air can have positive effects on well-being such as increased vigor, friendliness, alertness, and performance. Improved reaction times and diminished anxiety have also been noted.[386] In psychiatric hospitals, negative ions in the air have had a pronounced effect in alleviating symptoms of psycho-neurosis, apprehension, and fear.[387] These don't appear to be a health effects *per se*, but they are more related to a general feeling of well-being. While there are a variety of anecdotal reports of positive effects attributable to negative ions, a review of 800 reports found little actual scientific evidence to prove a cause-and-effect relationship.[388] A drawback is the fact that negative-ion generators produce a small amount of ozone.[389]

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384 Rosalind C. Anderson and Julius H. Anderson, "Toxic Effects of Air Freshener Emissions," *Archives of Environmental Health* 52 (November/December 1997): 433-441.

385 "Carpet freshener study," *Inside IAQ* (Spring/Summer 1995): 3. #EPA/600/N-95/004.

386 Felix Gad Sulman, *The Effect of Air Ionization, Electric Fields, Atmospherics and Other Electrical Phenomena on Man and Animal* (Springfield, IL: Charles C. Thomas Publisher, 1980).

387 Alayne Yates and others, "Air Ions: Past Problems and Future Directions," *Environment International* 12 (1986): 99-108.

388 "Ionizers: Do they do anything?," *Solplan Review* (August/September 1994): 6.

389 Environmental Protection Agency (EPA) *Indoor Air facts No. 7: Residential Air Cleaners* (Washington, DC: EPA, February 1990). #20A-4001.

House Plants

Stories in the popular media continue to report that certain house plants can clean the indoor air—despite research that shows them to be of limited value. The stories began after some interesting research was done at NASA that showed that spider plants (*Chlorophytum elatum* var. *vittatum*) could absorb various indoor air contaminates.[390] [391] The purpose of this work was to find a possible biological method of reducing the concentration of air pollutants in spacecraft. In NASA's original experiments, specific quantities of formaldehyde, carbon monoxide, and nitrogen dioxide were injected into closed chambers containing spider plants or golden pothos (*Scindapsus aureus*). Both types of plants seemed to absorb the contaminates, with the spider plant being the most effective. Further research found that the pollutants were actually being metabolized and rendered harmless by specific soil microbes that lived with those particular plants. Unfortunately, NASA's original research, which was originally done in the early 1980s, continues to be reported in the media—yet it has limited value in a typical polluted house.

NASA's experiments were done in a closed chamber with a specific quantity of a single air pollutant. Houses typically contain a wide variety of pollution sources that continually outgas many different contaminates. For example, particle board, and other formaldehyde sources, outgas continually for years. In this type of real-world environment, the plants (actually the soil microbes) will indeed metabolize some pollutants—but additional pollutants are continually added to the air to replace them.

Research at Ball State University has shown that, for most residential environments, plants are ineffective at reducing indoor pollution levels.[392] In fact, having plants indoors tends to result in a higher relative humidity—and formaldehyde emissions increase as the relative humidity rises. So, in a real-life situation, the formaldehyde absorbed by the plants is replaced by an increased rate of outgassing. While there is a reduction of formaldehyde levels if there are enough plants in a house, the reduction isn't significant. In the meantime, the plants can be releasing pollen and mold spores into the air that are bothersome to sensitive occupants. Plus, having very many plants indoors can result in a high enough indoor relative humidity for mold to grow on surfaces.[393]

Bake-out

The outgassing from a material can often be hastened by heating the material. As

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[390] B.C. Wolverton, Rebecca C. McDonald, and E.A. Watkins, Jr., "Foliage Plants for Removing Indoor Air Pollutants from Energy Efficient Homes," *Economic Botany* 38 (1984): 224-228.

[391] B.C. Wolverton, Rebecca McDonald, and Hayne H. Mesick, "Foliage Plants for Indoor Removal of the Primary Combustion Gases Carbon Monoxide and Nitrogen Dioxide" *Journal of the Mississippi Academy of Sciences* 30 (1985).

[392] T. Godish, " Botanical air purification studies under dynamic chamber conditions," (Dallas, TX: *Proceedings of the 81st Annual Meeting of the Air Pollution Control Association*, 1988).

[393] "Nature's Filter," *Safe Home Digest* (August 1991): 1.

an example, a baked-enamel finish is often tolerable for sensitive people, whereas a conventional enamel paint might take many months to outgas by itself. A few years ago, the idea of heating materials to hasten outgassing was applied to entire buildings.[394] This is called a *bake-out*. Initial results of bake-outs seemed to indicate that they could be useful in reducing VOC concentrations—but the procedure occasionally damaged parts of the building. For example, in a commercial building, the concrete floor slabs moved slightly causing carpet and vinyl flooring to buckle, a window cracked, and some wood doors warped.[395]

A bake-out involves warming up the interior of a building with the furnace, for at least 48 hours, to an above-normal temperature (at least 95°F) and simultaneously ventilating the building at a higher-than-normal rate.[396] This is easiest to do when indoor and outdoor temperatures are similar. In the middle of winter a furnace may be operating at capacity, and not be able to raise the temperature that much.

After some initial positive results, as researchers started investigating bake-outs more thoroughly, they encountered some unforeseen problems. For example, because it's difficult to heat up an entire building uniformly (it takes longer to heat up a concrete floor slab than carpeting) there will be some surfaces where temperatures are lower than the air temperature. Moisture from the air, and some volatile gases, can condense on these cooler surfaces. In one 3-day, 90°F bake-out, alcohols, oxygenated compounds, and chlorinated chemicals were found in water that had condensed during the bake-out.[397] Researchers also found that some chemicals were released into the air that aren't released at normal room temperatures, and that the post-bake-out outgassing rates were hardly lower than the prebake emissions. Bake-outs seem to have little effect on formaldehyde levels in a building,[398] probably because formaldehyde-containing materials, such as particle board, are thick enough to have a substantial reservoir of formaldehyde in them. It's been suggested that part of the reduction in emissions that has been seen is due to the drying of concrete during a bake-out. This results in a lower relative humidity indoors, and lower outgassing rates.[399]

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394 John Girman, "The Bake-out of an Office Building: A Case Study," *Environment International* 15: 449-453.

395 John Girman, "Volatile Organic Compounds and Building Bake-out," *Occupational Medicine: State of the Art Reviews* 4 (October/December 1989): 695-712.

396 J. Hicks, K. Worl, and K. Hall "Building Bake-Out During Commissioning: Effects on VOC Concentrations" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 3, Characteristics of Indoor Air*, 1990): 413-418.

397 "Bake-offs may not cure 'sick buildings'," *Science News* 136 (September 23, 1989): 206.

398 "Building Bakeout: A Treatment for Sick Buildings, Not a Cure," *The Wary Canary* #5: 9.

399 Charlene Bayer, Georgia Tech Univ., Personal communication.

The results of bake-outs are, at best, mixed. In fact, the concentrations of some compounds are higher after a bake-out, while others are lower. For thick materials, such as particle board, bake-outs have little long-term effect. Probably the best use of a bake-out is in a controlled setting by a manufacturer. In this way, a procedure can be tailored specifically to reducing emissions in one particular product.[400] This is already being done successfully with baked-on paints.

Ozone

Ozone is a well-studied air pollutant. It's very reactive and quickly damages soft human tissue. Yet, ozone is occasionally promoted as a *solution* to indoor air pollution.[401] This is because of its ability to react with certain pollutants and neutralize them. Proponents of ozone point to a chemical reaction showing that ozone and formaldehyde react to form oxygen and water vapor—two innocuous compounds.[402] Researchers at the National Institute of Occupational Safety and Health (NIOSH) point out that this reaction is exceedingly slow, and that ozone and formaldehyde can also react to form carboxylic acids.[403] In fact, a NIOSH study found ozone to be "ineffective in reducing the concentration of formaldehyde." [404]And another study found that there are many irritating chemicals that can be created by using ozone indoors—chemicals not there before—that are more irritating than the original chemicals.[405] Actually, at the very low ozone concentrations that are considered safe for humans, there isn't enough ozone to have any effect on indoor air pollutants.[406]

In a study where carpet was exposed to ozone, the concentration of some compounds went down, but formaldehyde, acetaldehyde, and a number of higher-molecular-weight aldehydes actually increased in concentration. Furthermore, the total

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400 Charlene Bayer. "An Investigation into the Effect of 'Building bakeout' Conditions on Building Materials and Furnishings" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate*, Vol. 3, Characteristics of Indoor Air, 1990): 581-586.

401 Barbara Baffa, "My amazing ozone generator—purifier & energizer," *The Wary Canary* #8 (1992): 10-11.

402 Henry Berman, "Industry taking second look at ozone technology for indoor air clean-ups," *Indoor Environment Review* (January 1997): 20-21.

403 Eric Esswein and Mark Boeniger, "NIOSH researchers find flaw in writer's letter" (letter), *Indoor Air Review* (May 1996): 6.

404 Tim Hickey, "NIOSH tests reveal serious flaws in ozone-generating purifiers," *Indoor Air Review* (January 1996): 1.

405 "Research indicates ozone can produce irritating chemicals indoors," *IEQ Strategies* (February 1998): 6-7.

406 "Research sheds new, unfavorable light on ozone generators," *IEQ Strategies* (February 1998): 2-4.

VOC level in the air actually increased in the presence of ozone. These additional VOCs were oxidation products resulting from the chemical reaction between ozone and non-volatile or semi-volatile materials.[407] If there is styrene in the air, ozone can react with it and produce formaldehyde, benzaldehyde, benzoaic acid, and acetophenone.[408] On the plus side, one Russian study did find that levels of phenol and formaldehyde in plastic-processing plants went down in the presence of a low concentration of ozone[409]—of course, houses aren't plastic-processing plants.

Most people develop symptoms within an hour or so when exposed to more than 0.3 ppm of ozone. However, repeated exposure causes a person's system to adapt, and symptoms no longer manifest themselves. According to the U.S. Food and Drug Administration ozone paralyzes a person's olfactory nerves, deadening their sense of smell.[410] This doesn't mean that an exposed individual is protected from adverse effects, it just means that they no longer sense what's happening to their body. Most indoor air quality experts frown on the use of ozone to clean up the air because it is unpredictable—and potentially dangerous to occupants. The **EPA** puts it simply on their web site: "When inhaled, ozone can damage the lungs."

In some cases, ozone can damage furnishings. For example, it will react with rubber compounds, leading to deterioration and, in at least one case, it bleached out a valuable Oriental rug.

Several states have issued statements against the use of ozone. In 1992, Minnesota's Attorney General brought a lawsuit for fraud against an ozone manufacturer,[411] and North Carolina health officials issued a statement recommending against their use.[412] Then, in 1996, an investigation by the Florida Attorney General into the claims of ozone-equipment manufacturers found no scientific evidence to prove

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407 C.J. Weschler and A.T. Hodgson, "Indoor VOCs: Is what you measure on Tuesday the same as what you measure on Wednesday afternoon?," *Proceedings of the ASHRAE national conference* 1992: 137-142.

408 Richard Kadulski, "Ozone generators," *Solplan Review* (March 1997): 6-7.

409 Galina Smirnova, "Improvement of indoor air quality by ozoning the incoming air" (Helsinki: *Proceedings of the 6th International Conference on Indoor Air Quality & Climate, Vol. 6, Thermal Environment, Building Technology, Cleaning*, 1993): 435-437.

410 Harold Hopkins, "The Cans and Can'ts of Air Purifiers," *FDA Consumer* (October 1982): 5-7.

411 *Summary of the Minnesota Attorney General's lawsuit against Alpine Air Products*, (Minneapolis: State of Minnesota Attorney General's Office, 1992).

412 Mike Ethredge, "North Carolina cautions against use of ozone-generating air purifiers, recommends addressing pollution source," *Indoor Air Review* (July 1992): 12-13.

ozone generators improve indoor air quality.[413] The California Department of Health Services has said "People should avoid using indoor air cleaning devices that produce ozone…(because) they can quickly produce enough ozone in a confined space to exceed California Stage 2 and 3 smog alert levels as well as worker health and safety standards."[414] In 1999, Health Canada advised the public not to use ozone generators in their homes.[415]

Ultraviolet Light

When air passes through ultraviolet light, a variety of things happen.[416] For example, viruses and other microorganisms can be killed,[417] some VOCs will be converted into other (sometimes less noxious) compounds, and a certain amount of ozone will be produced. At one time, ultraviolet lamps were marketed with a claim that they acted as a room deodorant. While ultraviolet light can be a useful method of cleaning the air in a specialized industrial, food-processing, or medical setting, it doesn't seem to be a viable approach for residences. **Allerx** offers a Bio-Fighter ultraviolet-light unit that is installed inside forced-air heating/cooling ductwork.

Filters for Sensitive People

While air filters are designed to remove pollutants from the air, they can also *generate* tiny amounts of air pollution. In other words, in the process of cleaning the air, filters can put something into the air that wasn't there before. In general, they remove far more particulates and gases than they emit so, in most applications, there is an overall benefit—often a significant one. However, some hypersensitive people are bothered by air filters. While they are usually bothered more by the pollutants the filter is removing from the air, they are sometimes also bothered by the tiny amount of pollution released by the filter. Here's why.

Mechanical particulate filters (*e.g.* standard furnace filters, medium-efficiency filters, and HEPA filters) are made of fiberglass or polyester fibers held together with some type of synthetic resin. Some filters are sprayed with a thin oil film to enhance their dust-capturing ability. In some cases, filters are treated with chemicals designed to kill mold, viruses, and bacteria. The amount of outgassing from these resins, oils, or coatings

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413 Anne-Marie Jennings, "Ozone generator manufacturers defend products, dispute recent Florida probe," *Indoor Environment Review* (March 1997): 1.

414 California Department of Health Services (CDHS), "News Release: State issues warning about ozone air cleaning devices" (Sacramento, CA: CDHS, April 27, 1997).

415 "Health Canada issues advisory on ozone generators," *Solplan Review* (March 1999): 6.

416 Cecily Dourrachad, "Researchers Could Clean Up Indoor Air with UV Light," *Indoor Air Review* (January 1994): 6.

417 Thomas J. Kelley, "Illuminate your mold," *Environmental Design & Construction* (May/June 2000): 37-41.

is quite small, and isn't considered a problem for most people, but some sensitive individuals can react to it. It's sometimes possible to reduce the outgassing from a particulate filter by "baking" it in an oven at 200°F for a couple hours. (Be sure the sensitive person is out of the house, the range hood is used, and the kitchen and oven are thoroughly aired out after the baking has been completed.) It's a good idea to check with the filter manufacturer before baking a filter because the high temperature can sometimes cause the resin to deteriorate and the filter to fall apart.

Because many particulate filters are made of fiberglass or polyester, they can shed tiny fibers into the airstream. This slight shedding occurs more when a filter is new. It's not considered a significant problem because most filters tend to remove far more fibers than they add.[418]

Electrostatic precipitators and negative-ion generators contain no resin, so there is no outgassing, but during normal operation they do generate small amounts of ozone. In most cases, these units put out less than 0.05 parts per million of ozone—for most people, this is not enough ozone to worry about. But some sensitive people are bothered by very low levels—levels that are considered safe by many experts—sometimes they are affected as low as 0.001 parts per million.[419] Electrostatic air filters don't generate ozone, but they are made of plastic which can bother someone sensitive to synthetic materials.

If an adsorption filter is placed downwind of a particulate filter, it can either adsorb the outgassing of the resin from a mechanical filter or catalyze the ozone from an electrostatic precipitator, converting it into oxygen. This is a good idea, but it has its drawbacks. Adsorption materials, such as activated carbon, are generally very dusty and they can release this fine dust into the air. In fact, they are often placed *upwind* of a particulate filter so the particulate filter will capture the dust that's released. If you want to place an adsorption filter downwind of a particulate filter, the dust can be minimized by thoroughly vacuuming the adsorption filter prior to installation.

If a warm fan motor is bothersome to a sensitive person, an adsorption filter could be placed downwind to adsorb the odors released by the fan. But from an engineering standpoint, locating a filter upwind of a fan is more desirable. This is because filtration is more effective when air is pulled through a filter than when air is pushed through it.

A variety of adsorption materials are available on the market, and sensitive people sometimes react to one but not another. For example, activated carbon made from coconut husks may be tolerable but that made from coal may not be.

In the vast majority of situations, filters can improve the quality of the indoor air. However, with hypersensitive people it's very important to determine if they will be affected by the filter itself before any equipment is installed. For example, it can be helpful to test a filter for personal tolerance before actually purchasing it. Some companies offer a guarantee, whereby a portable filter can be tested in the home and returned if it is intolerable.

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418 Monroe Shumate and John Wilhelm, *Evaluation of fiber shedding characteristics under laboratory conditions and in commercial installations* (Denver: Schuller International, n.d.).

419 John Bower, "Air Filters," *East West* (September/October 1991): 28-35.

Summary

People often look upon air filters as almost magical devices capable of purifying the air, no matter what it contains. In fact, filters are marvelous inventions, and engineers use them effectively in many ways. HEPA filters are used regularly in clean rooms in the electronics industry and in medical research labs. Adsorption filters keep airport terminals free of the odor of jet fuel and exhaust. Similar high-tech approaches can be used in residences, but the cost can be high because of the equipment itself, and the engineering design necessary.

In general, it is far more cost-effective to first practice the other healthy house design principles first: Eliminate pollution sources, Separate those you can't eliminate, and rely on Ventilation. Then, filtration can be used to deal with any minor pollutants that are left. This is even true in the electronics industry and in airports. For example, clean rooms are, first-of-all, built with healthy materials, and the best way to build an airport terminal is to construct the structure very tightly to separate as many outdoor pollutants from the interior space as possible, then filter the air before it is brought indoors by a mechanical ventilation system.

Yes, filtration can be important, but it is best used in conjunction with other strategies—as a part of the system approach to design.

9. Tight Construction

Without a doubt, modern construction practices have resulted in houses that are much tighter than those built a hundred years ago. Studies have even found that, on average, houses built in 1994 are tighter than those built in 1982.[420] In fact, the houses built in the last 5 years are 35% tighter than the houses built in the previous 5 years.[421] One of the reasons for this evolving tightness is the use of sheet materials—with drywall and plywood, there are fewer random holes for air to pass through. Plus, windows and doors continue to improve—today, virtually all manufacturers make products that seal very tightly.

In the 1970s, builders began experimenting with houses that were built as tight as possible.[422] These superinsulated houses had phenomenal energy efficiency—in the midst of an energy crisis, they had heating bills of only $100 for an entire year. Of course, there were some early mistakes, but these houses eventually led to a very good understanding as to how a house can be both healthful and energy efficient. Today, builders specializing in tight, energy-efficient construction often have reputations for building high-quality, healthy homes.[423]

But some people still remember the early mistakes and they condemn tight construction, citing the poor indoor air quality and excess moisture found in a few of the first houses that were built as tight as possible. And medical professionals sometimes link tight construction to indoor pollution, without having an understanding of building science.[424] That's like having a contractor discuss brain surgery. Some people have gone so far as to suggest that we return to building loose houses. This isn't very forward thinking. If we built houses like they used to, we wouldn't be able to afford the energy bills and, even with the high bills, we'd still be cold in the winter. A large turn-of-the-nineteenth-century midwestern farmhouse could have easily used a train-car load of coal in the winter—and still be drafty and uncomfortable. Instead of moving backwards, we should look at the tight houses that have no moisture problems—and good indoor air quality—and learn from them.

Even with houses getting tighter, there is still room for improvement. In other words, with a little effort, many of the houses being built today could be built even

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420 "Airtightness of Houses," *Solplan Review* (November 1996): 9.

421 "Airtightness Construction Trends," *Solplan Review* (May 1998): 8-9.

422 William A. Surcliff, *Super-Insulated Houses and Double Envelope Houses* (Andover, MA: Brick House Publishing Company, 1981).

423 Steve Andrews, "Weather Wise Guys," *Custom Builder* (June 1989): 16-18.

424 Robert McCunney, "The role of building construction and ventilation in indoor air pollution," *New York State Journal of Medicine* (April 1987): 203-209.

tighter.[425] In the previous few chapters, repeated references were made to tight construction. This chapter will tie together what is known about tight construction, show why it is a good idea, and explain how it is integral to the systematic approach to house design and construction.

Misconceptions

Misconception #1: *Tight houses have poor indoor-air quality*. Some do, but so do some loose houses. The problem isn't related to tightness as much as it is to the use of unhealthy building materials—and a lack of mechanical ventilation.

Misconception #2: *Tight houses have moisture and mold problems*. Some do, but excessive moisture and mold are also common in loose houses. Moisture and mold problems are often due to foundation or roof leaks, leaky plumbing, poor construction, a lack of mechanical ventilation, choosing an improper ventilation strategy, or accidental ventilation.

Misconception #3: *Chimneys don't function well in tight houses*. Again, this is true for some tight houses, but chimneys don't always function well in loose houses either. One answer is to use combustion-fired heating devices that have sealed combustion chambers.

Problems of poor indoor air quality, moisture, and poor chimney function are typically not due to tightness itself, but rather a failure to view a house as a system. According to one informed architect, "You can build tight buildings as long as you don't fill them full of poisons." [426] Fortunately there are ways of achieving energy efficiency without sacrificing health. According to an editorial in the *Journal of the American Medical Association*, "There is no doubt that unless a reasonable and logical plan is developed, the deleterious health impacts of excessive home tightening will be enormous." [427] The good news is that a reasonable and logical plan has been developed—the plan involves understanding a house as an integrated system consisting of various components and sub-systems that continually interact.

Loose vs. Tight Construction

With tight construction, healthy materials, controlled ventilation, and direct-vent, sealed-combustion heating devices, you can have a tight house *and* good indoor air quality. If you consider a house to be a system, tight construction has many advantages over loose construction. Most building scientists are of the opinion that tighter houses are an excellent idea, and the tighter the better. Here's how tight and loose compare.

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[425] Arnie Katz, "What's being built out there? Performance tests of 100 new homes," *Home Energy* (September/October 1997): 29-34.

[426] Mark Alvarez, "Healthy Building," *Practical Homeowner* (February 1987): 30-35.

[427] Peter A. Breysse, "The Health Costs of 'Tight' Homes," *JAMA* 245 (January 16, 1981): 267.

Comfort

Loose houses can be drafty and uncomfortable. This is especially true in the winter when wind and stack effect (natural ventilation) cause excessive cold air to enter the living space through the random holes in the structure. Too much of this natural ventilation during cold weather leads to excessively dry, uncomfortable indoor air. Tight houses are more comfortable because there are no holes for the cold air to enter through. Thus, tight houses aren't drafty, and they're generally not too dry in the winter—unless they are overventilated by a poorly designed mechanical ventilator.

Though it takes some effort, existing houses can be tightened enough to reduce drafts significantly.[428]

High Energy Bills

Loose houses can be expensive to heat. This is also most noticeable in the winter when stack effect is responsible for excessive infiltration and exfiltration. This form of natural ventilation often results in far more air exchange than necessary during the coldest part of the year—just when heating bills are already high. Tight houses are cheaper to heat because there are no holes for stack effect (or wind) to move air through. In fact, there are mortgages available for energy-efficient houses that take into consideration the fact that such houses have low energy bills. **RESNET** is a clearinghouse for information on energy-efficient mortgages.

Pollutant Entry

If a loose house becomes depressurized (something that happens fairly regularly in all houses) pollutants originating outside the living space can be sucked indoors. For example, air passing from the outdoors, through a wall, into the living space, can bring with it mold and pollen from outdoor plants, exhaust gases from passing traffic, or particulates and gases from materials inside the wall cavity—most notably from insulation. This is where the second healthy-design principle of Separation was derived—*separate* problem materials from the living space by building an air-tight barrier.

It isn't unusual for air to be sucked from the outdoors, through porous soil, through cracks in a foundation, and into a basement when the lower portion of a house is depressurized.[429] As the air moves through the soil, it can pick up contaminates like radon, lawn chemicals, termite-killing chemicals, spills from underground storage tanks, and ground moisture, and bring them all into the living space.[430] In a California study,

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428 Fred Lugano, "Fixing a Cold, Drafty House," *Fine Homebuilding* (October/ November 1996): 92-97.

429 Canada Mortgage and Housing Corp. (CMHC), *Soil gases and housing: A guide for municipalities* (Ottawa, ON, Canada: CMHC, 1993).

430 Jon Traudt, "Protecting People and Houses While Saving Energy," *Energy Exchange* (October 1993).

trichloroethylene was pulled into the air of a school from contaminated ground water.[431] In Ontario, methane from the soil of a former landfill site leaked into townhouses built there.[432] With tight houses, pollutants and moisture can't be sucked in because there are no random holes for them to pass through. Of course, pollutants could be brought indoors through a deliberate hole by a controlled ventilation system, but in such a situation you have the option of installing an air filter.

Tight construction not only keeps unwanted pollutants out, it also keeps insects out. Flies, spiders, even wasps, find their way indoors through the many gaps and cracks in a loose house.[433]

Hidden Moisture Problems

When an air-pressure difference causes air to move through the random holes in a loose house, it can carry moisture with it. If that moisture finds a cool surface inside the wall cavity, it can condense there—leading to mold growth. This can happen in the *winter* when a house is *pressurized*, and warm humid indoor air passes into a wall cavity and condenses on the cold sheathing or siding. If an air-conditioned house in the *summer* is *depressurized*, hot, humid outdoor air can get into a wall cavity and condense on the back side of a cool interior vinyl wall covering. With tight houses, there are still going to be air pressure differences, but with no holes, there are no pathways for the moisture to travel through to get into building cavities.

The Cost of Ventilation

Tight houses require mechanical ventilation, and ventilation equipment costs money to install and operate. Yes it does, but when you analyze all the factors involved, the energy costs in a tight, mechanically ventilated house are typically lower than in a loose, accidentally and naturally ventilated house. Plus, in a tight house, you have the option of installing an air filter on the incoming air supply. The actual operating cost of mechanical ventilation is routinely in the neighborhood of $100 a year in most parts of the U.S.—less than most people pay for telephone or TV-cable service, and far less that we routinely pay for health insurance coverage. Ventilation is just not a significant expense. In a loose house, there is definitely a cost associated with excessive natural ventilation—often a high cost—that is hidden in the high heating bills. The bottom line: The cost of mechanical ventilation in a tight house is typically less than the hidden cost of infiltration in a loose house.

Lack of Control

The big disadvantage to loose construction is lack of control—you simply have no control whatsoever over the indoor air supply. Mother Nature moves air in and out

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431 Marilyn Underwood, "Assessing the indoor air impact from a hazardous waste site: A case study," *Toxicology and Industrial Health* 12 (1996): 179-188.

432 Canada Mortgage and Housing Corp. (CMHC), *Study of houses affected by hazardous lands* (Ottawa, ON, Canada: CMHC, 1992).

433 "Air Sealing," *Solplan Review* (September 1997):3-4.

whenever she pleases, and she doesn't care if the natural ventilation rate is too high, too low, too uncomfortable, or too expensive. Chimneys and leaky ducts provide accidental ventilation which, in some cases doesn't cause problems, but it's common for combustion by-products and other pollutants to be sucked indoors. With no control, you sometimes have too much ventilation, but at other times you have none. On a calm day, when the outdoor temperature is mild, Mother Nature won't move any air into or out of a house, even if the windows are open.

For sensitive people, the control afforded by tight construction is an especially important advantage. This is because it allows them to operate their ventilation system intermittently, whenever the outdoor air is clean. Consider a house next to an orchard where trees are sprayed periodically with pesticides. In a loose house, pesticides will enter the living space due to natural and accidental ventilation whenever the orchard is sprayed. But with a tight house, you can turn off the mechanical ventilation system during spraying, and be perfectly safe. Then, once the outdoor air clears, you can turn the system back on. Most areas have some form of periodic outdoor pollution that can be avoided in a tight house with a ventilation system that is occasionally shut off. Smoke from a neighbor's wood stove or fireplace often hangs near the ground at night, polluting the neighborhood. In a tight house with the ventilation system turned off at night, the indoor air will be smoke-free.

When you have a tight house built with healthy materials and a controlled ventilation system, you have the best of all worlds. You'll have none of the disadvantages of loose construction and all the advantages of tight construction. If a house is overventilated naturally, energy is wasted, and the indoor air will be overly dry in the winter. When a house is underventilated, it can be unhealthy. But with controlled, mechanical ventilation you can have a rate that's "just right" all the time.

Tight Construction

In order to prevent an air-pressure difference from pushing or pulling air (which contains moisture and pollutants) through the random holes in the walls (and floors, and ceilings) of a house, you have two choices: 1) you can eliminate the air-pressure differences or 2) you can eliminate the holes.

Eliminating Air-Pressure Differences

You can certainly eliminate some of the accidental pressures—and that's often a good idea. For example, leaky ducts should be sealed whenever possible. On the other hand, most people wouldn't want to give up using a clothes dryer, which is also responsible for accidental ventilation. You might choose a controlled ventilation strategy that has balanced airflows, because it will not contribute to air-pressure differences in the house. But you can't possibly stop Mother Nature from applying pressures due to wind and stack effect. So, if you decide to eliminate air-pressure differences, you soon realize that you can eliminate some, but not all.

Sealing Holes

As it turns out, it's fairly easy to seal some of the holes in a house. In an existing house, you can plug up the holes that are easy to visualize and easy to get to, but there are other holes hidden inside building cavities that were cut by plumbers, electricians, and carpenters when the house was originally built, that you can't seal. If, for example, all the holes in an existing house added together equaled a hole about 2 sq. ft. in size (this is called the *effective leakage area* or ELA), after conscientious sealing, you might be able reduce the ELA to about 1 sq. ft. In existing houses, some leaks just can't be sealed—they must be lived with.[434]

Some of the biggest holes in houses transport air currents inside building cavities. For example, older houses often have huge gaps around chimneys, inside walls, above dropped ceilings, within kitchen soffits, *etc*.[435] Weatherization contractors call these *by-passes* and, when air moves through them, there can be a significant amount of heat loss in the winter.[436] [437] However, the air moving through bypasses may not affect the indoor air quality—after all, the air is moving inside building cavities, not within the living space itself. Sealing by-passes will often significantly lower heating bills.[438]

In new construction, with a little thought, you can eliminate almost all of the random holes. While it is not possible to seal 100% of the holes, many builders are able to build houses with ELAs of just a few square inches. Although not hermetically sealed, such a house will have many advantages over typical loose construction. The process of tightening a house is often called *air sealing*.

Materials for Sealing

To seal up the holes and prevent an air-pressure difference from moving air through the structure of a house, it's more important how materials are put together, than what materials are used. For example, if you built a house entirely of paper and securely taped every seam, there would be no holes, thus no way for air to move into or out of it. Granted, a paper house wouldn't be very sturdy, but the point is this—even something as flimsy as paper can be used to make an air-tight house. It's just a matter of sealing all the seams.

When you look at how a typical house is built, you quickly see that there are many different materials involved—wood, drywall, masonry, insulation, *etc*. The secret is to assemble all the pieces so, when two different components come together, there is some way to prevent air from moving between them. In the paper-house example above, we used tape where the different pieces of paper came together. But you could also use

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[434] Bruce Sullivan, "Tighten up with air sealing," *Journal of Light Construction* (January 1993): 33-34.

[435] *Minnesota House Warming Guide Series: Attic Bypasses* (St. Paul: Energy Information Center, July 1994).

[436] Alex Wilson and Steven Nadev, *Contractor's Guide to Finding and Sealing Hidden Air Leaks* (Lincoln, MA: Massachusetts Audubon Society, 1993).

[437] Dennis Creech, "Bypasses—Major Sources of Air Leakage in Homes," *The Southface Journal* (Winter 1992): 4-6.

[438] Thomas Blandy, "Finding Hidden Heat Leaks," *Journal of Light Construction* (August 1992): 25-28.

library paste, or silicone caulking, or anything else that would make a tight seal between the individual pieces of paper.

Library paste isn't a good sealing material in house construction because it isn't durable enough. If you want a house to remain sealed for several decades after it's built, you must use a long-lasting product. Some popular, and durable, materials include gaskets, caulking, aerosol-foam insulation, and drywall joint compound over paper tape. Yes, in some situations, paper tape works just fine. The durability of the sealing materials is actually quite important.[439] After all, you don't want to create an airtight house using materials that will degrade over time, yielding a house that isn't airtight a year into the future. Following are some materials that should stand the test of time.

A long-lasting caulking can be used in a variety of places to seal a house. A product called *acoustical caulking* has often been recommended because it remains non-hardening and flexible, so it has less chance of cracking over the life of a house. The Acoustical Sealant manufactured by **Tremco** is widely used by builders of energy-efficient houses. It has a fairly strong odor when wet but tends to lose its odor over time. Because, when used, it's sandwiched between building components, and not directly exposed to the living space, it should not affect indoor air quality. As an alternative, 100%-silicone caulking also works well, and aerosol-foam insulation is widely used to seal around doors and windows.

Seams between pieces of polyethylene sheeting can be sealed with 3-M #8086 contractors tape (**3M**), which can be mail-ordered from **Shelter Supply**. Two companies, **Denarco, Inc.** (Sure-Seal) and **Shelter Supply**, sell gaskets that are often used by builders who specialize in tight construction. Airtight electrical boxes are sold by **Thomas & Betts** (Nu-Tek brand) and **Ryeco Products** (R & S Enviro brand).

If the airtight electrical boxes mentioned above aren't sealed properly, or if they develop a leak after installation (perhaps resulting from a loose gasket) they can't be easily resealed—unless you tear out some of the drywall. There is a Lessco plastic box (**Low Energy Systems Supply Co**.) that can be used to make a conventional plastic or metal electrical box airtight. If a Lessco box develops a leak, it can be made airtight by drilling a small hole next to the electrical box, and injecting some urethane foam into the space between the Lessco box and the electrical box. A variety of these types of energy-related construction products can be mail-ordered from **EFI**.

Ryeco Products (R & S Enviro brand) offers an insert device to make existing electrical boxes airtight. And **K-Products** has a gasketed cover plate, with small easy-to-use sliding doors over the receptacles, to make an electrical box both air tight and child safe. However, one of the easiest ways to tighten an existing electrical box is to install a foam gasket behind the cover plate. Although they won't be as tightly sealed as in new construction using airtight boxes, these gaskets do a reasonably good job. They are routinely available in hardware stores and building-supply centers.

Most of the recessed ceiling lights on the market are quite leaky. They can allow excess heat from the living space to enter the attic,[440] which results in energy losses—and

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[439] Durability of Airtightness Techniques," *Solplan Review* (September 1998): 11.

[440] "Air and moisture leakage through recessed ceiling light fixtures," *Energy Design Update* (January 1994): 6-7.

moisture in the attic, which can result in damage. It's been estimated that a single leaky recessed ceiling light is responsible for $5-30 worth of energy per year being lost.[441] But airtight recessed fixtures—though not commonly used—are readily available.[442] Manufacturers include **Hubbell Lighting** (ICX7-ES, ICX&-ES2), **Juno Lighting** (Air-Loc), and **Cooper Lighting** (Halo AIR-TITE).

Scientific Component Systems has a series of recessed airtight light fixtures that accept compact-fluorescent bulbs. Some are designed for new construction, and some can be retrofitted to existing recessed fixtures to make them airtight. Retrofitting existing fixtures can be much easier than removing old fixtures and installing new ones.

Ado Products has a Quick-Seal Insulated Attic Hatch Cover that seals to the ceiling with a foam gasket. It can easily be removed for access by turning four special turnbuckle fasteners.

Air-Pressure Barriers (Retarders)

People often talk about an air barrier (more correctly called an air-pressure barrier, or an air-flow barrier) as if it were a single material. But an air-pressure barrier is really more of a concept. In our paper-house example, two materials—paper and tape—were combined to form an air-pressure barrier. An air-pressure barrier typically consists of a number of different materials combined to form a continuous surface with no holes in it.

Actually, because it is impossible to seal a house 100%, it isn't technically correct to use the word *barrier*—the word *retarder* is more accurate. That's because the airflow can't be blocked completely, but it can be retarded a great deal. So, we should say *air retarder,* or *air-pressure retarder*, or *air-flow retarder* instead of using the word *barrier*. Still, the term *air barrier* continues to be widely used.

There are a number of ways an air-pressure retarder can be incorporated into new house construction, but two are popular: sealed plastic sheeting and the airtight drywall approach (ADA).

Sealed Plastic Sheeting

After a house has been insulated, many builders cover the inside surface of the insulation with large sheets of polyethylene plastic. This is often referred to as a moisture barrier or moisture *retarder*. (We'll talk about this later in this chapter. For now, we'll only consider the concept of an air-pressure retarder.) The plastic sheeting is typically applied directly to the studs prior to attaching drywall, plaster, or wood paneling.

In most houses where plastic sheeting is used, it isn't sealed very well. Two sheets may overlap, but there is no tape or caulking between them. A sheet may be stapled loosely along its edges, without being secured to the floor. Openings around windows are rarely sealed, nor are the openings in the plastic sheeting around electrical outlets.

In order for plastic sheeting to block the flow of air due to air-pressure

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441 "Airtight recessed ceiling light fixtures for moisture control," *Energy Design Update* (February 1992): 7-9.

442 J.D. Ned Nisson, "New, improved recessed lights," *Journal of Light Construction* (November 1992): 36-37.

differences, it must be combined with other materials to form a single unbroken surface completely surrounding the living space. This takes a bit of thought, but it can be, and is being, done by builders throughout North America. For example, to prevent air from moving around the edges, plastic sheathing can be caulked to the subfloor, caulked to window and door frames, and caulked to other pieces of sheeting.[443] Special airtight electrical boxes are manufactured to prevent additional air movement, and details have been worked out to seal the sheeting around plumbing lines and heating/cooling duct penetrations.

For more information about the techniques for sealing an air-pressure retarder consisting primarily of plastic sheeting, see the *Builder's Field Guide*[444] which is available from the **Bonneville Power Administration**. A few key details are also available in the **Shelter Supply** catalog. And climate-specific details can be found in a series of excellent *Builder's Guides* produced by **Building Science Corp.**

One disadvantage to polyethylene is that it can deteriorate inside a wall cavity and become damaged and ineffective without the occupants being aware of it. This generally occurs behind electric baseboard heaters where the elevated temperature causes the plastic to break down, become brittle, and fall apart. Ozone, generated by electrostatic precipitators or other appliances, will also contribute to deterioration. **Sto-Cote Products, Inc.** (Tu-Tuf) and **Yunker Plastics, Inc.** (Dura Tuff) produce heavy-duty polyethylene products that are quite durable.

Some sensitive people are concerned about outgassing from plastic sheeting or caulking migrating into the living space. While this is possible, it is unlikely that enough outgassing would get through the drywall or plaster to be a problem. After all, if you seal up the holes, there will be no air pressure differences to push pollutants through a wall assembly.

Airtight Drywall Approach (ADA)

Because of difficulties some builders have with sealing flexible polyethylene sheeting, a different method of construction has been developed. It avoids the pitfall of having the polyethylene deteriorate inside the wall cavity. It's called the Airtight Drywall Approach (ADA). The actual construction techniques are not difficult and they can be

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443 Clayton DeKorne, "Sealing around Windows," *Journal of Light Construction* (June 1990): 28.

444 Oregon State University, *Builders Field Guide* (Portland, OR: Bonneville Power Administration, n.d.). Available from **Bonneville Power Administration**.

applied to virtually any style house.[445] [446] [447]

With ADA, drywall is the principle material used to form the air-pressure retarder. During installation, care is taken to insure that the joints between the drywall and various other materials are sealed thoroughly. Special care is taken around windows, doors, electrical outlets, *etc*.

A common leakage point in houses is the small gap formed where a wall meets the floor. With ADA, a bead of caulking, or a special gasket, is placed on the subfloor before the wall frame is even erected. Once this is done by the framing crew, the wiring, plumbing, insulation, *etc*., are installed in a conventional manner. Then, another bead of caulking, or a gasket, is applied to the inside face of the lower 2x4 (or 2x6) wall plate. When the drywall is installed, it will compress this second gasket, and will be sealed against the plate. So, by using just a few different materials, the floor is sealed to the lower wall plate, and the wall plate is sealed to the drywall, forming a continuous well-sealed surface.

Simply using paper tape and drywall joint compound in the standard manner will prevent air from moving between the sheets of drywall. With special provisions around electrical outlets, windows, doors, *etc*., ADA can provide a continuous and tight air-pressure retarder.

Some of the materials used in the ADA technique can be bothersome to very sensitive people. For example, rubber gaskets, caulking, and aerosol-foam insulation can be problematic if they are exposed directly to the living space. But with ADA, these materials are not exposed to the living space, so they are rarely a problem. In fact, the advantages of tight construction far out weigh the small chance that these materials would be bothersome. Besides, these materials are installed relatively early in the construction process, so they will have some time to outgas before the interior of a house is finished and occupied by a sensitive person.

Good sources of information about ADA include the *Builder's Field Guide,*[448] published by **Advanced Energy**, *The Airtight House*,[449] published by the Iowa State University Research Foundation, and the *Builder's Guides* published by **Building Science Corp.** *Healthy House Building for the New Millennium* by John Bower shows the technique in a step-by-step manner in both photos and text.

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[445] G.O. Handegord, *A System For Tighter Wood-Frame Construction* (Ottawa, ON, Canada: Division of Building Research, National Research Council Canada, January 1984). Building Research Note #207.

[446] "Feature The Airtight Drywall Approach," *Energy Design Update* (September 1984): 5-10.

[447] Rich Slayton, "The Airtight Drywall Approach," *Fine Homebuilding* #9 (February/March 1987): 62-65.

[448] Applied Building Science Center, *Exemplary Home Builder's Field Guide* (Raleigh, NC: North Carolina Alternative Energy Corp., n.d.).

[449] James Lischkoff and Joseph Lstiburek, *The Airtight House: Using the airtight drywall approach* (Ames, IA: Iowa State University Research Foundation, 1985).

Determining Tightness

You can tell a builder to build a tight house, but how do you know if he really did a good job? And how can you tell if a weatherization contractor or insulation installer really tightened up your existing house? In other words, how can you tell just how tight a house is?

Blower-door testing is being used more and more by general contractors, insulation installers, weatherization agencies, and utilities to determine house tightness. It involves using a special fan (a blower door) to pressurize (or depressurize) a house under controlled conditions.[450] [451] Most blower-door operators exhaust enough air to cause a house to be depressurized to 50 Pascals (A Pascal [Pa.] is a tiny unit of pressure measurement. There are about 7,000 Pa. in one pound per square inch.), then they precisely measure the airflow through the fan. If they need to exhaust a great deal of air to reach 50 Pa., it means the house is loosely constructed. But if they get to 50 Pa. by only exhausting a little air, the house is tight.

So, if you want to know just how tight a house is, you should have it tested with a blower door. In leaky houses, you may need to exhaust 4,000 cfm or more to reach 50 Pa. (Technicians refer to this as 4,000 cfm_{50}.) Some of the tightest houses can be depressurized to 50 Pa. by blowing as little as 100-200 cfm out of them (100-200 cfm_{50}). Although there are a number of factors to consider, it's generally stated that if a house is tighter than about 1,500 cfm_{50}, it should have mechanical ventilation. There are several blower-door manufacturers, including **The Energy Conservatory** (Minneapolis Blower Doors) and **Retrotec, Inc.**

House tightness can also be measured by using a tracer gas. This involves injecting a certain quantity of an inert gas into a house, measuring its concentration, then waiting a specified time and measuring the concentration again. The second measurement will be lower because some of the gas will have leaked out through the random gaps and holes in the house. The leakier the house, the less gas will be left when the second measurement is taken. The problem with this approach is that it will only give you information for the time the house was tested. Because the amount of air flowing into and out of a house is a function of many factors (*e.g.* wind, stack effect, duct leakage, *etc*.), a blower door is more commonly used because it can overcome all those factors and give you a standardized evaluation that can be compared to other houses. Still, tracer-gas testing has a place and is used by some researchers. Both ASTM[452] and ASHRAE[453] have standard protocols available.

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450 Marc Rosenbaum, "Testing Homes for Air Leaks," *Fine Homebuilding* (February/March 1994): 51-53.

451 Gary Nelson, Robert Nevitt, and Gary Anderson, "Are your Houses Too Tight?," *Journal of Light Construction* (August 1994): 29-33.

452 ASTM, *Standard Test Method for Determining AirChange in a Single Zone by Means of a Tracer Gas Dilution*, (Philadelphia: ASTM) Standard E741-95.

453 ASHRAE, *Standard 129-1997—Measuring Air Change Effectiveness* (Atlanta: ASHRAE).

What About Diffusion?

When an air-pressure difference moves air through a hole, the air typically contains gaseous pollutants, particulate pollutants, and water vapor. But there is another way pollutants and moisture can move through a wall—by diffusion. With diffusion, *some* components of air can actually move through a solid material—holes and air-pressure differences are not a factor. But diffusion can only account for the movement of gases and vapors, it cannot account for the movement of particulates. So if you build an airtight house with no holes, particles of insulation, mold spores, and pollen won't be able to pass through. But diffusion can be a factor.

How Does Diffusion Work?

Diffusion only moves a gas or vapor through a solid surface if there is a difference in concentration of that gas or vapor from one side of the surface to the other. For example, if there is a low concentration of formaldehyde both inside and outside a house, but for some reason there is a high concentration within a wall cavity, then the formaldehyde will diffuse through the materials making up the wall, both towards the indoors and the outdoors, to try to make the concentrations the same indoors, outdoors, and within the wall cavity.

If there is more water vapor on one side of a solid material than on another side, it will diffuse through the surface until the concentrations are the same on both sides. But if a gas or vapor is present in the same concentration on both sides of a solid material, the concentrations will remain equal and unchanged.

Is Diffusion Important?

Something that surprises many people is the fact that diffusion is extremely slow—so slow that the quantity of pollutants and moisture that travel through walls (and floors, and ceilings), just because of diffusion, is generally insignificant.

In fact, if you carefully analyze the laws of physics that apply, it can be determined that, in a typical house, 99% of the moisture and pollution travels through holes in the structure because of air-pressure differences—and only 1% of the moisture and pollution travels through a typical structure because of diffusion. So, if you build an airtight house by sealing up all the holes, you will solve 99% of the problem. Unfortunately, there is widespread misunderstanding in the construction industry about how insignificant diffusion is, and how important it is to seal holes.[454]

Why the Confusion?

The confusion surrounding diffusion goes back to the energy crisis of the 1970s when serious house tightening first got under way. Part of the problem is related to terminology. When early superinsulated houses started experiencing moisture condensation inside insulated building cavities in the winter, it was quickly understood that the moisture was getting into the cavities from the living space. For example, in research studies, water was found condensing inside walls in the vicinity of holes in

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454 Scott Gibson, "Air and vapor barriers," *Fine Homebuilding* (April/May 1994): 48-53.

polyethylene sheeting near electrical outlets.[455] It didn't take long before there were heated discussions about *moisture barriers*. Builders started carefully sealing the seams in the plastic sheeting they were using, and the moisture problems went away. When scientists started analyzing the way moisture was getting into the building cavities, they realized there were two mechanisms at work—moisture was primarily moving through holes because of air-pressure differences, and secondarily because of diffusion.

As builders started sealing the plastic sheeting very well, they began calling the plastic an *air/moisture barrier* or an *air/vapor barrier*, because it was actually performing two functions—it was blocking the transport of water vapor by diffusion, and blocking the air-pressures that moved air through holes. Then, the experts realized that most building materials weren't true *barriers* to diffusion. For example, plastic sheeting did an excellent job of blocking diffusion, but it wasn't perfect. So, they started referring to *air/moisture retarders* and *air/vapor retarders*. About the same time, a few people realized you could use two different materials to perform the two different functions. So, they started calling the materials that blocked the air movement through holes *air barriers* (and later *air retarders*), and the materials that blocked water vapor by diffusion *vapor barriers* (and later *vapor retarders*).[456]

Because water vapor could be transported through a building because of both air pressure and diffusion, *vapor retarder* evolved into *vapor-diffusion retarder*. Then, people realized that we were really talking about more than water vapor—we were talking about gases like carbon monoxide and formaldehyde too. So, today, *vapor-diffusion retarder* has been shortened to simply *diffusion retarder*.

As was mentioned earlier, because it's impossible to seal *all* the holes in a house, the terms *air barrier* and *air-pressure barrier* and *air-flow barrier* aren't technically correct. So, as with diffusion terminology, when blocking air movement the word *barrier* is being replaced with the word *retarder*. Thus, the more correct terminology to use is *air retarder* (or *air-flow retarder* or *air-pressure retarder)* and *diffusion retarder*.

The thing that has gotten lost in all the jargon is the fact that diffusion is not very significant. In fact, some experts believe that, if you do a very good job of sealing up all the holes in a house, diffusion can be ignored! Well, that may be so, but a diffusion retarder isn't very expensive, and it's easy to install, so most tight-house builders use one anyway—as cheap insurance. Plus, because building codes often require them. (Because building codes tend to lag somewhat behind state-of-the-art technological knowledge, they don't yet address the importance of sealing holes, but they do address the less important diffusion retarder.)

Diffusion-Retarder Materials

Diffusion describes how gases and vapors pass through a solid material. Gases

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455 G.E. Sherwood, *Condensation Potential in High Thermal Performance Walls - Cold Winter Climate* (Madison, WI: U.S. Forest Products Laboratory, May 1983). Research Paper FPL 433.

456 R.L. Quirouette, *Building Practice Note: The difference between a vapour barrier and an air barrier* (Ottawa, ON, Canada: National Research Council Canada, Division of Building Research, 1985). #BPN 54.

and vapors will move through some materials faster than others. If a material only allows for a very slow rate of diffusion, it is said to be a diffusion retarder.

Most common building materials have been tested to determine their perm (permeance) rating. This is the rate at which water vapor travels through them. A perm rating of zero means no moisture will pass through. Aluminum foil and glass have perm ratings of zero. Polyethylene sheeting (4 mil thickness) has a very low perm rating of 0.08, and enamel paint has a perm rating of about 1.0. Although diffusion ratings are different for different gases, a low perm rating for water vapor generally also means a low gas-diffusion rate.

When used in an existing house, a paint with a low perm rating is usually sufficient to minimize diffusion. Many manufacturers have primers that function as diffusion retarders. They typically contain an ingredient called styrene butadiene[457] which is also used in carpet backings, and has been suspected of causing health problems related to new-carpet installations. Actually, if you have a good air-pressure retarder, most ordinary paints have enough of a perm rating to prevent most diffusion.[458]

In new construction, several common materials function well as diffusion retarders. The asphalt-impregnated paper on fiberglass insulation, and polyethylene sheeting, are commonly used. Builder's foil, which is a sandwich of aluminum foil and Kraft paper, also works well. It's usually available in 3'-4' wide rolls. Most manufacturers offer it as a solid material, which functions well as a diffusion retarder, and perforated with hundreds of tiny pin pricks, which can block airflow but not diffusion. **Denny Sales Corp.** sells four different foil/Kraft paper sandwich products (Denny foil). They have a solid material with foil on either one or both sides of the Kraft paper, and a perforated material with foil on either one or both sides. See *Reflective-foil insulation* in *Chapter 17, Insulation* for additional suppliers of builders foil.

Foil-backed drywall also works well as a diffusion retarder, but it must usually be special ordered. Foil-backed drywall is readily available from all drywall manufacturers, but it's rarely stocked by local suppliers, but they can usually get it if given a few days lead time.

Diffusion-Retarder Location

The most important component of air that diffusion must address is water vapor. This is because water vapor is often found at a significant difference in concentration from one side of a wall to another. To minimize the amount of water vapor that will diffuse through a wall, and to minimize the possibility of condensation within wall cavities, a diffusion retarder needs to be in a certain location inside a wall—and that location is different in different climates. Most of the books dealing with diffusion

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457 "The reliability of vapor barrier paints," *Energy Design Update* (May 1995): 6-9.

458 "Ordinary paint as replacement for poly vapor retarder," *Energy Design Update* (May 1994): 5-7.

retarders say they should be located on the warm side of the wall.[459] [460] The rule of thumb is this: in cold climates the diffusion retarder should be installed close to the indoors, and in hot climates it should be located close to the outdoors. So, in Minnesota, a diffusion retarder might be installed just behind the drywall, but in Florida it should be close to the exterior siding.[461]

If you extend the above rule of thumb to apply to the central U.S., where it's cold part of the year and hot part of the year, you might think that the diffusion retarder should go in the center of a wall. And that's exactly where it should go. In practice, that can be difficult to accomplish, but the same effect can be achieved by using a layer of insulating foam sheathing on a house. This works because the foam itself acts as a diffusion retarder and its thickness (typically 1-3"), means the inner surface is thermally in the center of the wall.[462] While a detailed discussion of diffusion and moisture transport is beyond the scope of this book, one of the most complete sources of information is the *Moisture Control Handbook*.[463] Although not nearly as complete, the 51-page *Controlling Moisture in Homes* discusses basic moisture-control concepts.[464]

In a cold climate, a diffusion retarder near the indoors will help prevent water vapor from the living space from diffusing into insulated building cavities, and it will also help prevent gases from the insulation from diffusing in the other direction—into the living space. In hot climates, a diffusion retarder near the outdoors will help prevent water vapor from outdoors from diffusing into the insulated building cavities,[465] but it won't prevent the diffusion of gases from the insulation from diffusing into the living space. However, this isn't a significant concern, because the quantity of gases transferred by diffusion is so insignificant when compared to quantity of gases transferred by air-pressure differences through holes.

Diffusion retarders should always be installed where they will best minimize

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459 National Center for Appropriate Technology (NCAT), *Moisture and Home Energy Conservation*, (Butte, MT: NCAT, n.d.). GPO 061-000-00615-0.

460 D. Eyre and D. Jennings, *Air-Vapour Barriers* (Ottawa, ON, Canada: Energy, Mines and Resources Canada, 1983).

461 Gary Cook and Virginia Peart, *Construction and Design Protocol for Reducing Moisture and Other Indoor Air Quality Problems in Warm, Humid Climates* (Gainsville, FL: University of Florida, Florida Energy Extension Service, 1993).

462 J.D. Ned Nisson, "A wall for all seasons," *Journal of Light Construction* (January 1990): 40-41.

463 Joseph Lstiburek and John Carmody, *Moisture Control Handbook* (New York: Van Nostrand Reinhold, 1993).

464 National Association of Home Builders (NAHB), *Controlling Moisture in Homes* (Washington, DC: NAHB, 1987).

465 Joseph Lstiburek, "Moisture woes in the South," *Custom Builder* (January/February 1994): 28-32.

moisture problems. It's been estimated that half of the houses in hot, humid climates have the potential for hidden moisture problems—often because the diffusion retarder is in the wrong location.[466]

Sealing a Diffusion Retarder

An air-pressure retarder should be as tight as possible because it is the primary line of defense at reducing moisture and pollutant transfer through walls. On the other hand, because diffusion is such an insignificant factor, a diffusion retarder can be imperfect.[467] So, if you plan to use polyethylene sheeting as a diffusion retarder, and regular drywall as an air-pressure retarder, you should seal the drywall as tightly as you can, but the diffusion retarder doesn't need to be sealed very well at all. Of course, if you plan to use polyethylene sheeting as *both* a diffusion retarder, *and* an air-pressure retarder, it should be securely taped and very well sealed wherever there could be air movement through or around it.

Summary

Airtight construction, heating/cooling, ventilation, and filtration are the most interrelated parts of a house and they should all be planned for together. In general, airtight construction has many advantages, not the least of which is improved indoor air quality, but it must always be combined with the use of a controlled ventilation system. An airtight house without ventilation is like a scuba diver without an air supply.

When designing a tight house, pressure-tight is far more important than diffusion-tight, but in most cases a diffusion retarder is a good idea because it's easy to install.

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466 Joseph Lstiburek, Building Science Corp., Personal communication.

467 "The last word (we hope) on vapor barriers," *Journal of Light Construction* (August 1993): 13-17.

Part 3: MATERIALS AND COMPONENTS

10. Concrete and Masonry

Concrete and masonry products can be used in a variety of ways in house construction. For example, concrete is often used in foundation and flooring systems, but it can also be used for walls and roofs. Masonry is commonly used for walls, both above and below ground. In general, these materials are well tolerated by sensitive people, however there are occasional instances where they have caused health problems.

Concrete

Concrete is a mixture of cement, aggregate, water, and admixtures. When these ingredients are combined, the cement and water undergo a chemical reaction and solidify. If you place your hand on concrete as it hardens, it will feel warm, evidence of the chemical reaction taking place. Many people use the terms *concrete* and *cement* interchangeably, but they are not the same thing. Cement is one ingredient of concrete, just as flour is one ingredient of bread.

There are several different cements that can be used in making concrete, although only one is commonly available. Similarly, there are different materials that can be used for aggregate. In most cases, the aggregate will be a material that's readily available in your particular geographic area. The water is generally tap water.

The exposed surface of concrete usually has either a smooth or a brushed finish. There are, however, other attractive finishes. For example, exposed aggregate can provide more color and texture, or metal forms can be used to impress a pattern in the surface before the concrete solidifies. Both approaches require some skill, so they are best left to an experienced contractor.[468] Pattern-form manufacturers include **Increte Systems** and **Bomanite Corp.** Patterns include brick, field stones, slate, wood plank, flagstone, *etc*. The pattern form manufacturers can direct you to a trained contractor in your area. Colorants are readily available (see below) if you aren't particularly enamored with the standard gray. Concrete doesn't have to be plain and dull looking. With a little thought and planning, it can be a striking architectural accent.

Cement

Cement acts like a glue to hold concrete together. Type I Portland cement is by far the most widely used today. Portland cement got its name in 1824 because it resembled a type of building stone found in Portland, England. There are five different Portland cements available—Type I is a general purpose cement. Types II, III, IV, and V have specialized uses and are rarely used in general construction. For example, Type IV produces very little heat when it hardens. This quality is only important when large, massive structures are being built, such as Hoover Dam. Type III is a rapid-hardening cement that is sometimes used in cold weather and Type V is used where the ground

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[468] Dennis Golden, "Specialty Finishes for Concrete Slabs," *Journal of Light Construction* (October 1996): 29-32.

water or soil has high sulfate levels.[469]

Type I Portland cement contains mostly calcium oxide, with lesser amounts of silica, alumina, and iron oxide. A small amount of gypsum may also be added. The other types of Portland cement contain similar ingredients in different proportions.

Portland cement is produced by heating the ingredients in a kiln to a temperature of about 2,700°F. The materials melt to form *clinkers* which are ground into a powder. Cement kilns are fueled by coal, natural gas, electricity—and hazardous waste. Beginning in the early 1980s, some cement kilns have been used as hazardous waste incinerators. The **EPA** allows cement kilns to burn 125 different chemicals, and they burned about 2.6 billion pounds of liquid and solid hazardous waste in 1991 alone.[470] They can burn such things as used motor oil, solvents, printing inks, and scrap tires. In theory, the high kiln temperature causes the hazardous waste to break down into less-toxic by-products.[471] Promoters say this is a good way to dispose of hazardous waste and, at the same time, produce a marketable product—cement. Detractors point out that incinerators don't always burn toxics completely, they can produce air pollution, they are difficult to monitor, and they sometimes create by-products like dioxin. Actually, cement kilns operate at much higher temperatures than municipal solid-waste incinerators so, in theory, they should burn more cleanly, and produce less emissions.[472] However, cement kilns are relatively unregulated[473] and toxic residues can end up in cement dust, or be released into the atmosphere through a kiln's smokestack.[474]

Coal, coke, and hazardous waste are the most polluting fuels in the cement industry, while natural gas and electricity are the cleanest. Many other building materials are much more serious air polluters than cement but, if a potentially unhealthy product can be avoided, it's a good idea to do so. Today, approximately half of the cement kilns in the U.S. burn some hazardous waste. To locate one that doesn't, contact your local concrete supplier and ask where their cement comes from, then call the cement manufacturer and ask them what they use for fuel.

While it's possible that some fuels could contaminate the cement, it's unlikely such contamination would seriously affect the air quality in a house containing concrete. This is especially true if the concrete isn't directly exposed to the living space—for example, when used in concrete footings, or in a concrete slab covered with ceramic tile.

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469 Clayton DeKorne, "Ordering Ready-Mix Concrete," *Journal of Light Construction* (October 1992): 22-24.

470 "Cement Dust," *Our Toxic Times* (April 1993): 2-3.

471 Ed Randegger, "Toxic Cement: A Burning Issue," *Environ* #12 (1991): 5-10.

472 "Cement and Concrete: Environmental Considerations," *Environmental Building News* 2 (March/April 1993): 1.

473 Betsy Carpenter and David Bowermaster, "The Cement Makers' Long, Sweet Ride," *U.S. News and World Report* (July 19, 1993): 51-53.

474 Susan McCrone (letter and editorial reply), "On Burning Hazardous Waste in Cement Kilns," *Environmental Building News* 2 (May/June 1993): 2.

Aggregate

The aggregate in concrete typically consists of sand and gravel or crushed stone. The strongest concrete has various sizes of aggregate packed together in the cement/water mixture. The aggregate must be clean or the cement will not adhere.

Sand and gravel can be simply dug out of the earth for use as aggregate. A variety of materials, such as limestone, granite, or old concrete, can be crushed to make aggregate. In the southeastern U.S., seashells have been used for aggregate, and in some parts of the country, slag from blast furnaces is used, as well as fly ash, cinders, and volcanic material. Smashed bricks have been used in some cases. Vermiculite, perlite, and expanded polystyrene are occasionally used for aggregate in lightweight or insulating concrete.

Sometimes aggregate can give off radon. This can occur to a small degree with natural stone, but the biggest problems have involved using radioactive tailings from uranium mines to make concrete. Radon problems with concrete are not common and they generally occur in clusters where one particular supplier used an inappropriate aggregate. Aggregates are basically rocks, and most rocks are relatively inert. But if a contaminated material is used as an aggregate (*e.g.* tailings from a uranium mine, or old concrete from a hazardous waste facility) the concrete could also become contaminated.

While a variety of materials been used as aggregates in the past, most of today's concrete suppliers use just sand and gravel or crushed stone, and they obtain their aggregate from only a few clean sources. Thus, aggregate is rarely a problem.

Water

The water used in making concrete must be clean and relatively uncontaminated. If not, there can be an adverse chemical reaction with the cement, resulting in weak concrete. Water stored in gasoline or oil cans should never be used, but nearly any water suitable for drinking can be used to make concrete, whether from a municipal water supply or a private well.

Most water supplies today have a variety of minor pollutants, some naturally occurring, some man-made, and some added purposefully at water treatment plants. These contaminants are almost never concentrated enough to affect the strength of concrete. Pesticide residue, chlorine, fluoride or other contaminants may be bothersome to a chemically sensitive person if ingested, but it is doubtful if they would be a problem in concrete.

Admixtures

Admixtures are chemicals that are added to the basic concrete mix to give it different properties. Accelerators and retarders affect the speed at which the concrete cures. Fungicides, germicides, and insecticides are occasionally used. Other admixtures include: air-entraining agents, gas forming agents, pozzolans, expansion inhibitors, dampproofing agents, permeability reducing agents, workability agents, and colorants.[475] Though widely used, admixtures are not necessary in most residential applications.

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475 Frederick S. Merritt, *Building Construction Handbook* (New York: McGraw Hill, 1965, 2nd ed.): 5.12-5.16.

As a rule, admixtures add to the cost of concrete, and they are only used if a contractor specifically requests them. A common exception is air-entrained concrete which is used in cold climates when concrete is placed outdoors where it will be exposed to freezing temperatures, such as in sidewalks and patios. Air-entrained concrete has literally millions of microscopic air bubbles in it—up to 10% of the volume of the concrete. These bubbles help absorb some of the pressure concrete is subjected to in freezing weather. This reduces the likelihood of surface deterioration. The bubbles are not added with an air compressor—they are the result of a chemical admixture.

When ordering concrete from a supplier, a contractor is often asked where it will be used. If it is for a patio in a cold climate, air-entrained concrete may be automatically supplied. If it is for a foundation footing or an interior concrete slab, it probably won't contain air-entraining admixtures because those locations aren't subject to freezing temperatures.

Air-entraining agents are sometimes added to the powdered cement at the factory. They can be identified by the addition of the letter A to the cement's type number (*e.g.* Type IA). Air-entraining agents can also be added at the concrete plant as the concrete is being mixed. Alkyl benzene sulphonates and methyl-ester-derived cocamid diethanolamine are sometimes used as air-entraining admixtures. Other agents include: wood, resin, fats and oils, wetting agents, soaps, sodium sulfate, hydrogen peroxide, and aluminum powder.[476] When used outdoors, it is doubtful if air-entrained concrete would be a problem for chemically sensitive people.

Another admixture that may be added to concrete without being specifically requested is a water-reducing agent. The more water used in making concrete, the more it will shrink when it hardens, and the weaker it will be. Water-reducing agents improve the workability with minimal shrinkage or loss of strength. There might typically be only 0.03-0.15% of a water-reducing agent—such as sulfonated melamine-formaldehyde or sulfonated naphthalene formaldehyde condensate[477]—in a cubic yard of concrete, but that can be enough to change the properties of the concrete while it is being worked. Most people would not be able to sense the tiny amount of a water-reducing agent found in concrete, and it is unlikely it would be a significant problem for chemically sensitive people. But, to be extra safe, sensitive individuals should not have such concrete exposed to the living space. If it us covered with ceramic tile or an insulated wall, it should not pose any problems.

Colorants are also considered admixtures. Aniline-based colors, common lampblack, or dyes should not be used because they may not be tolerable to sensitive individuals, they generally don't produce a high-quality color, and they can be subject to fading. Most Portland cement is gray in color, so the concrete is also gray. The particular shade of gray varies, depending on the precise ingredients fed into the kiln. Type I Portland cement can usually be special ordered in white, which is manufactured without iron compounds. White cement is often recommended when using colorants to obtain a

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[476] Sybil P. Parker, ed. *Encyclopedia of Science and Technology* (New York: McGraw Hill, 1987), s.v. "Air Entraining Portland Cement," by J.H. Walker.

[477] "The fly ash revolution: Making better concrete with less cement," *Environmental Building News* (June 1999): 13.

brighter color. Some colorants are made to be dusted on, and worked into, the surface of concrete before it cures. They tend to yield brighter colors than those mixed all the way through concrete.[478] Some colorants could contain chromium or other heavy-metal compounds that can be toxic if inhaled in their powder form.

The healthiest colorants are high-quality, mineral pigments. These materials are basically ground rocks, usually forms of iron oxide. Iron-oxide pigments come in a variety of colors—variations of yellow, red, black, *etc*.—that are colorfast and long-lasting.[479] Manufacturers include **Bomanite Corp.**, **Davis Colors**, **DMC²**, and **Solomon Colors.** Consult your local concrete supplier to determine which colors are available. In general, colored concrete can cost twice as much as the standard gray variety.

As a rule, admixtures are not required in most residential applications and, if they are, they are added in tiny amounts to concrete, so they are rarely implicated in significant outgassing.

Other Considerations

There are a number of health-related concerns that do not involve the concrete itself. Most are more likely to affect indoor air quality and a sensitive person than the actual ingredients in the concrete.

Forms

Several different materials can be used for forms to hold concrete in place until it hardens. With a sidewalk, a few 2x4s are often all that are necessary at the edges. For walls, reusable metal or plywood forms are common. Reusable forms are often sprayed with petroleum-based oil to prevent concrete from sticking to them. This allows the forms to be removed easily once the concrete has hardened. Unfortunately, the oil is often very odorous and it can contaminate the porous surface of the concrete. This is one of the chief ways concrete can become contaminated enough to bother sensitive people, so it's important to use a less-toxic form oil. In some cases, a good coat of paint or wax is enough to prevent the concrete from sticking. But edible vegetable oils tend to work better, and they are often acceptable to concrete contractors who prefer conventional form oil. One house-building project became known as "the Wesson oil party" after workers used the vegetable oil as a form-release agent.[480] Another builder successfully used Shaklee's Basic H, a popular cleaning product, as a form release agent.[481]

Less-toxic commercially produced form-release agents are now becoming available. For example, **Tamms Industries** offers a water-based Aquaform product, and **W.R. Meadows, Inc.** has a water-based Duogard II form-release agent. One of the least-toxic form-release agents is Bio-Form by **Leahy-Wolf**. Bio-Form is made from canola oil and other agricultural oils. According to the producer, "If we manufactured it in stainless

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478 Phillip Arnold, "Color in Concrete," *Concrete Products* (February 1986).

479 Rod Keehn, "Using mortar color successfully," *Masonry Construction* (January 1992): 27-29.

480 Richard Parker, "Building Safe at 7,000 Feet," *Environ* #10: 6-9.

481 Oliver Drerup, Drerup Armstrong Ltd., Personal communication.

steel, it would be edible."[482]

Old forms that have been sprayed in the past with a noxious oil, may be too contaminated to use for some sensitive people, even if a less-toxic oil is used on their project. The best solution is to use a less-toxic oil on new forms. Or, you can eliminate oil completely by lining forms with plastic sheeting to prevent the concrete from sticking. When the forms are removed, the plastic can simply be peeled away. Plastic sheeting is particularly useful when older forms (that are already contaminated with form oil) are used.

In recent years, forms made of foam insulation have been gaining acceptance among builders.[483] They are usually called Insulating Concrete Forms (ICFs) and they are available in a variety of styles. Some resemble large Lego building blocks while other systems use sheets of foam.[484] These forms are designed to remain in place, so they become an integral part of the wall. This saves the trouble of stripping off reusable forms and then insulating a concrete wall after it's hardened. Foam insulations have some minor outgassing characteristics. However, building codes generally specify that foam insulation be covered up with a material like drywall to prevent a fire from reaching it quickly, and this minimizes occupant exposure under normal circumstances. Manufacturers of ICFs include **American Polysteel Forms**, **American ConForm Industries**, and **ICE Block Building Systems**.

Sealers

Concrete is actually fairly porous and it stains easily. For this reason, sealers are often used. Most sealers are bothersome to sensitive people. The exception is a product called sodium silicate. It is also known as water glass because it's a liquid that's chemically similar to glass. Sodium silicate reacts with the calcium in concrete and forms a crystalline structure in the surface. This not only seals the surface, but it helps to cure and harden the concrete as well. A drawback is that some paints or sealers don't always adhere well to concrete once it's been coated with sodium silicate. Sodium silicate is available from **AFM** in three different consistencies: Penetrating Water Stop has a thin formula to soak in easily, Water Shield is thicker for use more as a surface coating, and Grout Sealer is thin and has the addition of acrylic and other synthetic resins. **Aqua Mix** has a thin-bodied product called Penetrating Sealer. Sensitive people can often be around sodium silicate even when it's wet.

Sodium silicate can be used to seal the surface of a concrete floor to minimize wear due to foot traffic. Such wear can produce a very fine dust that can aggravate an asthmatic's condition.

A very similar product is available from **Concure**, however it is made of *potassium* silicate. Their Concrete Admixture can be mixed into wet concrete or grout

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482 "A Green Release Agent for Concrete Forms," *Environmental Building News* 6 (January 1997): 7-8.

483 Robert Flower, "Concrete Concoctions, *Practical Homeowner* (May/June 1988): 76-78.

484 "Insulating Concrete Formwork," *Energy Design Update* (February 1993): 10-14.

before it is placed (10 oz. per 100 pounds of grout), and their Concrete Flooring Sealant can be applied to concrete or grout after it has hardened.

Curing Concrete

Concrete cures by a chemical reaction between the Portland cement and the water. If concrete is allowed to cure slowly, its strength, abrasion resistance, and durability will be enhanced.[485] This is traditionally accomplished by keeping the surface of the fresh concrete wet with a garden hose or sprinkler. Dampening fresh concrete with water and covering it with a sheet of plastic also helps it cure slowly. Sometimes the surface is flooded after it has begun to set. The longer the concrete is kept damp, the better, but from a practical standpoint, most builders only cure concrete for a few days. In hot weather (above 90°F), damp curing is especially important to prevent the concrete from drying too quickly.

Special chemical curing compounds should generally be avoided (except for the sodium silicate or potassium silicate mentioned above). They are sometimes sprayed on concrete to slow the evaporation of moisture from the surface.

Cleaners

Muriatic acid is a good concrete cleaner that's available from hardware stores. It's a powerful product that actually etches the surface of the concrete. It is primarily used to clean cement residues from finished surfaces like ceramic tile. It should not be used near aluminum because it will severely corrode it. Muriatic acid should be used sparingly, and should be thoroughly diluted and washed off.

Sensitive individuals should not use muriatic acid themselves. But there is a product they often tolerate that can remove isolated stains from concrete—Fuller's earth. This is a natural powdered clay that, when mixed with water, is applied to a stain on concrete as a paste. It should be allowed to set overnight, then the dried residue can be brushed off and vacuumed up. Fuller's earth will actually draw a variety of stains out of concrete. Though not widely available, it can be special ordered through most pharmacies.

Miscellaneous

Reinforcing steel is often placed in concrete to give it added strength, either in the form of steel bars (rebars) or welded wire mesh. Rebars are usually $^3/_8$" and larger in diameter, and the mesh is typically 6" x 6" and sold in rolls. Reinforcing steel is desirable in many situations and should cause no tolerability problems. Some people are concerned that it might exacerbate electromagnetic fields in a house, but this would only be the case if the steel was inadvertently touching an electrical wire and actually carrying an electrical charge—an unlikely event, but it could happen.

Small nylon and polypropylene fibers are also being used in concrete as a reinforcing material. Fibrous reinforcing is not meant to replace steel reinforcing bars, but

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485 David Carns, "Curing Concrete," *Journal of Light Construction* (March 1993): 19-22.

it can be used instead of steel wire-mesh reinforcing[486] for people interested in minimizing electromagnetic-field concerns. It's unlikely that the fibers would have any affect on indoor air quality, but some will be exposed in the surface of the concrete. Manufacturers of fiber reinforcing for concrete include **Fibermesh** and **Nycon, Inc.**

Sheets of plastic are often placed under concrete slabs, as diffusion retarders, to prevent ground moisture from migrating up from the soil, through the concrete, and into the living space. While some concrete experts say this prevents the concrete from drying (and curing properly) downward, it is routinely done to minimize moisture problems. While the plastic may not be tolerable to a sensitive person when exposed to it directly, in this application, it is separated from the living space by a layer of concrete, so it should pose no problem.

Large or irregularly shaped concrete slabs can be prone to cracking, so it is often better to separate a floor slab into several smaller slabs.[487] Isolation joints between the slabs are often made of asphalt-impregnated fiber board, something that is intolerable to many sensitive people. When they are necessary, isolation joints can be made of less-bothersome redwood boards, or specially designed metal control joints.

Sometimes a large slab will be divided into smaller sections with troweled-in joints, or the slab will be scored with a diamond saw. These control joints don't prevent cracks, they just force the cracks to occur at the joints, rather than at unsightly irregular angles. Whenever there is a crack or gap—whether it occurs naturally, or is placed in the concrete on purpose—there is a pathway for radon or other soil gases to enter a house, so joints must be planned and located with care. To make the joints between adjacent concrete slabs air-tight, flexible waterstops can be cast into abutting slabs during construction.

Masonry

Masonry refers to construction using materials such as concrete blocks, bricks, stone, tiles, *etc*. held together with mortar. Masonry walls are generally strong enough to hold up a house, but they can be purely decorative as well. While some simple concrete block walls are rather plain looking, with a little thought and planning, masonry walls can be very attractive. Because masonry is usually well tolerated by sensitive people, we will discuss some of the more attractive materials as well as the functional ones.

Mortar

Mortar is similar to concrete. It is a mixture containing cement, aggregate (usually sand), and water, with the addition of hydrated lime (a product of limestone) to increase its workability and improve its waterproofing qualities. Masonry cement is simply a premixed product containing Portland cement and hydrated lime. There are actually different types of mortars, but they all have the same basic ingredients in different

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486 "Fiber use in concrete increasing," *Journal of Light Construction* (February 1991): 4.

487 Peter Schober, "Pouring Successful Slabs," *Journal of Light Construction* (July 1992): 20-23.

proportions to yield slightly different properties. Type M, for instance, contains 1 part Portland cement and $^1/_4$ part hydrated lime and 3 parts sand. Masonry sand should be clean, angular, and of uniform size.

As with concrete, mortar can also contain various admixtures. One of the most common admixtures is antifreeze, which allows masons to work in temperatures below freezing. Antifreeze is often added to mortar routinely in cold weather. Because this can be bothersome to sensitive people, it's very important that the individual masons on the job understand that no admixtures are to be used in the house of a sensitive person without prior testing. In some cases, a masonry job can be draped with plastic sheeting and kept above freezing temperatures with portable heaters, but this will need to be coordinated beforehand—because most heaters used on construction sites burn a fuel, such as kerosene, that can bother sensitive people. **Fostoria Industries, Inc.** has 34,000 and 51,000 BTU portable electric heaters that operate on 240 volts. **Allmand Bros. Inc.** manufactures large, wheeled, portable heaters to deliver warm air that is free of combustion by-products. They have enclosed burners and are rated at 1,000,000 BTUs per hour at a maximum of 5,600 cfm.

Mortar is colored more often than concrete. White Portland cement and white sand will yield white mortar. This can be very attractive but difficult to keep clean. If other colors are desired, the mineral pigments mentioned above are suitable.

Masonry Blocks

Concrete blocks are widely available throughout the country. Being made of concrete, they contain cement, aggregate, and water. The aggregate is usually sand with some slightly larger particles, but occasionally another material is used. Concrete blocks are sometimes called cinder blocks because cinders can be used as the aggregate to reduce weight and increase the insulative value. Concrete blocks are somewhat porous and they can absorb odors, but this isn't common.

Many concrete-block manufacturers offer blocks with different appearances. Besides the standard smooth-faced variety, various textures or shapes are often available. Call your local supplier for availability and pricing. The **Burns and Russell Co.** produces a concrete block (Spectra-Glaze) with a glazed, glass-like surface that is attractive, durable, and easy-to-keep-clean. These are available in a variety of standard shapes and sizes as well as in dozens of colors. Used primarily in commercial projects, they can be costly. They never need painting, and can be used both indoors and outdoors.

Glazed-tile blocks are also maintenance-free. These are made of clay (not concrete) with a glazed surface and they are fired in a ceramic kiln—like pottery. They are available in a variety of shapes and colors and can be used for partition walls or for load-bearing applications. One manufacturer is **Stark Ceramics, Inc.** These are actually made like ceramic tile, so they are very inert—but they can also be expensive. They are primarily used in commercial applications, but can also be used in residences.

Clear glass block is available in a variety of patterns and sizes. Glass block can be very decorative when used as an accent wall by letting in light, but not the view.[488]

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[488] Ann Patterson, "Walls warm up to glass block," *Custom Builder* (November 1991): 67-70.

Installation requires more care than other forms of masonry because glass blocks don't absorb moisture and it's difficult for mortar to adhere to glass.[489] The blocks are sometimes coated with a plastic resin on the edges to improve bonding. This is covered with mortar after installation, so it's doubtful that it would be bothersome to sensitive people. Glass blocks are manufactured in the U.S. by **Pittsburgh Corning Corp.** and they are imported by other companies.

Stone

Stone can either be cut into very uniform shapes, or used in a rough natural state. Common varieties include: limestone, sandstone, granite, and marble. Stone provides a nice accent both indoors and outdoors, but softer stones are more absorbent and easily stained. In general, the only danger in using stone masonry is if the stone contains an excessive amount of radon. Many stones contain a tiny amount of radon, but it tends to be trapped within the stone itself. So, indoor airborne radon from natural stones usually isn't a problem—but in rare instances it can be.

Brick

Brick is made of clay and/or shale that has been fired and hardened in a kiln. Harder bricks are less likely to absorb moisture or odors. While bricks are not as hard as other ceramic materials—like some floor tiles that are fired at higher temperatures—they are generally quite inert. Bricks are available in a variety of colors, sizes, shapes, and textures. Although usually confined to outdoor use, they can be used indoors as well. A decorative wall indoors can be very attractive, but it can be difficult to clean because of the uneven surface.

Brick pavers are widely used for sidewalks, but they can also be used for driveways.[490] They can either be set on a concrete base or on a base of sand, and they are available at many building-supply stores in a variety of styles.[491]

Brick Veneer

Brick veneer is popular on the exteriors of houses. With this construction method, a framed and insulated wall supports the building and the outer surface is protected from the weather with a decorative facing of brick. Brick is a low-maintenance product, but it is not waterproof. A certain amount of moisture will pass through both the brick and the mortar. To prevent this moisture from causing damage inside the wall, it is imperative that a brick-veneer wall be designed and built so the moisture can escape back toward the

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489 Michael Byrne, "Glass block in the bathroom," *Journal of Light Construction* (November 1992): 17-20.

490 John Robinson, "Dry-laid paving," *Popular Science* (July 1988): 66-67.

491 Brian Trimble, "Landscaping with brick pavers," *Journal of Light Construction* (June 1990): 34-36.

outdoors.[492] There are certain well-established guidelines that should be followed.

First of all, there needs to be a *base flashing* at the bottom of the brick wall to catch any water that penetrates through the brick and runs down the back side of the it. Then there need to be *weep holes* at the bottom, through the brick, to allow the moisture to drain back toward the outdoors. There should be a 1-2" *air space* between the brick and the framed wall, and it is important that this space be kept free of mortar droppings. This is difficult to do, but if the space becomes clogged with mortar, and water passes through the brick, then through the droppings, it will get the framing and insulation wet. The result can be hidden mold growth and rot. When steel studs are used instead of wood, they can be prone to rusting if they get wet repeatedly.[493] [494] The final point has to do with tying the brick to the framing. Metal ties should be placed about every three square feet, and they should *slope slightly toward the brick*. If they slope toward the framing, water will run down them and wet the framing and insulation—again, resulting in possible mold and rot.

Health Effects

Most sensitive people can tolerate concrete once it has cured. However, a few people have reported various symptoms, occasionally to concrete containing admixtures. If an admixture must be used in the house of a sensitive person, a building contractor can often obtain a sample of a particular concrete mix from their concrete supplier. Usually in the shape of small cylinder, such samples are often used for strength testing. The sensitive person can use the sample to determine if there are going to be any tolerability problems.

Health problems related to concrete by sensitive people are most often related to form oil, sealers, and curing agents. Spills can also be a significant problem. For example, if a pesticide or gasoline is spilled on concrete, it can be very difficult to completely remove all residual traces of the contaminant.

It's been reported that some women with severe reactions to silicone breast implants, can't tolerate other silicone-containing products. Some have had difficulty being around sand, which is silicone dioxide.[495] While reactions to sand certainly aren't common, this is an example of how individual sensitivities can be both unusual and severe.

Chronic exposure to dust from sand can lead to silicosis, or white lung disease. This has been reported among workers in concrete plants. Symptoms can range from a

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[492] Robert Beiner and Robert Rhault, "Success with brick veneer," *Journal of Light Construction* (June 1989): 28-31.

[493] Canada Mortgage and Housing Corp. (CMHC), *Field investigation of brick veneer/steel stud wall systems* (Ottawa, ON, Canada: CMHC, November 30, 1989).

[494] Jim Cowie and Mike Wilson, "Brick veneer & steel studs" Performance questions," *Journal of Light Construction* (April 1991): 21-23.

[495] Paula Davey, MD, Personal communication.

slight cough to pneumonia.[496]

Although not a problem at all after concrete has cured, cement dermatitis is a well-known, though relatively uncommon, problem in the concrete industry. When water is added to dry cement it produces calcium hydroxide, a very strong corrosive alkali. This acts like lye, and prolonged contact can cause severe burns and skin-tissue destruction.[497] This usually happens when workmen walk in wet concrete without proper protective clothing. For example, wet concrete can get inside loose-fitting boots and splash up on unprotected legs. Occasionally, burns are the result of dry cement reacting with perspiration on the skin and causing localized burning. Once the concrete cures and becomes hard, caustic burns are no longer a problem because the calcium hydroxide reacts with carbon dioxide in the air and becomes inactive.

Do-it-yourselfers should be aware that tissue damage caused by exposure to wet cement or concrete can result in third-degree burns requiring skin grafting after a relatively short exposure of 20 minutes.[498] Various creams and lotions have been used as preventative measures, but the best method is to avoid contact with wet cement or concrete. As with most reactions, some individuals are more susceptible than others. Most concrete workers spend their entire lives without experiencing a single ill effect. Others are burned on their first exposure. Damage can be so severe as to cause injury to nerve endings and chronic pain.[499]

There are other less devastating effects of working with concrete or mortar. The cement particles or the aggregate can act like sandpaper causing irritation. Perspiration-cement or water-cement mixtures can remove protective oils from the skin causing drying and cracking, or they can clog pores.[500] A do-it-yourselfer should take proper precautions to protect exposed skin when working with wet concrete.

Summary

For the most part, concrete and masonry products are generally well tolerated by sensitive individuals. With a few precautions—such as avoiding admixtures, noxious form-release agents, and sealants—there is no reason why a healthy house can't contain these materials. However, for extremely sensitive people, some testing prior to using them may be necessary. With thoughtful design and careful selection of materials, concrete and masonry can yield a very warm and attractive house.

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496 S.H. Zaidi, *Experimental Pneumoconiosis* (Baltimore, MD: Johns Hopkins Press, 1969).

497 Susan H. Early and Roger L. Simpson, "Caustic Burns From Contact With Wet Cement," *JAMA* 254 (July 26,1985): 528-529.

498 *Ibid*.

499 Peter R. Lane and Daniel J. Hogan, "Chronic Pain and Scarring From Cement Burns," *Archives of Dermatology* 121 (March 1985): 368-369.

500 A.J.R. Curtis, "Cement Dermatitis" (letter), *Journal of the American Concrete Institute* (November 1943): 175-176.

11. Foundations

The purpose of a foundation is to support a house and transmit its loads to the soil. To minimize uneven settlement, which could result in the foundation cracking or damage to the house, a foundation designer should take into consideration the type of soil the house will sit on. While most residential foundations are designed with “rules of thumb,” when weak or unusual soil conditions exist, it’s a good idea to have a qualified architect or engineer perform some soil-analysis testing as a part of the design process.

Foundation cracks are not only unsightly, they can be unhealthy as well—because pollutants can easily pass through very small cracks in a foundation, particularly when the lower portion of a house is depressurized. Cracks can also allow moisture to pass through a foundation. And subterranean termites can invade a house by passing from the soil through cracks in the foundation.

Design Considerations

In some cases, part of a foundation is exposed directly to the living space. For example, a basement wall supports the structure of the house, but it can also be the finished wall of a basement bedroom or recreation room. When a foundation is directly exposed to the living space, material selection can influence indoor air quality.

A foundation also acts as a bridge between the living space and the ground. Therefore, it can be a pathway for pollutants to pass from the soil, through the foundation, and into the occupied part of the house. Two common pollutants in the soil that get into houses are radon and termite-killing chemicals. Soils also typically contain a certain amount of moisture which, if not properly dealt with, can pass through a foundation and contribute to a mold or rot problem in the living space. Moisture also invites insects such as termites and carpenter ants.

The energy efficiency of a foundation also has an effect on health. This is because the temperature of the ground is generally different than the temperature in the occupied space. This can lead to cool surfaces near parts of the foundation that are exposed to the soil, and a high relative humidity near those surfaces that can result in mold growth.

Material Selection

In most cases, the foundation materials most likely to affect indoor air quality are those directly exposed to the living space—for example, basement walls and concrete floor slabs. The materials used for crawl-space construction, or for part of a foundation that isn’t directly exposed to the living space, usually don’t significantly affect indoor air quality. But, in any case, tight construction is important.

Concrete and masonry are popular choices for constructing foundations. In the majority of cases, they are healthy materials and are usually well-tolerated by sensitive people. But there are a few ways these materials can be unhealthy. Health effects related to concrete, admixtures, sealers, form oil, *etc*. were all covered in the previous chapter.

Pressure-treated wood containing arsenic salts is being used more and more for foundations.[501] Such foundations are often called All-Weather Wood Foundations (AWWF) and they have a number of advantages: they're less costly, easy to insulate, and easy to finish.[502] However, pressure-treated wood can contaminate basements with arsenic dust. If the arsenic gets into the occupied part of a basement, children playing on the floor can easily get it on their clothes and hands, and inadvertently into their mouths. But, with proper design—and tight construction techniques—unhealthy materials like pressure-treated wood will be well-separated from the living space.

In the past, foundation coatings were often composed of Portland-cement mixtures. Today, a wide variety of plastic membranes, films, and bituminous mastics are popular. These products have the *potential* to affect health, especially with very sensitive people, but because they are typically covered with soil, and are outside the living space, they rarely affect indoor air quality.

Drainage and Moisture

Moisture control is very important with all foundations for a number of reasons. For example, if the structural design is not done correctly, wet soil freezing in the winter can apply tremendous pressure to a foundation and actually push the building with enough force to cause structural damage. More commonly, moisture passes through a foundation into a basement or crawl space where it results in mold growth and musty odors. Mold in basements should be avoided at all costs. But mold in a crawl space isn't good either, because it can get pulled into the living space of a loosely constructed house, or into leaky ducts. Excessive moisture can also result in decay, deterioration of mortar joints, or structural damage. In general, foundations should be designed to prevent moisture from migrating into any enclosed spaces (*i.e.* basements, crawl spaces, or above-ground living spaces).

Moisture passes through a foundation by four mechanisms: *liquid flow*, *capillary action*, *air movement*, and *diffusion*.[503] Liquid flow occurs when water actually flows through cracks in a foundation. The water can originate above ground (*e.g.* rain) or below ground (*e.g.* a high water table), and it can easily move through cracks in a foundation into a basement or crawl space. With capillary action, water is sucked into concrete in the same way water wicks into a paper napkin dipped into a glass of water. In a foundation, soil moisture can wick up by capillary action through the bottom of a footing, into a foundation wall, and be released from the upper, exposed portion of the wall—either inward or outward. This is also called *rising damp*.[504] Moisture can also be transported from the outdoors, or through porous soils, through cracks in a foundation by an air-

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501 *All Weather Wood Foundation System* (Tacoma, WA, American Plywood Association, 1979). Publication #A400.

502 Merle Henkenius, "The Right Foundation," *Practical Homeowner* (May/June 1989): 75.

503 Lstiburek, *Moisture Control*, 15.

504 T.A. Oxley and E.G. Gobert, *Dampness in Buildings* (Kent, England: Butterworths, 1983).

pressure difference. This is the same mechanism that accounts for moisture and pollutant transport above grade. Finally, a certain amount of moisture can be transported through a foundation by diffusion—moisture molecules traveling through the solid surface of the foundation itself. Liquid flow is capable of moving the most moisture through a foundation, but a good designer will also address capillary action, air movement, and diffusion.

Liquid Moisture Flow

The first step to control the liquid flow of water is to have positive surface drainage away from the house. The ground should slope so any rainfall or snow melt flows away from, not toward, the structure. This is usually done by building a house up high enough so the surrounding area can be sloped correctly. The amount of slope does not need to be great, but it does need to be sufficient to direct surface drainage away from the house. Six to eight inches of fall in ten feet is usually sufficient for grassy areas. Gutters and down spouts should direct roof water far away from the structure. Without gutters, large quantities of rain can be deposited on the ground near the foundation. This can soak into the ground and pass through the foundation underground.[505]

Liquid flow below ground from a high water table is best addressed by using a drainage system around the perimeter of a house to capture the water before it has a chance to pass through the foundation. The water table varies in depth considerably throughout the country, and it can vary seasonally, depending on the amount of precipitation. Underground water captured by a perimeter drain is typically run to a ditch, storm sewer, or sump pump. A sump pump should discharge its water far enough away from a house so it will not find its way back. During a power failure, a sump pump will not operate and water can back up, causing problems. Although it is almost never done, it can be a good idea to install clean-outs on footing drains so they can be cleaned if they should ever start to clog with silt.[506]

If there is a layer of gravel against the foundation wall, and it extends all the way down to the perimeter footing drain, any water near the foundation will run freely down through the gravel into the perimeter drain, and then away from the house. In some cases, this can take a great deal of gravel, which can be expensive. Special drainage mats or boards have been developed that do the same thing—direct water down into a perimeter drain.[507] They are installed adjacent to the outside of a foundation wall. These products are usually used in conjunction with a coating of some type that is applied to the wall. They are not a substitute for such a coating, they simply allow it to function better. (The coating blocks moisture flow by diffusion, and the drainage mat allows liquid water to drain away.) These drainage boards and mats are plastic products with a filter material to prevent the soil from clogging them. Manufacturers include **Colbond Geosynthetics**

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505 Gordon Tully, “Techniques that don’t work,” *Journal of Light Construction* (January 1992): 11.

506 “Cleaning Clogged Footing Drains,” *Journal of Light Construction* (February 1992): 8.

507 Don Best, “Right from the start,” *Practical Homeowner* (May/June 1991): 64-73.

(Enkadrain), **Eljen Corp.**, and **TC MiraDri** (Miradrain). **Koch Waterproofing** has a Tuff-N-Dri Waterproofing proprietary system that combines a foundation coating and a drainage board. It must be installed by a licensed contractor.

In existing houses, a drainage system can be added by excavating all around the outside of a house, or by excavating inside the foundation. Exterior excavation often involves removal of shrubbery and destroying the lawn. In a basement, interior excavation requires breaking up the concrete floor slab around the interior of the wall. Either proposition can be disruptive and costly.

Capillary Moisture Flow

Moisture moves through a substance by capillary action if the pores in that substance are a certain size. Capillarity is often described as a suction, because moisture molecules are actually pulled into the pores of a substance. Moisture is sucked up into trees from the soil, through roots, and into trunks and branches because of capillary action. The same thing happens with concrete. Any moisture in the soil that comes in direct contact with a concrete foundation can be sucked into the pores of the concrete. The moisture can travel many feet upward through concrete (or concrete block) in this way. Eventually, the moisture escapes where a foundation is exposed to the air.

Capillary action can be responsible for water rising as much as eleven feet up through the soil from the water table. Clay and silt are especially vulnerable to this phenomena. Less capillary rise is found with sand and none with gravel.

Moisture transport by capillary action can be prevented if the pores are either very large, or the pores are sealed up. When a foundation wall or floor slab is separated from the soil by a layer of gravel, the pores in the gravel are large enough to prevent the capillary suction. Thus, gravel is called a *capillary break*. A coating that is applied to the outside of a foundation wall seals the surface of a wall so the ground moisture can't reach the concrete's pores, so it is also called a capillary break. Plastic sheeting under a concrete slab does the same thing. In an existing house, it's possible to apply a coating to the inside of a foundation wall—although exterior coatings are generally preferred.

ChemRex, Inc. has a whole range of products for coating, patching, and sealing concrete and masonry. Their Thoroseal product is a Portland-cement-based waterproofing/dampproofing coating that can be used on the interior or exterior of a foundation wall. They recommend that it be mixed with both water and their Acryl 60 product, which is a water-based acrylic bonding agent. Thoroseal is odor-free once cured, and it has often been recommended for sensitive people. **Aquafin, Inc.** also has a number of foundation coatings, including a product similar to Thoroseal.

Phenoseal Liquid Waterproofing manufactured by **Gloucester Co., Inc.**, is a vinyl-acrylic product that outgases relatively quickly. It is water-based and designed primarily for interior use. **United Gilsonite Laboratories** has a water-based Drylok coating for either interior or exterior use.

Xypex (**Xypex Chemical Corp.**) is a Portland-cement-based foundation coating that contain chemicals designed to penetrate the pores of concrete walls forming a crystallizing seal. It is said to block not only capillary flow, but also water flowing through concrete because of hydrostatic pressure.[508] This product have a slight odor when wet but, once cured (7-10 days), it is odor free.

Air Transport of Moisture

Many soils are quite porous. Thus, air can move from the atmosphere, through a porous soil, through random cracks in a foundation, into the interior of a house—if there is an air-pressure difference, between the indoors and the outdoors, to push or pull the air. As the air moves through the soil, it can pick up moisture and bring it indoors. In one house, a building scientist was able to demonstrate that air could be pulled 50' through porous soil, through a foundation, and into the living space, because of air-pressure differences caused by leaky ducts.[509]

As with moisture transported through holes above grade because of air-pressure differences, tight construction also works below grade. By building a tight, crack-free foundation, no moisture will be transported through it due to air-pressure differences, because there are no holes.

Diffusion of Moisture

Diffusion occurs below ground just like it does in walls above ground—water molecules diffuse through the solid surface of a material when there is a difference in concentration from one side of the material to the other. The foundation coatings that prevent dampness from penetrating a foundation by capillary action can also prevent moisture movement by diffusion by acting as a diffusion retarder.

Radon

Radon is a radioactive gas that is often found in the soil. It can get into a house by diffusing through the solid materials making up the foundation. It can also enter a house if there is an air-pressure difference to pull it indoors through random cracks or holes in the foundation. As with above-ground moisture and pollutant transport, air-pressure differences move significantly more radon indoors than diffusion—often one-hundred times more.

It's also possible for the raw materials making up a foundation to release radon directly into the interior of a house. However, radon in building materials seems relatively rare in the U.S. It is more prevalent in Europe.[510]

A variety of radon-reduction techniques can be found in various publications

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508 Mac Wentz, "Basement waterproofing," *The Family Handyman* (October 1996): 40-44.

509 Joseph Lstiburek, Building Science Corp., Personal communication.

510 Phillip J. Walsh, Charles S. Dudney, and Emily D. Copenhauer, *Indoor Air Quality* (Boca Raton, FL: CRC Press, 1984): 146.

available through the **EPA**.[511] [512] Radon reduction usually involves one or more of the following mitigation strategies, each of which has several variations.

- Sealing cracks and pathways that air-pressure differences push or pull radon through.
- Manipulating air-pressures in, or under, a house so radon won't be pulled through the cracks and pathways that can't be sealed.
- Increasing the ventilation rate in the house to dilute the concentration of radon that does enter the living space.

It's very difficult to predict if a particular house will have a radon problem—you must actually perform a test and measure the radon level in the indoor air. At that point, the house can be evaluated to determine which mitigation measures will work the best. If you're planning to build a new house, you can't perform such a test until the house is complete so, during the design phase, it makes a great deal of sense to plan for some simple radon mitigation—whether you think you'll need it or not. It rarely costs much to do so and, if you end up with a high indoor radon level, it makes it very easy to remedy the situation. If you don't end up with a high radon concentration in the completed house, you really haven't invested much money. Most people consider the minor expense to be cheap insurance.

If it is done while a house is being built, roughing in a sub-slab radon depressurization system might add no more than $100-200 to the cost of a house—if a builder is familiar with the installation of these systems. (If your contractor is not familiar with radon removal systems, he might typically charge $350-500.) When installed after a house is built, a complete system typically costs over $1,000.[513]

The mechanisms that allow radon to enter a house can also cause other VOCs to enter as well, such as metabolic gases from soil microbes, termiticides, lawn chemicals, chemicals found in hazardous landfills, contaminated ground water, and hydrocarbon spills.[514] In one study, the degree of depressurization in the soil 0.5 meter from a house was 30-40% of the amount of depressurization measured in the basement. And, as far as 7-12 meters away from the house, the depressurization in the soil was still 10% of that

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511 Environmental Protection Agency (EPA), *Radon Reduction in New Construction: An Interim Guide* (Washington, DC: EPA, August 1987). Publication #OPA-87-009.

512 Environmental Protection Agency (EPA), *Radon Reduction Methods: A Homeowner's Guide* (Washington, DC: EPA, August 1986). Publication #OPA-86-005.

513 Alex Wilson, "Radon and other soil gases: Dealing with hazards from below," *Environmental Building News* (July/August 1998): 1.

514 Martin Adomait, *Soil Gas Containing VOCs Entering Homes Near Hazardous Lands* (Ottawa, ON, Canada: Canada Mortgage and Housing Corp., 1992).

found in the basement.[515] This means that whenever the basement is depressurized, any gases in the soil around the house will be pulled into the basement—unless mitigation measures are in place.

Sealing Cracks

There are many possible pathways for radon (and other soil gases) to follow to get into the living space. Covering exposed earth in basements and crawls spaces will help block radon's entry. One of the best materials to use is a continuous layer of concrete—as long as it is crack-free. Plastic barriers can do the job if they are well-sealed at all seams and around the perimeter with mastic.[516] Sump pump pits should be fitted with a sealed cover because radon can get into drain tiles and enter a basement through a sump pit. Sealing cracks and openings in floors and walls, or where plumbing or electrical lines enter a basement below grade, is also helpful. Radon can get inside concrete-block walls, so sealing the open cores at the top of a concrete-block wall can prevent its escape into the basement.

Manipulating Air Pressures

A number of factors can lead to a depressurized house (*e.g.* leaky ducts, chimneys, exhaust fans, *etc*.), all of which can contribute to radon being pulled indoors. By installing a dedicated make-up-air supply for air to enter, rather than allowing it to enter through the random cracks, depressurization can be minimized. Sealing leaky ducts can also help a great deal.

If a house has a drain tile around the perimeter, then a suction fan can be hooked up to the drainage system (which is rarely completely full of water), and pull air through the tile. This lowers the air pressure inside the tile and causes the radon to enter the tile rather than the house. The radon is then blown outdoors, into the atmosphere, where it dissipates. Because concrete blocks are hollow, sometimes a suction fan is connected to a concrete block wall to depressurize the cores, intercept the radon, and blow it outside before it can pass the rest of the way through the wall and enter the house.

With sub-slab suction, a fan pulls radon from the gravel beneath a concrete floor slab and blows it outdoors. In this method, holes are cut in the floor and plastic pipes are run from the holes, to a fan, to the outdoors. In new construction, one or more perforated plastic pipes are placed in the gravel under the slab to capture the radon more easily.

Ventilation

Natural ventilation involves opening windows in a basement or adding vents to a crawl space. This has been shown to reduce radon levels, but can result in increased heating bills during cold months. It can also mean frozen pipes. Mechanical ventilation relies on the use of one or more fans to exchange and dilute the air after the radon enters a basement or crawl space. This can also mean higher heating bills in cold climates. By

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515 K. Garbesi, *Experiments and Modeling of the Soil-Gas Transport of Volatile Organic Compounds into a Residential basement* (Berkeley, CA: Lawrence Berkeley Laboratory, December 1988). #LBL-25519.

516 G.K. Yuill and Associates, *Airtightness of Concrete Basement Slabs* (Ottawa, ON, Canada: Canada Mortgage and Housing Corp., 1991).

using a heat-recovery ventilation system, the operating cost will be less in a harsh climate. A supply-ventilation strategy can be used to pressurize a house (or a basement, or a crawl space) to prevent radon from being sucked in.

Not all radon-reduction methods work well in all houses. In order to determine which method, or methods, is best for a particular situation, the **EPA**'s *Technical Guidance* publication is a very good source.[517] It goes into considerable detail on the various techniques and is applicable to most houses. Additional information about radon can be found in *Chapter 25, An in-depth evaluation of six common pollutants*.

Subterranean Termites

Subterranean termites can pass through tiny cracks in a foundation to get at the wooden structure of a house. They are often dealt with by installing a barrier between the soil and the house that termites can't cross. Or, if a house is built of materials termites won't eat, they will look elsewhere for food.

Subterranean termites feed on the wood in a house, but they live in the soil. Their bodies dry out very easily so, if they are not regularly exposed to the moisture in the soil, they cannot survive. As a result, they constantly travel back and forth between the soil and the wooden parts of a house.

There are several different species of termites in the U.S. and you can't deal will them all in the same way. The discussion below is limited to subterranean termites. Control of other termite species—those that do not live in the soil—will be dealt with in the next chapter.

General Strategies

In new construction, it's important to keep lumber scraps, wood debris, stumps, *etc*., out of the backfill around a foundation.[518] When this type of material is buried, it can be easily found by termites. This will keep them busy for a while, but the scraps will be the *hors d'oeuvres* that invite subterranean termites to eat the house itself as a main course.

The wood portions of a house should be at least 18" from the soil. This will make it more difficult for termites to get from the soil to the wood. This is rarely the case—eight inches or less of separation is common. But, most importantly, there should never be any direct contact between wood and soil—unless the wood is termite resistant.

Because subterranean termites prefer damp conditions, proper drainage and moisture control are very important. They prefer wood that is damp, so they're often found around bathrooms or plumbing leaks.

Stacks of firewood or lumber should not be in direct contact with the ground when stored outdoors. Such wood can become infested and, when brought indoors, transfer termites into the living space.

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517 Environmental Protection Agency (EPA), *Radon Reduction Techniques for Detached Houses: Technical Guidance* (Washington, DC: EPA, June 1986). #EPA/625/5-86/019.

518 William Currie and John Gingrich, "Termites and their management—Part three: Prevention and control," *Informed Consent* (November/ December 1994): 44-51

If a small underground colony of subterranean termites is discovered in the soil near a house, it can sometimes be dug out. Even though it won't be possible to remove an entire colony, enough of the soil can be disturbed so that ants, or other natural enemies, will destroy the remaining insects. If this strategy is used, the area should be checked periodically to make sure that the colony doesn't reestablish itself.

One of the best methods of avoiding termites is to use building materials that termites cannot eat, such as concrete, masonry, metal, or termite-resistant woods. When these materials are used in the structure of a building, it will not be subject to termite attack. However, the insects can still enter and attack non-structural components such as cabinetry, woodwork, *etc*. They also like to eat the cellulose in paper—which is made from trees. In some cases, they have destroyed books, and eaten the paper off drywall.

Termite Barriers

Termite barriers are often installed in conjunction with foundations. They work by denying termites access to a house. Traditionally, this has been done by injecting toxic chemicals into the ground around a house. This forms chemical barrier that subterranean termites won't cross. They may be living happily one foot away from your house, but if a chemical barrier completely surrounds the house, they won't dig through it. Of course, they could tunnel under the barrier, so the chemicals must extend underneath as well as around the structure to be completely effective.

Termite shields are metal barriers that are placed on top of a concrete or masonry foundation wall to block termites from getting up into the wooden part of the house. However, they can't block the insects completely, because termites can climb around the shields. When they do so, they usually construct mud tubes to travel through. This is necessary because, when exposed to the air for very long, a subterranean termite's body dries out quickly, and it dies. What termite shields actually do is force termites to build mud tubes around the shields so you can see where they are—then you can deal with them at that location.[519] Metal shields must be very tightly constructed with all joints properly sealed. The best approach is to solder the joints. However, a tar-like bituminous compound can also be used—if it doesn't bother sensitive occupants. Shields are not often used because they can interfere with the siding and the interior finish in basements.[520]

A relatively new low-tox approach to subterranean termite control is the sand barrier. With this strategy, a layer of sand is placed under and around a house. Surprisingly, if the sand has a certain grain size, the termites can't tunnel through it—the individual grains of sand are too large and heavy for them to move out of the way, and the spaces separating the grains are too small for them to fit between.[521] There should be at

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519 Ward Hitchings, "Termite protection without chlordane," *Journal of Light Construction* (June 1989): 33-36.

520 Henry Spies, "Termite barriers" (Letter and reply), *Journal of Light Construction* (October 1990): 9.

521 "Sand barriers: Nontoxic tool for termite control," *Journal of Light Construction* (March 1994): 11.

least a 4" layer of sand against the outside of a foundation wall, as well as a 4" layer of sand under a concrete floor slab. With crawl spaces, there should be a 4" layer of sand around the interior of the foundation wall and around any piers.[522] To be effective, the size of the sand must be in the 1.6 to 2.5 mm range, and all possible paths between the soil and the wood framing must have a sand barrier.[523] Sand barriers show a great deal of promise—but they must be installed conscientiously.

There is a finely woven stainless-steel mesh available from **Termi-Mesh USA** that is designed to be used as a barrier under and around foundations to prevent termites from entering a building and getting to the wood. Originally developed in Australia, it is said to add $600-1,500 to the cost of a 2,000 sq. ft. slab-on-grade house.[524] This can be a very effective and non-toxic approach, but it must be installed conscientiously. If it is torn during installation, termites will be able to pass through the rip and get at the wood parts of a house.

The big drawback to barriers of all sorts is the fact that they must be perfect. If they are not, termites can find a way around or through them. For example, if you use a chemical barrier in the soil, or a sand barrier, or stainless-steel mesh, and there is a small gap in the barrier, termites will have access to the foundation, and your house.[525] With metal termite shields, that are visible above grade, you can inspect the barrier. But with below-grade barriers, inspection is impossible, so you can never be 100% sure they are continuous.

Termite Poisons

While termites can certainly destroy a house, the poisons used as chemical barriers to control them constitute a significant health threat to human beings. When these chemicals are injected into the soil, they can easily migrate into the living space. In the same way radon and ground moisture gets into houses, termite chemicals also move from the soil into the living space—primarily with air that moves through holes and cracks in the foundation because of air-pressure differences, and secondarily by diffusion. The same techniques that control radon can often be used to keep termite chemicals in the soil out of the living space—as long as the chemicals were never sprayed directly in the living space. Still, because most termite chemicals can be very toxic to people, they should be avoided whenever possible.

Of the common chemical treatments available for termites, it's been stated that

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522 "Sand barrier termite control," *Environmental Building News* (March/April 1994): 6-7.

523 Jason Fry, "The long-sought silver bullet against termites is...sand,?" *Indoor Air Review* (June 1994): 10.

524 "New Tools and Materials for '99," *Journal of Light Construction* (July 1999): 38.

525 William Olkowski, Helga Olkowski and Shiela Daar, "Termites—New, Less Toxic Controls," *Common Sense Pest Control Quarterly* #1 (Fall 1984): 16.

"no single material can…be called significantly less toxic than any other."[526] If chemical means are required, spot treatment will reduce exposure to potentially toxic chemicals. Spot treatment simply means treating the areas that are infested, rather than the whole house.

The dangers of the termite-killing chemical chlordane were sufficient to have production stopped in August 1987. However, this material was used to treat millions of houses. Once a home has been treated with chlordane, it will always be there—and it will always be outgassing.[527] Aldrin, diedrin, heptachlor, and endrin are popular long-lived termiticides belonging to the same chlorinated-hydrocarbon family as chlordane.

Another chemical, said to be less toxic, is the organophosphate Dursban. However, there are negative health effects associated with it as well. One report lists symptoms of drooling, sweating, nausea, diarrhea, abdominal pain, weakness, fatigue, and anxiety that occurred in office workers within a few hours of a building being treated.[528] In mid-2000, regulations were passed by the **EPA** to phase out the use of Dursban, but it will be several years before the ban takes complete effect, and some uses will still be allowed.[529] As a termite treatment, Dursban can not be sold for whole-house treatment of existing houses after December 31, 2001, and for spot treating of existing houses the label will have a stop-use date of December 31, 2002. However, it can continue to be applied for pre-construction use until December 31, 2005.[530]

One termite-control chemical that has been tolerated by some sensitive individuals is Ficam-W (manufactured by **Agrevo USA).** This is a relatively short-lived product, lasting approximately six months. Because it doesn't have a very long life, if this product is used, regular inspections are recommended.

Chemically treated lumber can also be considered a termite poison, and there are now some chemical treatments available that are considerably less toxic to humans. See *Chapter 12, Wood and Wood Products*.

Termite Bait

A relatively new termite-control method, that uses less-toxic chemicals, is the bait-block technique. With this approach, blocks of wood are strategically placed around

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526 Daniel Zwordling, "All Things Considered," on National Public Radio, WFIU Bloomington, IN, January 22, 1987.

527 Michael J. Hodgson, Geoffrey D. Block and David K. Parkinson, "Organophosphate Poisoning in Office Workers," *Journal of Occupational Medicine* 28 (June 1986): 434-437.

528 "Dursban to be phased out," *Environmental Building News* (June 2000): 5-6.

529 Jay Feldman, "The Low-Down on Dursban: MOEd Down by EPA," *Pesticides and You* (Spring 2000): 14-18.

530 Rodney C. Degroot, "Alternatives to Termiticides in Building Protection," in: Khasawinah, Abdallah M., ed., *Termiticides in Building Protection*: Proceedings of a Workshop; September 22-23, 1982, Washington, DC (Chicago: Velsicol Chemical Corp., 1983): 91-94.

a structure. These act as bait and they are sometimes treated with an attractant, or feeding stimulant, along with a termiticide. They draw termites away from a building and also kill them.[531]

A commercial baiting technique, called the Sentricon System, is produced by **Dow AgroSciences.** It must be maintained by a pest-control operator but it is a relatively low-tox approach to subterranean termites. The Sentricon System involves placing a number of plastic feeding stations in the soil around a house (every 1-10') that contain a material termites like to eat. When a termite finds a station, it leaves a scent trail for other members of the colony to follow. Once feeding is underway at a station, it is filled with a bait containing a low-tox chemical (called Recruit) that stops a termite's natural molting process. In time, all the termites in a colony will stop molting (this prevents them from growing) and they will die. This system should not be used if there is the possibility that the stations will be flooded, because runoff water could enter a pond or stream—and the bait can be toxic to fish.

Spectrum Brands has a Terminate product that is very similar to the Sentricon System just mentioned. The major difference is that Terminate is a do-it-yourself product that consumers can use themselves. To many people this sounds like a good idea, and a way to save money and, in some cases, it can be. However, if a home has an existing termite problem, and the homeowner doesn't understand fully the extent of the infestation, a do-it-yourself solution may not be the best answer. This is because a homeowner may not install the product in a way that will completely handle the situation. In other words, they may believe they have addressed the problem adequately—when they have not—and, thus, have a false sense of security as termites continue eating the house. Still, if a homeowner understands the infestation adequately, this can be a very useful product.

Nematodes

A biological method of attacking subterranean termites involves the use of a particular species of nematodes to eat them. These microscopic worms are mixed in a water solution and injected into the wood or soil near termite colonies. Nematodes are natural predators that seek out the termites and destroy them. They will live for up to two years—depending on moisture conditions. Actual tests of nematodes have yielded mixed results with some applicators claiming 95% effectiveness, and others reporting 50% effectiveness with follow-up visits necessary. Proper applicator training is essential. Termite-eating nematodes are available from **N-Viro Products Ltd.** Some states require nematodes to be registered as pesticides and applied by certified pest-control professionals.

Energy

Controlling energy losses with insulation is important when part of a foundation is directly exposed to the living space. This will help keep utility bills low and minimize condensation and mold growth by keeping the interior surfaces of a foundation close to room temperature. Cool basement walls, that are damp due to condensation, can be a

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531 "Foam board voids termite guarantee," *Journal of Light Construction* (November 1991): 6.

home to mold. If done correctly, insulating a basement wall will make the space warmer, drier and more livable.[532]

Foam insulation boards are often used to insulate foundations. Outgassing is minimal from these products, especially once they have been covered with soil or a finishing material. However, there can be a problem with foam insulation with regards to insect control—termites can travel virtually unnoticed between the foam and the foundation wall—or they can tunnel through the foam itself. Actually, termites are known to be attracted to carbon dioxide, and some foam boards are manufactured using carbon dioxide as an expansion agent. Because of termites traveling through foam, one major termite extermination company quit guaranteeing homes with foam foundation insulation[533] and a major building code has restricted its use in sections of the country with a high probability of termite infestation—primarily southern California and the Gulf states from Texas to Florida.[534] Of course, termites have been found in foam foundation insulation in other parts of the country as well, so the use of foam in those climates is also being debated.[535] One way to prevent the insects from getting to the wood is to carefully design termite shields to extend over the top of the foam, but this can be a difficult detail in some applications. Carpenter ants have also been found nesting in, and tunneling through, foam.[536]

Foundation Types

There are a variety of different ways to build a foundation. The specific materials and techniques will depend on the style of the house, the lay of the land, the type of soil, and the normal depth of frost penetration in the winter. In general, any foundation can be built in a healthy manner.

To design a healthy foundation, you should be concerned with material selection (to minimize outgassing into the living space), moisture control (to minimize dampness and mold growth), deterring termites (to avoid toxic chemicals), radon mitigation (to reduce your risk of lung cancer), and energy savings (to save money and minimize condensation).

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[532] "CABO limits rigid foam in ground contact," *Journal of Light Construction* (August 1998)) 12.

[533] "Insect infestation of buried foam," *Journal of Light Construction*," (October 1998): 87-93.

[534] Richard Kendall, "Antsy about insulation" (letter), *Journal of Light Construction* (June 1989): 4.

[535] Kenneth Labs and others, *Building Foundation Design Handbook* (Oak Ridge, TN, Oak Ridge National Laboratories, May 1988). #ORNL/Sub/86-72143/1. (Available from **National Technical Information Service**).

[536] John Carmody, Jeffry Christian, and Kenneth Labs, *Builder's Foundation Handbook* Oak Ridge, TN, Oak Ridge National Laboratories, May 1991). #ORNL/CON-295. (Available from **National Technical Information Service**).

Oak Ridge National Laboratory is responsible for two very good books dealing with foundation design and construction. The *Building Foundation Design Handbook*[537] is primarily for designers and the *Builder's Foundation Handbook*[538] is a smaller guide for contractors. In addition, the booklet, *Concrete Foundations*[539] by **Canada Mortgage and Housing Corp.** has some good general information and the *Canadian Home Builders' Association Builders' Manual*[540] offers excellent illustrations and construction details.

Pier Foundations

A pier foundation is the easiest to build in a healthy manner. But it's less conventional than other foundation types. While they can look out-of-place in many subdivisions, piers can be a striking design element for a house that sits by itself. Pier foundations are often used in hot, humid climates,[541] and they can be especially dramatic on hillside lots by lifting a house up in the air to enhance the view.[542] Of course, hillside lots can require some extra design and care during construction.[543] [544]

When a pier foundation lifts a house up off the ground, the house is Separated (the second healthy-house design principle) from the soil. Because there is little direct contact with the ground, radon, moisture, and termites are less of a problem than with other foundations. The piers themselves can be made of concrete, masonry, or insect-resistant (usually chemically treated) wood.[545]

From an energy standpoint, a pier foundation itself doesn't need to be insulated,

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537 Canada Mortgage and Housing Corp. (CMHC), *Concrete Foundations* (Ottawa, ON, Canada: CMHC, 1988).

538 Canadian Home Builders' Association (CHBA), *Canadian Home Builders' Association Builders' Manual* (Ottawa, ON, Canada: CHBA, 1994). Available from **Canadian Home Builders' Association**.

539 Lucy Oatly, "Offshore and On," *Custom Builder* (March 1989): 17-19.

540 Arthur Levin, *Hillside Building, Design and Construction* (Santa Monica, CA: Arts & Architecture Press, 1991).

541 Greg Casorso, "Hillside Foundations, Part One," *Journal of Light Construction* (March 1993): 15-18.

542 Greg Casorso, "Hillside Foundations, Part Two," *Journal of Light Construction* (April 1993): 19-23.

543 Donald Patterson, *Pole Building Design* (McLean, VA: American Wood Preservers Institute, April 1977).

544 J.D. Ned Nisson, "Moisture problems from 'dry' basements," *Journal of Light Construction* (May 1992): 46-48.

545 Unies, Ltd. *Basement Condensation: Field Study of New Homes in Winnipeg* (Ottawa, ON, Canada: Canada Mortgage and Housing Corp., December 1987).

but the floor system of the house should be. The floor will, in effect, function just like an exterior wall and it should be insulated, tightly constructed, and fitted with a diffusion retarder accordingly. A pier foundation can be combined with a variety of floor framing systems: metal or wood joists, wood or concrete subfloor.

It's important to provide proper drainage with a pier foundation to direct surface water away from the structure because, if the ground slopes toward the structure, water will run under the house and form puddles, which could be havens for microorganisms, or insects such as mosquitoes. A high water table will require an underground drainage system to minimize uneven settlement and frost heaving.

The bare ground under a house built on piers can be unsightly and dusty. A covering of crushed stone or gravel will improve appearance and help control the dust. Because the area under the house is shielded from both sun and rain, weeds are generally not a problem. If there is the possibility of weeds, plastic sheeting can be placed under the gravel. A latticework of wood or metal around the perimeter can sometimes enhance the appearance and make the foundation look more conventional, but the space under the house should not be totally sealed with a skirting material—as is done with mobile homes—because it will begin to function like a crawl space, and moisture and radon could build up there. It's better to leave the area under the house as open as possible.

The tops of the piers can be capped with a metal termite shield so insects cannot sneak into the house through small cracks or openings in the piers. If piers are made of masonry, and a termite shield is not used, the tops should be well-sealed to prevent radon from rising up through them into the floor system.

Concrete-Slab Foundations

Concrete-slab foundations are relatively easy to construct in a healthy manner. They are often used in healthy houses because they are easy to cover with a low-tox floor covering like ceramic tile. While it's possible to install a wood floor over a concrete slab, it usually involves more work.

A concrete floor slab can be an integral part of the foundation that supports the rest of the house. In such a case, the footings, foundation wall, and the floor slab are all part of a single monolithic concrete foundation. It is also possible to have the footings, foundation walls, and floor slab as different elements of a foundation. Neither approach is healthier, and both must be constructed and insulated with care.

From a thermal standpoint, an insulated floor slab is more connected to the living space than to the ground. An uninsulated slab is somewhat cooler than the air in the room, especially in the winter, so there will be a microclimate of higher relative humidity near the floor and possible mold growth. The most effective use of insulation is around the perimeter, because it's in close proximity to the extremes of air temperature. The center of a floor slab is further removed from the extremes of air temperature so, in moderate climates, it may not be necessary to insulate under the center of a floor slab. Besides being energy saving, warm floors are more comfortable to walk on in winter.

To minimize cracking in a floor slab, the concrete should typically be mixed with the correct amount of water and be reinforced with steel. Wooden grade stakes used during the construction of a slab should be removed because they can become pathways for radon and other soil gases as the wood deteriorates. Any joints between the slab and any walls, pipes, wires, *etc*. should be well-sealed with caulking or aerosol-foam insulation. If a concrete floor slab is made in one piece, and all cracks and gaps have been sealed, it can be effective at blocking the air-pressure differences that move radon, ground moisture, lawn chemicals, *etc*. from the soil into the living space. If control joints are required in a multi-piece floor slab, they should be fitted with flexible water stops during construction to prevent soil gases from passing through the gaps.

Perforated drainage tiles should be used around the perimeter of a concrete-slab foundation to divert any excessive ground water from the structure. A 4"-layer of gravel under the slab can act as a capillary break to prevent moisture from wicking up through the slab into the living space. A perforated drainage tile is often placed under the center of a house within the gravel for a future radon-removal system—should that ever become necessary. The perforated tile should be connected to a length of solid pipe that is stubbed up through the slab and capped. If, when the house is complete, there are high radon levels in the house, it is a very simple matter to connect a fan to the capped pipe to suck radon from under the slab and blow it outdoors.

A floor slab should have a layer of 4-to-6-mil-thick polyethylene plastic sheeting beneath it. Any seams should be lapped at least 12". This material functions as a diffusion retarder to minimize the migration of moisture, radon, and other soil gases through the floor itself. It can also function as an air-pressure retarder to a certain extent if it is well-sealed and the concrete ever develops any cracks. If there is no gravel under the slab, the plastic acts as a capillary break to prevent moisture from wicking up through the slab into the living space. A dampproof coating on the outside of the foundation wall will prevent moisture from moving horizontally through the foundation wall by capillary suction and diffusion.

Some builders are now installing plastic sheeting under concrete footings, or a dampproof coating on top of them, to prevent moisture from wicking up through them into the foundation wall and then evaporating into the living space. Plastic sheeting might be a problem for sensitive persons if they are exposed to it directly, but when separated from the living space by concrete it's almost never a problem—especially when the floor system is airtight.

Metal termite shields can be placed under wood-framed walls with a slab foundation, but this is often difficult to do effectively. The area beneath a concrete-slab foundation is inaccessible once a house is complete, and this is often where termites reside. If a slab is crack-free, they will not be able to pass through it. But they can pass around electrical wires, plumbing drains, *etc*. that penetrate the slab by chewing their way through caulking and sealants. For these reasons, toxic chemicals are often sprayed under slabs to deter termites. In typical leaky houses, these chemicals can easily enter the living space because of air-pressure differences and diffusion. In new, healthy construction, all the measures taken to block the entry of radon and ground moisture will also prevent termite chemicals from entering the living space. If chemicals are used, and they are later found to be moving from the soil into the house, a radon-removal system can also function as a termite-chemical removal system.

Heating ducts imbedded in concrete slabs should be avoided because they can be difficult to clean, and if there is a water spill, they can remain damp and harbor mold growth. Plumbing supply lines under slabs should be minimized because they are difficult to repair if a leak develops. Plumbing drain lines under slabs should have cleanouts in appropriate places so they can be maintained.

Basement Foundations

A basement is often considered inexpensive floor space. In fact, the cost per sq. ft. for basement construction can be below the cost of above-ground space. But then, many basements are cold, damp, moldy, radon-filled, and unhealthy. It is certainly possible to build a dry, warm, comfortable, and healthy basement—but it will add to the cost of the house.

A drainage system should be used on the outside of the basement walls to divert ground water away from the structure. If a sump pump is used, it should have a sealed cover. Floor drains can be run by gravity to the outdoors or to a sump pit. A foundation coating will minimize capillary suction and diffusion of moisture through the walls. As with concrete slabs, some builders install plastic sheeting beneath, or coatings on top of, footings to stop moisture from wicking up through them by capillary action into the basement walls. Capillary action can be responsible for a significant amount of moisture entering a basement through the footings.[546] Concrete basement floor slabs should be constructed in the same way as the floors described above for concrete-slab foundations. Radon-removal piping is installed in a similar way in both cases.

Basements can be insulated, either on the exterior of the foundation wall, or on the interior. Exterior insulation generally consists of sheets of foam boards, but virtually any material can be used on the interior. Often, a 2x4 wall is constructed just inside the foundation wall and insulated just like the above-ground walls. Such a wall can be sealed with caulking, gaskets, *etc*. like other walls to make it warm, energy-efficient, and air-tight.

In new construction, concrete basement walls need a certain amount of time to dry out. So, if they are to be insulated on the interior, one source says the work should be delayed for approximately a year after the concrete has been placed.[547] This can be difficult if the plans call for a finished basement immediately. However, if a basement can be left unfinished for a while, the concrete can dry before being covered up.

The upper row of a concrete block wall should be sealed to prevent termites and soil gases from passing into the hollow cores then into the basement, but an additional metal termite shield on top may also be necessary. Unfortunately, all the methods of insulating a basement wall create hidden pathways for termites to travel unnoticed between the soil and the wooden structure. For example, they often travel between a foundation wall and the insulation.

Many basements are used for living space to some extent, so the heating/cooling system should be designed to maintain a comfortable temperature and humidity year round. The air should also be exchanged regularly with a mechanical ventilation system. If a basement is neither heated nor ventilated, its temperature will reach an equilibrium between the house temperature and that of the ground. During various times of the year, the relative humidity can be high, resulting in a mold problem. In severe cases, moisture

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[546] Canada Mortgage and Housing Corp. (CMHC), *Investigating, Diagnosing, and Treating Your Damp Basement* (Ottawa, ON, CMHC, 1992).

[547] Gerale Sherwood and Anton TenWolde, "Moisture movement in light-frame structures," *Forest Products Journal* 32 (October 1982): 69-73.

can condense on cool walls or floors. Anything stored in such a basement will become food for mold. Old books, magazines, suitcases, and clothing are especially susceptible. Dirty, little-used basements often contain a large amount of dust, some of which finds its way upstairs into the rest of the house aggravating symptoms in dust-sensitive persons.

Many people build a house with a basement thinking they will later convert it into living space—perhaps a family room or guest bedroom. Yet, for years the basement remains unfinished, uninsulated, and unused, except for the washer and dryer that are inconveniently located there. It is basically shut off from the rest of the house, with a high potential for mold growth. It's not unusual, once such a basement is finally converted into living space, for the occupants to comment that it would have been nicer if the space was above ground where it would be more airy, warmer, cleaner, more useful, better illuminated, and less moldy. If the square footage isn't needed immediately for living, it may be better to eliminate the basement altogether and build an above ground addition when needed. If you want a basement to be healthy—treat it as living space.

Because many existing basements were not constructed with proper attention to moisture control, insulation, *etc*., it can be difficult, or impractical, to treat them as part of the conditioned and ventilated living space. If mold or radon are problems, it may make sense to seal the basement off from the rest of the house as much as possible. This is often easier said than done, because there are typically many, many cracks and holes that air-pressure differences can push mold, moisture, radon, and other soil gases through between the basement and the upper floors.

There are a variety of ways to deal with radon in an existing basement, but they must usually be tailored to the specific situation. One of the most effective is to connect a radon suction fan to a sealed sump pit to depressurize the area under the floor and blow the radon outdoors into the atmosphere.

Mold and moisture problems are extremely common in existing basements. In many cases, the only practical thing to do is to run one or more portable dehumidifiers, or install a central dehumidifier such as made by **Therma-Stor Products.** But the best thing is to first analyze exactly why a basement is damp and moldy, and then take whatever appropriate remedial measures are necessary. Because there are so many possible problem areas, the book *Investigating, Diagnosing, and Treating Your Damp Basement*[548] by **Canada Mortgage and Housing Corp.** can be very useful.

Crawl Space Foundations

A crawl space is not considered living space. Crawl spaces are usually entered only to repair pipes, ducts, or mechanical equipment, so they are never cleaned, painted, or maintained. They should not be used for storage because of the possibility of belongings becoming contaminated. If a crawl space ever does get contaminated, the occupants won't be aware of it until the contamination spreads into the living space as well. To protect the living space, all penetrations between the living space and the crawl

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548 Sebastian Moffatt, "Crawl spaces—ventilation control of humidity" (Washington, DC: *Proceedings of the Bugs, Mold, and Rot Workshop Sponsored by the Building Thermal Envelope Coordinating Council of the National Institute of Building Sciences*, May 20-2 J.D. Ned Nisson, "Crawl Spaces: To Vent or Not?," *Journal of Light Construction* (February 1990): 38-40.1, 1991): 35-48.

space should be sealed using standard tight-construction techniques.

It's important for all crawl spaces to have a drainage system around the perimeter to prevent ground water from entering. In most crawl spaces, evaporation from a bare dirt floor is the most significant moisture source.[549] To block evaporation from the floor, a layer of polyethylene plastic sheeting (4-6 mil thick) should be placed on the floor of the crawl space. It will prevent dampness from entering by diffusion and capillary action. The plastic is often covered with sand or fine gravel to protect it from punctures when it's walked or crawled on. It should be sealed around the perimeter to the foundation wall, and at any seams, with long-lasting caulking or mastic. Adding polyethylene to the floor or a dirt crawl space is often the most significant way of reducing moisture problems.[550]

Most building codes require that crawl spaces be vented, so there are usually a number of vents around the perimeter. In spite of the code requirements, building scientists and moisture-control experts are suggesting that some crawl spaces not be vented. In fact, some people are actively trying to get the codes rewritten. Here's the thinking behind the controversy.

In traditional crawl-space construction, it's common practice to leave the lower-level floor of a house uninsulated (this would be the ceiling of the crawl space). When this is done, a crawl space tends to be warmer than the outdoor temperature in the winter —warm enough to prevent freezing plumbing lines. To prevent excessive heat losses, homeowners routinely close the crawl-space vents in the winter. In fact, you can readily purchase crawl-space vents with a thermostatic control that shuts them automatically in cold weather. The vents exist to allow moisture to escape from the crawl space, but when they are closed in the winter, the dry outdoor air is kept out, and moisture can build up in the crawl space. Saving energy is definitely a good idea, but closing the vents in the winter can sometimes lead to a moisture problem, and eventual mold growth or rot.

In the summer, crawl-space vents are generally left open. But when hot, humid, outdoor air enters a cool crawl space, it can condense on cool surfaces, leading to mold growth or rot.[551] So, while it makes sense—for energy-conservation—to close the vents in the winter and open them in the summer, just the opposite is true for moisture-control. In other words, to minimize moisture problems the vents should be open in the winter and closed in the summer. So what do you do—vent or not vent?

Unvented Crawl Spaces

First, we'll look at what some experts are recommending, even though it's in violation of some building codes—the unvented crawl space. If a crawl space is unvented year round, it is imperative that moisture be kept out. This means the crawl space should

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549 J.D. Ned Nisson, "Crawl Spaces: To Vent or Not?," *Journal of Light Construction* (February 1990): 38-40.

550 Joseph Lstiburek, "The Southern Crawl Space (Northern Ones Too)," *Southern Comfort* (Fall 1989): 2-3.

551 "Hot, Dry Crawl Spaces," *Energy Design Update* (January 1992): 8.

be constructed just like a shallow basement.[552] It may not need a concrete floor, but there should be a continuous diffusion retarder (usually plastic sheeting) on both the walls and floor. The space should have insulated walls (and perhaps an insulated floor), but the ceiling (the floor of the living space above) should be uninsulated, and the ceiling should not contain a diffusion retarder. All this should be sealed very tightly with tape, caulking, gaskets, or whatever is appropriate. In some cases, it's recommended that the crawl space be pressurized (with a forced-air heating/cooling system or a ventilation system) to prevent water vapor from the soil, radon, *etc*. from entering. This type of crawl space will be near the temperature and humidity of the living space throughout the year. By doing everything you can to keep moisture out, mold growth should not be a problem. Any moisture that does enter the crawl space will escape, by diffusion, into the living space.

Pipes and ducts in an unvented crawl space generally don't need to be insulated, but ducts should be well-sealed so you'll have control over where the air is going. According to a Swedish study, unvented crawl spaces (if constructed correctly) are less prone to moisture problems than their vented counterparts, in both summer and winter.[553]

Vented Crawl Spaces

If a crawl space is to be vented year round, it's still important to prevent moisture from entering—primarily by the use of well-sealed plastic sheeting on the floor, and a perimeter drainage system. The ceiling of a vented crawl space (the upper level's floor) should be insulated and it should have a diffusion retarder. There should be vents spaced evenly around the perimeter, and they should not be blocked by shrubs.[554]

One source suggests that the vent area be $^{1}/_{150}$ of the crawl-space area and the screening in the vents be no larger than $^{1}/_{4}$".[555] The ratio of $^{1}/_{150}$ is usually recommended when a crawl space does not have a plastic diffusion retarder on the floor. A more recent recommendation suggests that, if you minimize moisture entry from both the soil and the living space, a $^{1}/_{1,500}$ ratio is sufficient.[556] Using this recommendation, a house having a 3,000 sq. ft. crawl space should have 2 sq. ft. of vents (3,000 ÷ 1,500) spaced around the perimeter. The $^{1}/_{4}$" screening can allow insects to enter, but if a finer screen is used, more vents are usually required. Vents are rated by their *free area*. This refers to the effective area of a vent after subtracting the louvers or screen. This information should be provided with the vent itself, or it can be obtained from the manufacturer. Surprising to many people, the above recommendations, which date back to 1942, aren't based on any hard research. Some recent research has found that a plastic ground cover is actually more

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552 "Should Crawl Spaces Be Ventilated or Sealed Tight?," *Journal of Light Construction* (October 1992): 37.

553 NCAT, *Moisture*, 20.

554 Lstiburek, *Moisture*, 172.

555 "The Mysterious Origins of Crawl-Space Ventilation," *Energy Design Update* (October 1993): 5.

556 "Wood Moisture Content in Sealed Crawl Spaces," *Energy Design Update* (October 1992): 6.

effective than ventilation in reducing moisture levels.[557] This was also the finding of a New Jersey report.[558]

Vents should be located as high as possible on crawl space walls, and at opposite ends of the space, to achieve good cross ventilation. If within three feet of corners, there will be fewer dead spots of stagnant air. In some cases, it may seem appropriate to install vents in the rim joist, rather than in the foundation wall. This location is satisfactory from a ventilation standpoint, but it means the floor cannot be insulated in that location—not a good idea.

If there are a great many vents—far more than the above recommendation—the temperature and humidity in the crawl space will be closer to that outdoors. So, extra vents make a crawl space act like a pier foundation, and there will be less chance of pollutants or moisture building up there.

Ducts that are located in a vented crawl space should be well sealed. They should also be insulated for energy efficiency, or if condensation on them is possible. Plumbing pipes should be insulated if freezing is likely.

Summary

With a little thought, any type of foundation can be built in a healthful manner. With basements, it's important that they be designed as part of the living space—and conditioned and ventilated accordingly. Because crawl spaces are not living spaces, their requirements may not seem as severe but, to keep radon, moisture, and mold from contaminating the living space, they should be constructed with care as well. Because of conflicting energy-control and moisture-control requirements, designing crawl spaces must be done carefully.

Concrete slab foundations are fairly easy to construct in a healthy manner, but attention to detail is still important. Pier foundations, are even easier to build in a healthy manner because they do the best job of separating the house from the soil.

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557 Pfeiffer, *The Household Environment,* 33.

558 "Terpenes and lung irritation," *The Human Ecologist* (Winter 1993): 22-23.

12. Wood and Wood Products

Wood is one of the most natural and popular materials used in house building. Yet wood can cause health problems in some individuals. In fact, for a few hypersensitive people, a house built without any wood is essential. Most people, however, have no problem with conventional wood construction.

In many houses, the wood itself isn't unhealthy. But the glues used in manufactured wood products, and the chemical treatments used to control termites and other creatures that attack wood, are very unhealthy.

Wood

Wood is typically classified as being either a *softwood* or a *hardwood*. Softwood trees are evergreen or needle-bearing (*e.g*. pine, fir, spruce, redwood, cedar, cypress, and hemlock). The technical name for softwood is *conifer* because many softwood trees bear cones. Hardwood trees are *deciduous,* meaning broad-leafed. Hardwoods are usually harder than softwoods—but not always. Balsa is classified as a hardwood because it doesn't have needles or cones and it isn't an evergreen. Common U.S. hardwoods include oak, maple, beech, birch, walnut, ash, and poplar.

Hardwoods are usually slower growing than softwoods. Because it takes longer to grow a hardwood tree, hardwood lumber tends to cost more than softwood lumber. Hardwoods often have attractive coloring and grain, so are widely used in the furniture industry. Flooring, doors, trim, and cabinetry are typical uses for hardwoods in houses. On the other hand, virtually all the wood framing in today's houses is derived from softwood trees because it can be produced more cheaply. In the U.S. most softwood lumber is grown in the South or the Pacific Northwest, most hardwood lumber in the Midwest.

It is very difficult to go to a lumberyard and find anything but softwood lumber, but occasionally some hardwood boards are stocked for hobbyists. A hundred years ago, lumberyards stocked material that was cut locally from whatever trees happened to be growing in the vicinity. If there were a lot of oak or walnut trees in the area, oak and walnut boards were readily available. There are old oak barns and walnut corn cribs still dotting the countryside that were built of native lumber. When they were originally constructed, oak and walnut just happened to be what was available. Today, walnut is relatively scarce because it takes so long to grow a walnut tree.

Plywood, particle board, oriented-strand board, and hardboard didn't even exist a hundred years ago. They were developed to lower the cost of wood-framed house construction. These products are somewhat cheaper than solid-wood boards and, in some ways, they have superior strength. However, they can be implicated in health problems, mainly because of the glues used to manufacture them.

Solid wood and manufactured-wood products can be chemically treated for a variety of reasons. Because wood can burn, be attacked by fungus, or be eaten by insects, fire retardants, fungicides, and insecticides are popular treatments. The chemicals used are not always healthy for people.

Softwoods

For some sensitive people, softwood lumber can trigger symptoms. There are a variety of volatile compounds outgassed by the natural resins in softwood trees. Terpenes are often blamed[559] and exposure to them can lead to lung irritation.[560] Actually, there are a number of different chemicals in softwood lumber that can be bothersome. Turpentine is derived from softwood trees, and everyone would agree that turpentine vapors are unhealthy to breathe. Sensitive people simply react to very low levels of the same chemicals released by softwood trees in their natural state.

The aroma from a cedar closet, or a Christmas tree, can often elicit symptoms in sensitive people. Of the various softwoods widely available, fir, spruce, or hemlock are a little less odorous than pine or cedar. For extremely sensitive people, most softwoods will trigger symptoms and need to be avoided. Redwood is sometimes an exception—it has less natural odor, and is often tolerated by sensitive people.

If you go to your local lumberyard to buy a 2x4, you will likely receive one that was cut from a softwood tree—often a pine tree. Lumber is usually marked with a stamp specifying which species of tree it was cut from. The most common stamp is "SPF", meaning Spruce-Pine-Fir. Lumber with this marking can come from any of those three types of trees. "Hem-Fir" is another stamp that means the lumber is either from a hemlock or a fir tree. Sometimes a single-species stamp is seen, such as "Spruce." Fir and Douglas Fir are sometimes used for longer, larger sizes of framing (*e.g.* a 24'-long 2x12). Redwood and cedar lumber might be available because of their decay resistance, but they are not often used for general construction because of increased cost.

It can be difficult to obtain lumber of a certain species, such as fir. If lumber is stamped S-P-F, it can by any one of those woods. Placing a special order could mean ordering a railroad-car full—not a very cost effective solution when you considering a small room addition. A few lumberyards do, however, stock lumber of certain individual species. For example, they may handle spruce boards instead of those stamped S-P-F in order to obtain more consistent quality.

Some of the softwood framing lumber in a house can be separated from the living space by the use of an air-tight, aluminum-foil barrier, thus protecting a sensitive occupant from bothersome odors. It's also possible to use less bothersome (but considerably more expensive) hardwood lumber from framing, or to eliminate wood completely and use something other than wood for framing. In many cases, a combination of softwood, hardwood, steel, concrete, and masonry can be a viable solution.

Redwood is often used for porches, decks, and in damp areas, because of its natural resistance to mold, decay, and insects. Therefore, it is usually readily available. While it is not always stocked, it can be special ordered through most lumberyards. Delivery is typically less than a week in most parts of the U.S. Redwood has fewer

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559 "Formaldehyde: EPA moving toward ban on flooring, cabinets," *Indoor Pollution News* (August 8, 1991): 3.

560 Charles Wardell, "OSB, particleboard, MDF and hardboard: what they are and what they can do," *Fine Homebuilding* (April/May 1991): 77-81.

volatile resins and oils than other softwoods, so it is often a reasonably safe choice for someone sensitive to the odors of pine, especially when used outdoors—where there is enough fresh air to counteract its very slight odor. But redwood isn't perfect—some workers report skin irritation from redwood sawdust, probably due to the natural chemicals in redwood that make it resistant to insect attack.

If a sensitive person plans to use interior trim, cabinetry, or doors made of softwood lumber, the wood can be coated with a tolerable paint or clear finish on all sides to seal in the odor. This can sometimes reduce the odor enough to make the wood tolerable—but not always. After testing a sample of sealed softwood for personal tolerance, many sensitive people opt for hardwood cabinets, interior trim, and doors.

Hardwoods

Hardwood lumber can be difficult to locate for construction purposes. In some parts of the country, there are small sawmills that can supply lumber cut from locally grown trees. A difficulty in purchasing such wood is the fact that it is still *green*. This refers to wood that is not dry enough to use. Its moisture content is well above 19% and it's subject to fungus attack. It's difficult to use green lumber successfully for construction because there will be a considerable amount of shrinkage as it dries.

Wood will dry to less than 19% on its own over time—if stored properly. This is called air drying and it can take a year or more. The process can be speeded up by kiln drying—if there happens to be a lumber kiln in the area of a local sawmill. Most furniture-grade hardwood lumber is kiln-dried.

Another difficulty with sawmill lumber is its roughness. It will not have a smooth surface and its dimensions can vary by as much as $^1/_4$". A 2x4 directly from the sawmill will measure 2" x 4"—plus or minus. A softwood 2x4 from the lumberyard will measure $1^1/_2$" x $3^1/_2$" because it has a smooth, planed surface. Green hardwood lumber purchased directly from a sawmill can seem reasonably priced, but by the time it's been kiln dried and planed smooth, it can end up being quite expensive.

Because of the increased cost, hardwoods are almost never used for house framing. Instead, hardwood is reserved for the finish cabinetry and woodwork. Lumberyards can generally order hardwood trim or doors. Or, there might be local woodworkers who can supply such material. Look in the telephone book under *Woodworking* or ask the high-school Industrial Arts teacher for a recommendation. Individual woodworkers will usually be able to supply a sensitive person with small samples of various woods for testing purposes.

Hardwoods are usually not as odorous as softwoods, but each species does have a characteristic smell, and some sensitive individuals may react to one species but not another. Maple, tulip poplar, beech, and birch are usually less odorous than oak and walnut. Oak is one of the more popular hardwoods currently in use, but it is also fairly odorous, and some sensitive people can't tolerate it, even after it has been coated with a paint or clear finish—unless it has also aired out for a couple of months. Prices vary considerably for different hardwood species with walnut being relatively expensive and poplar being lower in cost.

Manufactured wood products

The majority of manufactured wood products are held together with a formaldehyde-based glue or resin. There are a few exceptions—casein and isocyanate glue are also used, but not widely. Pesticides are sometimes added to the glues. There are two basic formaldehyde glues: urea-formaldehyde (UF) and phenol-formaldehyde (PF). The PF glue is water-resistant and slightly more expensive. The UF glue is cheaper and can't tolerate excessive moisture, so it's used in materials that won't be exposed to the weather. Of the two, the UF glue outgases considerably more formaldehyde than the PF glue. Products containing UF glue should never be used in a healthy house, but those containing the less-potent PF glue can sometimes be used—especially if they are not exposed to the living space.

The manufactured wood products used for interior wall paneling and cabinetry are almost always made with the more-potent UF glue. These are usually considered *furniture-grade* materials, as opposed to *construction-grade* materials, which use the less-potent PF glue. Furniture-grade products should be avoided because of the higher formaldehyde emissions. In 1991, the **EPA** proposed banning materials made with UF glue[561] but, today, these products are still on the market—often with a warning label stamped on the back, where it will hidden once installed. The following is typical:

> *WARNING: This product is manufactured with a urea-formaldehyde resin and will release small quantities of formaldehyde. Formaldehyde levels in the indoor air can cause temporary eye and respiratory irritation and may aggravate respiratory conditions or allergies. Ventilation will reduce indoor formaldehyde levels.*

Even though some manufactured wood products contain a less-volatile glue than others, they should all be avoided by someone hypersensitive to formaldehyde—unless serious measures are taken to separate them from the living space. Solid wood can often be substituted, but people bothered by formaldehyde often react to softwood lumber, which contains a tiny amount of formaldehyde naturally.

To put the formaldehyde levels in perspective, the amount in softwood lumber is, indeed, tiny. The amount in PF-glued products is typically 10 times higher, but it's at least 100 times higher in materials made with UF glue. With products currently being made, a particle-board subfloor made with UF glue can release enough formaldehyde to result in a 0.3 ppm concentration of formaldehyde in a room.[562] For healthy people who are not bothered by formaldehyde, the levels in softwood lumber and PF glue are usually not considered a serious health problem. After all, a healthy body can process a certain amount of air pollution. UF glue, on the other hand, has been implicated is *causing* people to become hypersensitive, so it should generally be avoided by both healthy people and sensitive people.

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561 Thomas J. Kelly, Battelle. *Determination of formaldehyde and toluene diisocyanate emissions from indoor residential sources*, (Sacramento, CA: California Air Resources Board, Research Division, November 1996):104. #93-315.

562 Bruce Tichenor, "Organic Emissions Via Small Chamber Testing" (Berlin: *Proceedings of the 4th International Conference on Indoor Air Quality & Climate, Vol. 1, Volatile Organic Compounds, Combustion Gases, Particles and Fibers, Microbiological Agents*, 1987): 8-15.

The actual emission rate of a particular sample of a product containing either PF or UF glue depends on several factors (*e.g.* age or quality of the resin, additives such as formaldehyde scavengers, application methods, mixing, *etc*.). So, while PF glue is generally less potent than UF glue, there is a wide variation between products that have the same glue. In fact, some strong PF products could be as potent as some weak UF products. It's also important to understand that the usual small amount of formaldehyde in PF glue may not be a problem by itself, but it could be a problem when combined with small amounts of the many other air pollutants found indoors. So, the most conservative recommendation would be to avoid manufactured wood products containing either PF or UF glue.

The outgassing of formaldehyde is measured in units of micrograms per square meter per hour ($\mu g/m^2/hr$). Following are the ranges that have actually been measured in different products in various studies.[563]

PARTICLEBOARD
(UF glue)..100-2,000 $\mu g/m^2/hr$
MEDIUM DENSITY FIBERBOARD
(UF glue)..210-2,300 $\mu g/m^2/hr$
FURNITURE-GRADE PLYWOOD
(UF glue)..7-1700 $\mu g/m^2/hr$
FURNITURE-GRADE PLYWOOD W/ VINYL OR LAMINATE SURFACE
(UF glue)..3-300 $\mu g/m^2/hr$
CONSTRUCTION-GRADE PLYWOOD
(PF glue)..2-83 $\mu g/m^2/hr$

The outgassing rates for both glues decrease with time. In fact, the half-life of the outgassing is usually between 3-5 years. This means that during the first 3-5 year period, half of the formaldehyde will have dissipated, and during the second 3-5 year period, half of the remainder will dissipate, and so on. The actual outgassing rate depends on several factors, such as how the glue was manufactured. Two significant variables are temperature and humidity. If a manufactured wood product is used in a hot, humid climate, it will outgas much faster than if in a cool, dry locale. But, in any case, a piece of 25-year-old material will be less problematic than a similar new product. So, if they are found in an older house, manufactured-wood products are often not bothersome.

To their credit, the wood-products industry has reduced formaldehyde emissions considerably over the years on a voluntary basis. However, the amount of formaldehyde released from products containing UF glue is still too high to be considered in a healthy house. Formaldehyde isn't the only chemical outgassed by manufactured wood products. One study also identified acetone, hexanol, propanol, butanone, benzaldehyde, and benzene.[564]

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563 John A. Emery, *Structural Wood Panels and Formaldehyde: A Few Facts* (Tacoma, WA: American Plywood Association, February 1993). # SPE-1040A.

564 Larry Schmukler, "OSB: Job-site report," *Journal of Light Construction* (April 1990): 20-22.

Plywood

Plywood is a manufactured product sold primarily in 4' x 8' sheets. It is made of several layers, or plys, of wood glued into a sandwich. Plywood can by used in a number of places in house construction. Construction-grade plywood is generally made from softwood trees while furniture-grade plywood is usually made from hardwood trees. Plywood is widely used because it is cheaper than solid wood, and in some ways stronger.

Virtually all construction-grade plywood, both interior and exterior grade, is made with PF glue and is stamped with an American Plywood Association (APA) grade stamp.[565] In the past, APA interior-grade construction plywood was made with UF glue. At that time all interior-rated products (both construction-grade and furniture-grade) used UF glue, but today, all APA-stamped interior-grade products use PF glue. So, while the recommendation used to be to avoid all interior-grade plywood, the recommendation today would be to avoid *furniture-grade* plywood (which is an interior-grade product), while *construction-grade* interior plywood is no longer as noxious as it once was.

When used for a roof deck, or for sheathing under siding, the lower-outgassing construction-grade plywood will be separated from the living space and it generally won't bother a sensitive person—especially if a house is very tightly constructed. When plywood is used for a subfloor, it is much closer to the occupants and could bother someone sensitive to formaldehyde. An aluminum-foil diffusion retarder placed between a plywood subfloor and a hardwood finish floor will tend to block the formaldehyde outgassing from diffusing into the living space.

Furniture-grade plywood generally has a hardwood surface veneer. It is an interior-grade product and is widely used in furniture, cabinetry, and wall paneling. This material is almost always held together with UF glue. So, the most potent plywood is used indoors, and the less noxious material is used outside of the living space. About the only way to obtain a low-emission furniture-grade plywood product is to have it custom made. This is certainly possible, but it can add cost to a project—sometimes substantially. **Midwest Veneer & Pressing, Inc.** will custom make small quantities (even 1-2 sheets) of a veneered product to your specifications. For example, they can use a low-emission base material—such as those made by **Sierra Pine Limited** (see below)—and laminate any number of different veneers (such as oak, cherry, hickory, or even exotic imported woods) to the front and back surfaces with a variety of different glues (such as a PF glue or a polyvinyl-acetate glue). **Architectural Forest Enterprises** produces custom-made EcoPanels, made with veneers from well-managed forests, adhered to non-toxic substrates that do not contain UF glue.

LongLac Wood Industries, Inc. manufactures a hybrid plywood/fiberboard product called Multi-Core that has lower formaldehyde emissions than some other furniture-grade products. It has a wood-fiber core that resembles oriented-strand board (see below) and is made with PF glue. The core has a layer of aspen hardwood laminated to each side, then a veneer of attractive hardwood laminated to the aspen. (Several species of hardwood are available.) Unfortunately, the hardwood veneer is attached with

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565 Paul Fisette, "Plywood vs. OSB," *Journal of Light Construction* (December 1996): 46-48.

UF glue. This is a furniture-grade product that can be used in place of most other furniture-grade materials. According to the manufacturer, its emission rate is about 29% of the rate for products made entirely with UF glue. Multi-Core is available in $^1/_2$" or $^3/_4$" thicknesses.

Oriented-Strand Board

Oriented-strand board (OSB) is made of layers of wood flakes. Sometimes called flakeboard, it consists of 2-to-3"-wide softwood flakes and is generally held together with a PF glue. This material is being used more and more as a substitute for construction-grade plywood because it is less expensive. It is slightly more offensive than plywood because it requires more glue to hold the individual flakes together. It is also more sensitive to moisture than plywood, and the edges can be susceptible to swelling if it is rained on a few times, so it should not be left exposed to the weather for an extended period of time.[566] Oriented-strand board can also take on moisture in a damp attic or crawl space, and it can swell or warp.[567] On the plus side, OSB is cheaper than plywood, and it can be a more-consistent product with no soft spots, or voids. As with construction-grade plywood, it can often be used in a healthy house if it is well-separated from the living space.

Manufactured Beams and Joists

In recent years, a variety of manufactured wood beams and joists have been introduced to replace standard framing material. These products are made of plys or flakes of softwood and are held together with PF glue. For healthy people, these materials are generally not problematic because PF glue is a low formaldehyde emitter and these products are rarely exposed directly to the living space. In fact, with proper attention to tight construction techniques, and a good diffusion retarder, they can often be used with sensitive people.

Particle Board

Particle board is made from small softwood particles that resemble coarse sawdust, and it is usually held together with a potent UF glue. Particle board has been used as an underlayment for carpeting, and it's one of the chief causes of high formaldehyde concentrations in mobile homes. Wall paneling, furniture, and kitchen and bath cabinets are often made with particle board that is covered with a thin veneer of an attractive hardwood—which does little to block the formaldehyde emissions. According to one report, products made from particle board containing UF glue "are among the

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[566] T.G. Matthews and others, "Surface Emission Monitoring of Pressed-Wood Products Containing Urea-Formaldehyde Resins," *Environment International* 12 (1986): 301.

[567] Peder Daugbjerg, "Is particle board in the home detrimental to health?," *Environmental Research* 48 (1989): 154-163.

strongest and most commonly used formaldehyde emitters in indoor environments.”[568] One study found that children living in houses with very much particle board were more likely to develop headache, wheezy bronchitis, and eye and nose irritation.[569]

Many particle-board manufacturers have the capacity to use other glues than those containing UF, and some will do so for special orders—especially large orders. However, a special factory run can be costly, unless a very large quantity of material is needed. There are a few companies now using isocyanate glues. Isocyanates are quite dangerous during the manufacturing process, but they outgas very quickly, so by the time products made with them get to consumers, they're quite inert. Among other things, when people are exposed to them during manufacturing, isocyanates have been shown to cause irritation and immunologic sensitization of the respiratory tract.[570]

In most situations, when particle board is used in cabinetry, it is covered with a fancy wood veneer (*e.g.* oak, cherry, walnut, *etc.*) to enhance its appearance. The particle-board products listed below are not manufactured with a wood-veneered surface. However, there are companies who do apply veneer to these products. To locate such a veneering company, contact one of the manufacturers below and ask them for a regional distributor in your area. Then call the distributor and tell them you are looking for a veneered version of that product. They should be able to steer you to an appropriate source. See also the veneering companies listed above under *Plywood* above.

Isobord makes a particleboard from straw that is held together with an isocyanate glue. It is available in a variety of densities and thicknesses ranging from $^{1}/_{8}$" to $1^{1}/_{2}$". This product is available in some Home Depot and some Lowes stores nationwide.

Meadowood Industries, Inc. produces MeadowBoard panels in high-density veneer or hardboard, medium-density standard board, and low density Bulletin or Tack Board. They also have decorative GrassBoard panels that are hand inlaid with dried florals, ferns, and branches for use as accent panels or architectural elements.

Natural Fibre has a formaldehyde-free “Sure Foot” wheat-fiber board that is often used as an underlayment. It is sold in $^{1}/_{4}$", and $^{3}/_{8}$" thicknesses. It has a mild straw-like odor, and is held together with an isocyanate glue.

Prairie Forest Products has a formaldehyde-free Strawboard in $^{3}/_{8}$", $^{7}/_{16}$", $^{1}/_{2}$", and $^{5}/_{8}$" thicknesses. This product is also made from wheat fiber and uses an isocyanate glue.

Primeboard, Inc. has a Prime Board product that is also made of wheat straw. It is produced in four thicknesses: $^{1}/_{2}$", $^{7}/_{16}$", $^{5}/_{8}$", and $^{3}/_{4}$". Prime Board is also made with an isocyanate glue so it contains no formaldehyde. It is lighter in weight and more moisture resistant than conventional particleboard.

Rodman Industries produces a “Resincore I” particle board in a variety of sizes

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568 G.K. Sangha, M. Matijak and Y. Alarie, “Comparison of Some Mono- and Diisocyanates as Sensory Irritants,” *Toxicology and Applied Pharmacology* 57 (1981): 241-246.

569 “High marks for straw-based particleboard,” *Environmental Building News* (March 1997): 5-7.

570 Gordon and Janet Groene, “Hardboard siding,” *Remodeling* (May 1989): 164.

and thicknesses with a PF glue. It is made from either all pine, or all local hardwoods, or a combination of pine and local hardwoods.

Although straw panels aren't yet widely available, straw may be a significant building material in the future. There are several straw-panel manufacturing plants currently under construction or in the planning stages.[571]

Medium-Density Fiberboard

Medium-density fiberboard (MDF) is similar to particle board, but it's made from even smaller wood particles, it's denser and heavier, and it uses more glue. It's considered a higher-grade product than particle board but, when made with UF glue, it's the strongest formaldehyde emitter currently used in houses. Medium-density fiberboard is used for closet shelving, where it can saturate your clothing with formaldehyde, and under hardwood veneer or plastic laminates in kitchen and bath cabinets, and countertops.

Sierra Pine Limited offers three medium-density fiberboard products called Medex (exterior rated), Medite II (interior rated), Medex NC (moisture resistant) and Medite FR (fire resistant) that are being used more and more by custom cabinet makers. These products are available in various thicknesses, are held together with an isocyanate glue, and they are becoming more widely available. Although formaldehyde isn't a problem, and the cured isocyanate glue they use isn't a problem, these products can have a strong pine odor that can bother some sensitive people.

Hardboard

Hardboard is a harder, denser product than particle board. It's usually medium- to dark-brown in color and is sold in 4' x 8' sheets in thicknesses of $^{1}/_{4}$" or less. Pegboard is a hardboard product that is perforated with holes. Masonite is one particular brand that is produced by the **Masonite Corp**. Hardboard is used for interior wall paneling, underlayment for carpeting, and exterior siding. It is sometimes prefinished and used on bathroom or kitchen walls.

Hardboard is produced by pressing wood fibers into a dense sheet by means of heat and pressure. The natural lignin in the wood holds hardboard together. While the lignin is the only glue that is actually required, a phenolic resin and other chemicals are often added during manufacturer to improve strength and moisture resistance.[572] These additives can be bothersome to sensitive people. Hardboard is one of the least offensive manufactured wood products but, because it is made from softwoods, sensitive people should test it for personal tolerance prior to use. Sometimes a denser, tempered hardboard product is better tolerated than the standard grade, but linseed or tung oil are used in the tempering process,[573] and they can be bothersome to some people.

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571 Louis Wagner, "Hardboard OK for Underlayment" (letter), *Journal of Light Construction* (February 1991): 3.

572 Forest Products Laboratory (FPL), *How to Protect Logs from Decay and Stain While Drying* (Madison WI: FPL, April 1984). #84-010.

573 Edmund Frederick Rasmussen, "Dry Kiln Operators Manual," *Agricultural Handbook #188*, (U.S. Dept. of Agriculture, Forest Service, March 1961): 142.

Wood Alternatives

To minimize the use of wood in an outdoor deck, **FSI** has a LockDry interlocking aluminum decking material. If the joints between each piece of the aluminum decking are caulked, the deck will be waterproof, thus it will protect whatever is beneath the deck from rain. This product is manufactured in three colors, and matching posts and railings are also available.

For deck railings, stainless-steel cables (Cable-Rail by **Feeney Wire Rope**) can be substituted for wood. They are strong and, because they are so thin, they allow for better views.

For some people, using one of the relatively new "plastic wood" products can be an option. The products made by **Trex Co., LLC**, **TimberTech Ltd.**, and **Weyerhauser** (ChoiceDek) are a combination of wood and plastic. These materials are used for maintenance-free outdoor decks. While they can have a minor odor when new, they are often better choices than chemically treated lumber. They are generally more slip-resistant than wood for outdoor decks that get wet.

Wood's Natural Enemies

Wood has several natural enemies, and they certainly have their ecological niche. If these adversaries didn't exist, the planet would be covered with dead trees. Creatures such as termites and decay organisms are very important to the ecosystem because they help recycle trees into soil. But they do have their place. When trees are used to build houses, we don't necessarily want them to be recycled—at least until the mortgage is paid off.

Most lumber passes through several hands before it reaches a building site. It might be sprayed with various water- or oil-based chemicals at different stages of processing. For example, foresters sometimes spray trees to control insects. Freshly cut logs—which are subject to mold growth or insect damage—may be sprayed again. The newly sawn surfaces of boards from a sawmill may need to be sprayed once more. During storage—until the boards are dried—there is still the danger of fungal attack and they might be sprayed another time.[574] When the wood is dried in a kiln, the temperatures are usually high enough to stop any fungal growth, but not high enough to actually kill the fungus or the spores. Therefore, a subsequent rise in the wood's moisture content can trigger a renewed growth, requiring additional chemical treatment.[575]

Fortunately, most lumber is not sprayed at each of these processing steps—and some lumber may not be sprayed at all. Plus, most of the chemicals tend to remain on the surface of the wood so, when the boards are finally planed smooth, the chemical residues remain primarily in the sawdust and shavings. As a result, by the time it reaches builders and consumers, most lumber has little chemical contamination remaining on it due to spraying.

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[574] Rodney DeGroot, I *Decay Ecosystem in Residential Construction* (Madison, WI: Forest Products Laboratory, 1976).

[575] Stephen Smulski, "Wood fungi, causes and cures," *Journal of Light Construction* (May 1993): 15-19.

The best way to insure that the wood used to build houses doesn't rot is to keep it dry. This generally means keeping the moisture content of the wood below 20%.[576] It usually takes a moisture content of over 28% for decay fungi to get started, but once the microbes start growing, 20% is sufficient to sustain their growth.[577] Most of the time, most of the wood in a house contains less moisture than this, sometimes it's as low as 3-5%. But if the relative humidity in the air surrounding the wood is very high for a long enough period of time, or the wood gets wet repeatedly, it can absorb sufficient moisture to start decaying.

Naturally Resistant Woods

Because of various oils, resins, tannins, and other chemicals, some woods are naturally resistant to fungal growth and insect attack. These woods can be used where excessive dampness is a problem. The heartwood from the center of a tree tends to have the highest decay resistance, while the outer sapwood generally lacks resistance. Trees whose heartwood has exceptional durability, even under conditions that favor decay, include black locust, red mulberry, and osage-orange. Those of high durability include cedars, black cherry, chestnut, junipers, redwood, black walnut, and Pacific yew.[578] Many of these species are difficult to obtain commercially, but a local sawmill may be able to find a source.

The resins and oils in resistant woods, that help them discourage fungal growth, sometimes bother sensitive individuals. Of the various resistant woods, redwood is the most widely available, and it is often well-tolerated by sensitive people. Cedar is also often readily available, but it is very odorous and not often tolerable.

Chemical Treatments

Wood can be treated with a variety of chemical preservatives to make it resistant to fungal growth or termite attack. Log cabins are often routinely treated today. Many of the chemicals currently in use are often toxic to humans, as well as to fungi and insects. While research is being done into non-toxic alternatives,[579] the toxic chemicals remain popular.

There are four classes of chemical treatments today that are commonly applied to wood after it has been dried and processed into lumber. These treatments are used to deter the natural enemies of wood—both insects and fungi. Treated wood should never be used near gardens because the chemicals might be taken up by the plants.

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576 Don Graf, *Basic Building Data*, 3rd ed., (New York: Van Nostrand Reinhold, 1985), 23.

577 Roger M. Rowell, "Nontoxic Wood Preservative Treatments," *Wood & Wood Products* 83 (February 1978): 81-82.

578 Larry Stains, "EPA Gives Wood Preservatives a Cautious Okay," *The Family Handyman* (July/August 1986): 86.

579 H. Levin and J. Hahn, "Pentachlorophenol in Indoor Air: Methods to Reduce Airborne Concentrations," *Environment International* 12 (1986): 333-341.

Oily Preservatives

Creosote is an oily preservative. It is derived from wood tar, often from beechwood trees. It is dark in color, very oily, and commonly used on utility poles. Creosote is a complex mixture of phenols and their ethers and it can be very odorous. Other oily preservatives are obtained from coal tar. Breathing vapors, especially on a hot day, can bother some people who aren't particularly sensitive. When chronically applied to the skin, creosote has been shown to lead to lesions and skin cancer.[580] Because of serious negative health concerns, creosote is no longer widely available—but it can be encountered on older products, such as used railroad ties.

Solvent-Soluble Organic Chemicals

Pentachlorophenol—penta for short—is a solvent-soluble organic chemical. It is dark in color, and can cause several negative health effects. Penta is not only used as a wood preservative, but can also be found in small amounts in paper, cleaning solutions, soaps, leather, and cotton. As a result, penta is routinely found in the urine of most human subjects in the U.S. Because of its widespread use in Hawaii, Hawaiians have seven times more penta than people from the mainland population have in their bodies. Penta can be absorbed by inhalation, ingestion, and through the skin, and it has been shown to cause fetal death and embryotoxity, as well as chloracne and significant liver damage in adults.[581] In one incident, three dairy farmers were poisoned by penta-treated wood and 600 cows died as a result of licking the wood.[582] Like creosote, penta is no longer widely available, but it can still be found on some older building products.

Water-Soluble Salts

Because of restrictions on oily preservatives and solvent-soluble organic chemicals by the **EPA**, it is difficult to find anything but wood treated with water-soluble salts at local lumberyards. For example, creosote used to be popular for utility poles, but many utilities are now using salt-treated poles instead.

Salt-treated lumber is less messy and cheaper than the above alternatives, it often has a greenish tint, and it is widely used for decks and porches. There are several types available, but the most common, ammonical copper arsenate (ACA) and chromated copper arsenate (CCA), both contain arsenic compounds. These water-soluble salts do *not* contain table salt. Consumer information sheets are available at lumber yards that stock this material. They warn that it should not be used where it can contaminate food—such as on countertops. Workers are cautioned to avoid breathing sawdust from treated wood, to wash exposed areas thoroughly before eating, and to wash their clothes separately from other clothing.

The surface of salt-treated wood can sometimes be covered with a white arsenic

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580 R.T. Johnson (letter), *Fine Homebuilding* #1 (February/March 1981): 6.

581 Paul Cooke, "Wood," *Nontoxic and Natural Newsletter* #1 (May/June 1985): 6.

582 Alex Wilson and Nadav Malin, "Pressure treated wood," *Environmental Building News* (January/February 1993): 1.

powder.[583] This is especially problematic if the wood was treated in cold weather. That's because at 70°F the chemical fixes into the wood within 3-4 days, but if the temperature is below 50°F it can take a couple of weeks before the chemical is properly fixed into the wood, and in freezing temperatures, there is virtually no fixation.[584] Thus, simply touching wood that was treated in cold weather can result in arsenic on the skin. Skin absorption is more likely when moisture is present, either in the form of wet wood or perspiration. Swipe tests of treated wood foundations, playground equipment, and wood decks often show arsenical residues, and you can be further exposed if you get a splinter.

Copper, chromium, and arsenic have all been found in the soil under CCA-treated wood decks. This could be evidence that the chemicals can leach out of the wood—or it could be contamination from sawdust when the decks were originally built. However, there is evidence that the leaching of chemicals from salt-treated wood can be exacerbated in the presence of acidic rain. Whatever the cause of the contamination under treated-wood decks, researchers have measured the concentration of arsenic in the soil under them at over seven times the level allowed by the **EPA** for land application of sewage sludge.[585]

One worker, who sawed salt-treated wood every day at his job, was so affected that he got severe nosebleeds and started vomiting large quantities of blood. He also suffered hair loss, cramping, itching, and fatigue, and was eventually placed on total disability. In the end, he settled a lawsuit against the manufacturers of treated wood for $667,000.[586]

Water-soluble salts are resistant to most mold and decay organisms, and to termites. So, salt-treated wood is sometimes being used to construct basement walls.[587] In such houses, traces of arsenic dust have been found in the basements.[588] Small amounts of arsenic compounds can be leached out of the wood into the surrounding soil.

There is some concern that the treatment isn't completely effective.[589] After all, the treatment doesn't extend all the way to the heart of the wood. So, if treated wood splits or is cut, untreated wood can be exposed. Cutting a 2x12 for a stair stringer, or

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583 "New Evidence of Leaching from CCA-Treated Decks," *Environmental Building News* (June 1997): 3.

584 "Arsenic in lumber."

585 Steve Andrews, "All-Wood Foundations," *Custom Builder* (October 1989): 30-39.

586 Nisson, *The Superinsulated House*, 122.

587 Virginia Hodgdon, "Pressure-treated concerns" (letter), *Fine Homebuilding* (February/March 1993): 4.

588 David Bowyer, "Sealing & painting treated wood," *Journal of Light Construction* (May 1990): 31.

589 Richie Goldstein, "Are we poisoning our kids with treated wood?," *Journal of Light Construction* (May 1989): 4.

simply cutting a post to length exposes untreated wood to termites. Most salt-treated lumber is made with Southern yellow pine—a species prone to cracking, cupping, warping, and splitting—so it generally needs a water-resistant coating simply to maintain its appearance.[590]

Dangers to small children crawling around on a treated wood deck or playground equipment seem obvious.[591] So do the dangers of constructing picnic tables of this material. Yet, salt-treated lumber continues to be widely and indiscriminately used in inappropriate ways. While human health issues related to salt-treated lumber are being debated, it may be that planetary health will be responsible for this product's eventual decline. It is very widely used, and has a useful service life of 30 years or so, but because it is classified as a hazardous material, there are not many ways to dispose of it. Researchers have estimated that 2.5 million board feet are being disposed of each year. Even though it doesn't rot, over time, it can become warped, twisted, or splintered and, therefore no longer useful. Because there is no good way to dispose of all this treated lumber (except in overcrowded landfills) one environmental magazine has called for its ban.[592]

Actually, under favorable conditions, some species of fungi can live in salt-treated lumber. They consume the arsenic and release arsenical gases such as arsine. In houses where this type of fungus has been found consuming the treated wood, there is a characteristic garlic-like odor.[593]

Although it is not a salt-treated process, **Chemical Specialties, Inc.** has an ACQ Preserve wood treatment process that is less toxic than the above-mentioned products containing arsenic or chromium. ACQ Preserve contains ammonia, copper and "quat" (quaternary ammonia, a disinfecting agent, to preserve the wood).[594] While it is not as innocuous as the boron-based compounds (see below), this product does have a "green" label from **Scientific Certification Systems**, meaning it creates far less toxic waste than arsenic- or chromium-containing products.[595] Because it will not leech out of the wood in damp environments, ACQ-treated wood can be used in contact with the soil

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590 "Disposal: The Achilles' heal of CCA-treated wood," *Environmental Building News* (March 1997): 1.

591 Forintek Canada Corp., *An Investigation of the Biomethylation of Arsenic in Preserved Wood Foundations* (Ottawa, ON, Canada: Canada Mortgage and Housing Corp.).

592 John Wagner, "Safer treated wood" (letter and reply), *Journal of Light Construction* (May 1995): 19.

593 Ted Cushman, "New treated lumber earns environmental OK," *Journal of Light Construction* (October 1994): 13.

594 "Borate preservatives for non-exposed wood," *Environmental Building News* (January/February 1993): 14.

595 Lonnie Williams, "Controlling termites and carpenter ants with borates," *Journal of Light Construction* (February 1987): 49-52.

and where it will be exposed to the weather—something that is not possible with the boron-based treatments. ACQ Preserve is not available in all parts of the country, so you may need to contact the company for the name of the nearest retail distributor.

Water-Soluble Boron Compounds

Boron compounds (*e.g*. borax and boric acid) have been widely used as less-toxic insecticides over the years.[596] More recently, a boron-based wood treatment, called Tim-Bor, has been introduced. Originally, Tim-Bor was manufactured by U.S. Borax Inc., but it is now made by **Nisus Corp.** This is a disodium-octaborate-tetrahydrate powder that, when mixed with water, can be applied to wood (by spraying, dipping, or soaking) as a permanent treatment. It works well at deterring termites, carpenter ants, mold, and decay organisms. More than a surface coating, this preservative will actually migrate toward the heart of the wood. It is probably no more toxic to humans than borax and, while it shouldn't be ingested, it doesn't outgas anything.

NiBor-D is a similar product, also manufactured by **Nisus Corp.** It is made of the same disodium-octaborate-tetrahydrate powder as Tim-Bor, but it has slightly different labeling. This company also makes a Bora-Care product which is NiBor-D (disodium-octaborate-tetrahydrate powder) in a glycol solution. Because of the glycol, it has a mild odor when wet that can bother some sensitive individuals. In addition, they have a concentrated version of Bora-Care called Jecta that is packaged in a 30 cc syringe and can be injected into small holes drilled into wood. Jecta is particularly useful for wood that has a water-resistant coating.

These boron-based products require a certain amount of moisture to be able to penetrate into wood effectively. Therefore, Tim-Bor and NiBor-D (which are mixed with water) will penetrate damp wood more easily and effectively than dry wood. On the other hand, Bora-Care (which is in a glycol solution) will readily penetrate dry wood. The manufacturer recommends Bora-Care for treating an active termite infestation because it be will more likely to penetrate all the way through the wood.

NiBor-D and Tim-Bor are often well-tolerated by sensitive people—even when wet. In the past, Tim-Bor was classified as a registered pesticide, and it had to be applied by a certified applicator[597] but that is no longer the case, and it can now be applied by contractors and homeowners. Termite-Prufe (**Copper Brite, Inc.**) is the same disodium-octaborate-tetrahydrate powder, and it is typically sold in one-pound cans in hardware stores.

A disadvantage to these boron compounds is the fact that they will remain water soluble—so they can't be used on wood that will be in contact with the soil, or outdoors where the wood will be exposed to the weather. In new house construction, they are typically applied to all the framing lumber once a house has been protected from the weather with roofing and siding. In existing construction, it's easy to spray exposed wood in attics and crawl spaces, but wood inside the walls is difficult—sometimes impossible—to access.

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596 Don Best, "Borate-treated wood," *Practical Homeowner* (October 1989): 22-24.

597 John Wagner, "Safer treated wood" (letter and reply), *Journal of Light Construction* (May 1995): 19.

In some parts of the world (*e.g*. the Virgin Islands and New Zealand) construction lumber pressure-treated with borate compounds is readily available.[598] This wasn't the case in the U.S until recently when **Louisiana-Pacific** introduced a SmartGuard treatment for framing lumber, sheathing, and siding. The actual boron compound used for their framing lumber is the same disodium-octaborate-tetrahydrate powder contained in Tim-Bor. Their sheathing and siding use a zinc-borate compound that has similar characteristics. Building materials treated with SmartGuard are available primarily in the southern U.S, from Louisiana to North Carolina—because of the high probability of termites in those climates. To obtain SmartGuard-treated products in other parts of the country, contact the manufacturer for the nearest distributor.

Osmose, Inc., a leading manufacturer of various types of preservatives used in pressure-treated wood, has a relatively new Advance Guard wood treatment that is boron-based. It contains the same disodium-octaborate-tetrahydrate powder contained in Tim-Bor. In fact, they supply **Louisiana-Pacific** with the chemicals for treating their SmartGuard lumber. Although Advance Guard is not yet available in all parts of the U.S., it should be more widely available in the future. Contact the company for a treated-wood distributor in your area.

As with the spray-on boron compounds (such as Tim-Bor), the pressure-treating compounds also remain water soluble, so they should not be used where they will be exposed continually to the weather or the soil. While it is possible that a house built with these materials might get rained on before it is enclosed, this is not considered a significant problem. After all, a rain shower would only represent an occasional exposure to moisture during the construction phase, and once the house is completed, the treated-wood components would no longer be exposed to the weather. (Treated siding would be exposed, but it should be painted to protect it from the weather.) If there is the possibility that boron-treated components of a house will be exposed repeatedly to rain over, say, several months, this could cause the boron compounds to be leached out.

For wood already in use that is damp (over 20% moisture content) and susceptible to rot, Ultra Rods (they used to be called Impel Rods) made by **Polecare** can be used. Available in various sizes, these borate-impregnated rods are inserted into holes drilled in the wood. Once in place, the borate compound migrates into the damp wood effectively protecting it from rot. Ultra Rods are often used on historic properties.

Woodcare Systems is a distributor that handles several boron-base products, including Tim-Bor, Ultra Rods, Bora-Care and Jecta.

Other Treatment Alternatives

Distributed by **Chemical Specialties, Inc.**, ACQ Preserve is a less-toxic wood preservative than the above-mentioned products containing arsenic or chromium. ACQ Preserve contains, ammonia, copper and "quat" (quaternary ammonia), a disinfecting agent, to preserve the wood. While it is not as innocuous as the boron compounds (see above), this product does have a "green" label from **Scientific Certification Systems**, meaning it creates far less toxic waste than arsenic- or chromium-containing products. Because it will not leech out of the wood in damp environments, ACQ-treated wood can

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598 Ted Cushman, "New treated lumber earns environmental OK," *Journal of Light Construction* (October 1994): 13.

be used in contact with the soil and where exposed to the weather—something that is not possible with the boron-based treatments. ACQ Preserve is not available in all parts of the country, so you may need to contact the company for the name of the nearest distributor.

Valhalla Wood Preservatives, Ltd. has a product called LifeTime Wood Treatment. Although the formula is a secret, the company claims that it is non-toxic to plants, people, animals, and even microorganisms in the soil. It is sold in powder form, to be mixed with water. Developed over 50 years ago, it has been used for a variety of applications in Canadian national parks, as well as in Sweden and the US. It is distributed in the US by **Schroeder Log Home Supply**, and is used regularly on log homes. While this product might work well as a "preservative" in dry climates, or for fences and other above-ground applications, there are apparently no independent tests showing it to be effective against rot or decay (when compared to conventionally treated wood), so it would seem to be risky to rely on it for in-ground use, particularly in a critical application or severe climate.[599] It should probably be considered a wood *treatment* rather than a *preservative*. It will impart a silver patina to the wood.

Mold and Decay

When freshly cut, wood contains a large amount of water, so it can readily support fungal growth, such as mold or decay. Wood must be dried to a moisture content (m.c.) of less than 20% before this is no longer a problem. The construction-grade softwood lumber used in houses has generally been dried to a m.c. of 19% or less. Furniture-grade hardwood lumber is usually somewhat drier.

Once incorporated into a house, wood will generally continue to dry until it reaches an equilibrium well below 19% m.c. But, if conditions are right, dry wood inside a house can absorb moisture from a variety of sources, and get wet enough to again support fungal growth. In severe cases, this can result in rot and decay—and a weakened structure. For this reason, care should be taken to design houses so they will remain as dry as possible.

The wood components of most houses take on a certain amount of moisture during part of the year (this is called the *wetting potential*) and then they dry out during the rest of the year (the *drying potential*). As long as wood has more drying potential than wetting potential, fungal growth is generally not a problem. In other words, wood can tolerate getting wet occasionally if it has a chance to dry out to below 19% m.c. regularly.

Bare wood used outdoors can get very wet after a rain shower, but if exposed to the sun and wind, it can also dry out quickly and not support mold or decay. This means it has more drying potential than wetting potential. Of course, bare wood outdoors can still deteriorate. The weathering seen on old unpainted wood is a result of the surface repeatedly expanding and shrinking as it gets wet and dries out. While mold growth and decay may not be problems, the weathering process does result in surface deterioration. It can mean that up to $^{1}/_{4}$" of the thickness of the wood will be lost per century.[600] So, in most situations, wood used outdoors should be protected with a coat of paint.

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599 "Non-toxic wood treatment?," *Solplan Review* (May 1998): 11.

600 Harry Ulrey, *Questions and Answers for Carpenters and Builders* (Indianapolis: Theodore Audel, 1966): 76.

Framing lumber that is protected from the weather—studs, joists, and rafters, for example—can periodically get wet because of changes in temperature and humidity, roof leaks, plumbing leaks, spills, *etc*. The wood can tolerate this as long as it has a chance to dry after a period of wetting. But if the wetting is long-term, there may not be enough drying potential, and fungal growth may develop. For example, a persistent roof leak can lead to decay, and a chronically damp bathroom can get moldy.

Termites

When told of a termite infestation, homeowners often imagine their house crumbling into a pile of sawdust. When you realize there are about 1,500 pounds of termites for every person in the world, it's not surprising we get paranoid about them. It's estimated that one in ten older houses is infested to some degree.[601] Termites actually eat wood—and other sources of cellulose such as paper and cardboard. As far as people are concerned, it's not the insects themselves, but rather the poisons used to control them, that are often a health threat.

Termites can be controlled in several different ways, but the strategy for dealing with one particular species may not work at all with another species. So, it's important to know what kind of termite you're dealing with. There are about 2,200 different species of termites in the world, but only four major groups in the U.S. The subterranean termite is by far the most widespread—and the most destructive, being responsible for 95% of the termite damage to houses in the U.S.[602] They thrive in all but the coldest parts of the country. Drywood, dampwood, and powder-post termites are generally confined to the warmer southern and western parts of the U.S. A pest-control professional can easily determine which variety is present, but homeowners can also learn to identify them.

The previous chapter discussed subterranean termites, which live in the soil. They are often controlled by blocking their entry into a house with a barrier, such as termite shields, chemicals, sand, *etc*. Barriers force them to stay in the soil—away from the wooden parts of a house. Other species of termites don't need to live in the soil. They can invade a house and live and feed there without ever leaving. Because they can enter virtually any part of a house, barriers aren't practical. Any crack in the exterior woodwork or siding can provide an entry point. Caulking, painting, and replacing defective or deteriorating materials will discourage them but, in general, they are dealt with in other ways. For example, if a house is built of materials termites can't eat (*e.g.* treated wood, concrete, steel), they tend to go somewhere else for a meal. If they do invade a house, they are often poisoned in place. In some instances, the boron-based treatments can be used, but there are also some other less-toxic approaches.

Ants have been used in some cases to eat termites because they are one of their natural enemies. The Argentine ant is especially good at feeding on them, but there are no scientific studies documenting their effectiveness.

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601 John Gingrich and William Currie, "Termites and their management—Part I: Characteristics and recognition," *Informed Consent* (May/June 1994): 38-43.

602 Stephen Smulski, "A builder's guide to wood-destroying insects," *Journal of Light Construction* (September 1992): 24-27.

Inspections

No method of termite control is 100% effective in controlling termites forever. Even toxic chemicals have their limitations. So, regular inspections are always recommended.

A regular termite inspection is an important aspect of home ownership that is often ignored. We routinely notice when the roof needs replacing or a coat of paint is necessary. But, termite inspections are usually only done when a house is being sold. By monitoring a house on a regular basis, an infestation can be discovered early. This means a problem can be solved before it gets out of hand—usually with a less toxic method.

Termite inspections can easily be done by a homeowner, thus avoiding the expense of a professional. Papers describing do-it-yourself identifying, inspection, and monitoring are available from the **Bio-Integral Resource Center (BIRC)**.[603] **BIRC** is a non-profit organization dedicated to finding less toxic methods of pest control. They publish both the *Common Sense Pest Control Quarterly* (for consumers) and the monthly, *IPM Practitioner* (for professionals). The staff at **BIRC** collaborated to write *Common-sense Pest Control*,[604] a 716-page book describing hundreds of less-toxic ways of dealing with everyday pests.

BIRC recommends the following program as the least-toxic method of controlling all types of termites: 1) monitor your building at least once per year, 2) if termites are found, identify the species, 3) correct structural conditions that led to their infestation, 4) apply physical or biological controls, 5) spot treat with chemicals, if necessary, and 6) check for effectiveness.

Fumigation

For non-subterranean termites, houses are often fumigated. This involves constructing a temporary tent around the entire house and filling the house and tent with a gaseous chemical. Occupants typically aren't allowed back indoors until the house has aired out for 24-48 hours. Methyl bromide has been a popular fumigant but, sometimes, when treated houses are ready for occupancy, methyl bromide levels can start rising above the "safe" level. This occurs when absorbent furnishings (*e.g.* drapes, carpets, furnishings) absorb the chemical during fumigation, then continue releasing it into the air after the airing-out period.[605] Some occupants have complained of blurred vision and tremors. In high concentrations, methyl bromide has caused birth defects in laboratory animals.

Sulfuryl fluoride can also be used for fumigation. According to the California Department of Pesticide Regulation, it is somewhat safer than methyl bromide.[606] But it's also somewhat more expensive. There are also some other less conventional approaches

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603 Olkowski, "Termites:" 7-19.

604 William Olkowski, Shiela Daar, and Helga Olkowski, *Common-Sense Pest Control* (Newton, CT: The Taunton Press, 1991).

605 "EPA, State of California agree to label changes of home fumigant," *Indoor Air Review* (May 1992): 10.

606 "Termite control: methyl bromide," *Safe Home Digest* (May/June 1992): 6.

that are even safer for the occupants. For someone considering any unconventional termite treatment, the booklet *Least Toxic Pest Management: Termites and Other Wood Damaging Pests* by the **Bio-Integral Resource Center** is highly informative.[607]

Electrocution

The "Extermax System" is an effective non-toxic method of killing drywood termites licensed by **Etex Ltd.** This process involves the use of an *electrogun*, which is a hand-held device with a probe that is inserted into the wood to actually electrocute termites.[608] It operates at 90,000 volts, but at a low wattage, so it is safe for operators. It emits no microwaves, X-rays, or ultraviolet radiation.

An electrogun's probe shoots an electric current into a termite colony. Some of the insects die immediately, but others take a few weeks to die. Properly trained operators often report fewer call-backs than with conventional pesticides.

Heat Treatment

It has long been known that many insects cannot survive high temperatures. This has led to the development of a termite-control strategy whereby a house is heated to 120°F.[609] When outdoor temperatures are mild, it takes about 6 hours to warm up the interior of a house to the correct temperature. This doesn't seem to damage the structure of the house itself, but some furnishings or belongings could be affected. Thus, it's important to remove heat-sensitive items such as candles, phonograph records, musical instruments, *etc*.[610]

At the other end of the temperature spectrum, some exterminators have had good luck using liquid nitrogen to freeze termites to death. For minor infestations, the liquid nitrogen (which is about -20°F) is injected into termite-ridden areas, killing the insects. This works best for small, localized infestations.[611]

Desiccating Dusts

Drywood termites can be treated with light, white, fluffy desiccating dusts (silica gels or silica aerogels) in both new and old construction. These materials are somewhat less toxic than methyl bromide and cause the insects to lose the protective waxy coating on their bodies—resulting in dehydration and death. Dri-Die, Drianone, and Drione are popular brands used by termite-control companies**.**

Resistant Materials

If a house is built with termite-resistant materials (*e.g*. concrete, adobe, steel,

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[607] *Bio-Integral Resource Center (BIRC), Least Toxic Pest Management: Termites and Other Wood Damaging Pests* (Berkeley, CA: BIRC).

[608] Kevin Cooney, "Drywood termite control enters the space age," *Pest Control* (April 1995).

[609] "Heat treat pests and toxics," *Environ* #9: 28-29.

[610] Gurney Williams, "Bug Busters," *Practical Homeowner* (May/June 1991): 82-87.

[611] "The Blizzard System," *Safe Home Digest* (May 1991): 12.

etc.), termites won't be a problem. Insect-resistant wood (*e.g*. redwood) can also be used. Most chemical treatments should be avoided wherever possible. However, sometimes wood can be treated with a low-tox product like one of the boron compounds mentioned above. As long as the wood isn't exposed to the weather, this can be a permanent treatment method.

Carpenter Ants

There are several carpenter-ant species in the U.S. They are typically $^1/_4$–$^1/_2$" long and, while their color varies, most are solid black. If a carpenter-ant colony has invaded your home, you might hear them moving around within your walls, or you might spot fine wood dust on your floors that they push out of their tunnels and nests. Unlike termites, carpenter ants can't digest wood—they only tunnel through it for housing. For food, they like sweet substances such as nectar. The ants are more active at night than during the day.

Carpenter ants tend to be attracted to damp wood. This may be because it's easier to bore through than dry wood, but they are also found in dry wood. Carpenter-ant infestations often spread from an outdoor *mother nest* to one or more indoor *daughter nests*. They typically enter a house through a crack in an outside wall.

To rid a house of carpenter ants, you first need to locate the nest. You may be able to do this by listening to the walls with a stethoscope or you may see small piles of wood dust. Once you've found a nest, you can drill small holes through the walls and inject a pyrethrin spray (an extract of chrysanthemum flowers) such as Tri-Die (**Whitmer Micro-Gen Research Laboratories, Inc.**) into the nest. This is a less-toxic chemical approach, but it does contain some solvents. You should also try to find and destroy the outdoor mother nest. It can be located by following the ants from where they enter your home back to their place of origin. A mother nest is often located in dead wood. The mother nest can also be sprayed with a desiccating silica gel such as Dri-Die, Drianone, or Drione.

Boric-acid powder is a popular low-tox approach to dealing with carpenter ants. It is simply dusted along their trails and into nests. (Although it is relatively non-toxic, be sure to keep pets away from boric acid.) In addition, the electrocution and heat-treatment methods mentioned above for controlling termites can be effective in dealing with carpenter ants. Desiccating dusts are also useful. Because carpenter ants prefer damp wood, you should be sure solve any moisture problems. Another option is to remove the infested wood and replace it with new wood.

Once you've cleared up a carpenter-ant invasion, you should repair all the cracks and openings in your home's foundation where they entered. This will help prevent future infestations.

Carpenter Bees

Carpenter bees look somewhat like bumble bees. While their buzzing can be loud and annoying, the males can't sting at all and the females rarely sting. In most cases, they are not responsible for extensive damage because they tend to tunnel into and build nests in exposed trim—not in load-bearing structural members—and their tunnels are usually not very long.

Carpenter bees prefer soft, unpainted wood because it is easy to tunnel into. So the first line of defense is to paint wood that is exposed outdoors. If there are tunnels already in the wood, don't use soft putty or caulking to fill them because the bees can dig right through it. Instead, fill tunnels with steel wool and then cover with aluminum, asphalt or fiberglass materials before repainting.

Almond oil or almond essence can be used to repel the bees when they are active. Then, when they are no longer active, any damaged areas can be repaired. The pyrethrin spray mentioned above under *Carpenter ants* can be a low-tox, but effective, product to actually kill the bees.

Health Aspects of Wood

The health effects of different woods vary widely. In medical records of occupational diseases from the Pacific Northwest, there are numerous reports of "cedar poisoning", "pine, spruce, hemlock & fir poisoning," *etc*.[612] Allergic dermatitis is the most common problem in the forest-products industry. Some woods are more problematic after they are dried because of the chemical changes the wood goes thorough. Some contain active allergens and some can cause systemic poisoning.[613] One article lists 220 different woods and documented sensitivities, primarily dermatitis, mucosal irritation, asthma, and general symptoms.[614]

A common problem in the wood-products industry is wood dust, something not encountered in a completed wood-frame house. Wood dust can settle on a workers' skin or enter their sinuses. Long term exposure to any kind of irritating dust can be harmful, and there have been reports of cancer affecting industrial workers after long-term exposure to wood dust. Hodgkin's disease is seen in woodworkers more often than in the general population.[615] While sawdust from exotic hardwoods is often more hazardous, workers should protect themselves from excessive exposure to sawdust from domestic woods as well.[616] Illnesses have also been reported involving reactions to glues and to bacteria or fungi growing on wood.

There are a variety of natural constituents in wood that can effect human health: alkaloids, anthraquinones, benzo- and naptho-quinones, catechols, flavonoids, furocoumarins, glycosides, minerals, phenols, saponins, sequiterpene lactones, stilbenes,

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612 Raymond R. Suskind, "Dermatitis in the Forest Product Industry," *Archives of Environmental Health* 15 (September 1967): 322-326.

613 Carey P. McCord, "The Toxic Properties of Some Timber Woods," *Industrial Medicine and Surgery* 27 (1958): 202-204.

614 B. Woods and C.D. Calnan, "Toxic Woods," *British Journal of Dermatology* 94 (13 Supplement, June 1976): 1-97.

615 Bjorn M. Hausen, *Woods Injurious to Human Health: A Manual* (New York: Walter de Gruyter, 1981): 158.

616 James Barrett, "Dust busting," *Practical Homeowner*, (November/December 1990):14-17.

and terpenes. Some are sensitizers and irritants, other cause cardiac and toxic effects.[617] Rosewood, teak, and other tropical woods are often found in the literature as causing various reactions. Violinists frequently place a handkerchief between their chin and the violin to avoid a skin reaction with the wood. For sensitive individuals, care should be taken in selecting woods, because practically every wood in use has some recorded negative health effect.

Of the woods commonly available in North America, chemically sensitive people are often bothered by softwoods—except redwood, which is usually tolerated. Of the common hardwoods, oak and walnut can be bothersome because of their strong natural odor. Beech, maple, and poplar are less odorous, and are often better tolerated. The odors of most woods diminish with time, and paints and finishes can be used to minimize the odor.

For sensitive people concerned with using wood in the construction of a house, testing can be easily done. A sample of a particular wood can be obtained to see if it causes symptoms. Because interior woodwork will generally be painted or coated with a clear finish, it's more realistic to test a sample that has already been finished. Framing lumber may be a problem when a sensitive person is exposed to it directly, but once the walls are covered with drywall or plaster, it may be tolerable.

Summary

The most serious health problems related to wood have to do with chemical treatments and glues. Because of their potential to contaminate the indoor air with formaldehyde, manufactured wood products should be avoided—especially those containing urea-formaldehyde glue. Materials containing phenol-formaldehyde glue or isocyanate glue are less of a problem.

For chemically sensitive individuals, softwoods are sometimes bothersome—if they are directly exposed to them. Hardwoods are less offensive, especially for exposed interior woodwork.

When chemically treated wood is specified, redwood is a very good substitute and, if it is not exposed to the weather, a boron-based treatment is generally acceptable. When wood is used in the construction of a house, you should carefully consider how the house can be protected from termites. This is easier to do before a house has been built—than after an infestation is in progress.

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617 Hausen, *Woods:* 22.

13. Alternative Framing Materials

The vast majority of houses in America are framed out of wood. The most serious disadvantage to wood is that it often needs to be treated for termites. In very cold, northern climates, termites are not a significant threat, but in many parts of the U.S. virtually all houses are in danger of attack. Some banks actually require houses to be treated with toxic chemicals before they will approve a mortgage. A secondary disadvantage to wood only concerns chemically sensitive people—for them the widely used softwood framing lumber can sometimes be bothersome.

There are a variety of framing technologies, besides conventional 2x4 wood framing, that are gaining popularity among some builders. Some address the health-related disadvantages of wood, some do not. From an indoor-air-quality/human-health standpoint, the framing of a house is not as much of a concern as the indoor finishing materials—simply because the framing is generally covered up. So, if cash is in limited supply (and for most of us, it is), you should spend your time and money on healthy materials that are actually inside the living space (*e.g.* flooring, cabinetry, paints, *etc.*) and use conventional wood framing because it's usually cheaper.

Manufactured Wood Products

Most builders have been incorporating manufactured wood products, such as plywood and oriented-strand board, into houses for several decades. Today, there are a host of new engineered wood materials available for framing. Wood I-beams, Trus-Joists, and Glu-Lam beams are now replacing some solid-wood framing members. These items are often stronger, straighter, and available in longer lengths than their solid-wood counterparts. Some are made in layers like plywood, others are constructed with wood flakes like oriented-strand board.

Engineered wood products are held together with a phenol-formaldehyde glue, which isn't considered a serious formaldehyde emitter. However, for very sensitive people it can be problematic, as can the fact that all engineered wood products are made from softwood lumber. These materials are no more or less susceptible to termite damage, so they must be protected just like solid wood.

Log Construction

Log construction has the same advantages and disadvantages as conventional wood framing—the individual pieces are just bigger. So, your first health concern should be selecting a method of termite control. If you are chemically sensitive and are bothered by the natural odor of wood, log construction can be more of a problem than conventional wood framing because there is much more wood exposed to the living space. If you are not bothered by the aroma of wood, and you take termite control into consideration, a log home can be healthy. One chemically sensitive woman successfully opted for this construction approach in a relatively unpolluted area of Texas.[618] However, she was extra careful to avoid polluting materials throughout the house (*e.g*. cabinets, paints, *etc*.).

Log buildings tend to settle over time as the wood dries and shrinks. This can cause some of the joints between the logs to open up. Thus, if you are interested in tight construction, you are going to need to periodically re-seal the structure. The *chinking* used to seal between joints has traditionally been composed of various mixtures of sand, cement, lime, clay, straw, and fireplace ashes. These materials tend to yield a rigid chinking that is prone to cracking, so some builders are now using a more flexible synthetic chinking. It tends to maintain a tight seal longer, but can be bothersome for sensitive people—until it has had time to air out.

Although it's no longer being done, many older log buildings were chemically treated with pentachlorophenol. This teratogenic and carcinogenic chemical outgases slowly over many years. It can be found in the indoor air of treated buildings 15-20 years after application—sometimes even longer. It is also found in the blood and urine of the occupants, with the highest levels in children. According to an **EPA** report, sealants are ineffective at reducing pentachlorophenol emissions.[619] If you have a treated log home, pentachlorophenol levels can be reduced somewhat by increasing the ventilation rate.[620]

Foam-Core Panels

A foam-core panel consists primarily of a thick layer of synthetic foam insulation. Most panels are made into a sandwich with facings of drywall, plywood, or oriented-strand board. Some have wood or steel framing members integrated into them for strength. They are usually available in 4' widths and in a variety of lengths. Some panels are structural, that is, they can be used without any other framing, to hold up a house.[621] Structural panels are called SIPs (Structural Insulated Panels). Other panels are non-structural and must be supported by some type of framing.

The foam insulation in the core of a panel varies by manufacturer, as do some of the construction details.[622] Expanded polystyrene, extruded polystyrene, urethane, and isocyanurate are all currently being used. No manufacturer currently uses urea-formaldehyde foam.

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618 Joseph and Carol Berke, "Healthy Home," *Log & Timber Style* (Spring 1999): 63-64.

619 Environmental Protection Agency (EPA) *Pentachlorophenol in log homes: A study of environmental and clinical aspects* (Washington, DC: EPA, December 1986). #EPA-560/5-87-001.

620 "Sealants ineffective for PCP control in log homes," *Indoor Air Quality Update* (September 1988): 5-6.

621 Steve Andrews, "Building with structural foam panels," *Journal of Light Construction* (February 1992): 13-17.

622 Steven Andrews, *Foam core panels & building systems* (Arlington, VA: Cutter Information Corp., 1992).

Foam-core panels can be erected fairly quickly, but some specialized tools are required. They are available in a number of thicknesses (typically ranging from $3^1/_2$" to $11^1/_4$"), so superinsulation is possible. Individual panels are generally sealed together at the seams, so houses built with them tend to be tightly constructed. These houses are usually slightly more expensive than conventionally framed houses (one source says they add about 2% to the overall cost of the house), but such houses are often much better insulated, so energy costs can be lower.

The foams currently in use do not usually have a significant effect on indoor air quality. In fact, for fire codes, foam materials must always be covered with something like drywall or plaster. While an interior plywood or oriented-strand board might be exposed to the living space, the phenol-formaldehyde glue isn't a significant formaldehyde emitter. However, it can be problematic—especially for sensitive people. For such individuals, emissions into the living space can be minimized by covering the interior surfaces with an aluminum-foil diffusion retarder, and well-sealed drywall. **Nu-Fab Building Products Ltd.** manufacturers a foam-core panel with a metal skin.

While carpenter ants won't eat the insulation used in foam-core panels, they can tunnel through it and make nests in it. This was a problem in some early foam-core-paneled houses.[623] Today, many manufacturers put insect repellents, such as the low-tox, boron-based Tim-Bor (**Nisus Corp.**), into the foam during manufacture, so ants are no longer a problem.[624]

Green Building

There are a number of ways of building that are becoming popular among environmentally conscious individuals. These *green* technologies are said to be "good for the planet" because they utilize indigenous or recycled materials.[625] [626] The *Guide to Resource Efficient Building Elements (GREBE)* is a good source for green building materials.[627]

A green building should address several issues:[628] occupant health (this should always be the first priority), energy efficiency (conserving energy saves resources and

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623 Paul Fisette, "Coping with ants in insulating foams," *Custom Builder* (August 1988): 35-36.

624 "Termite-proof below-grade insulation," *Environmental Building News* (September/October 1993): 7-8.

625 Steve Loken, "Recraft: An environmentally friendly home," *Journal of Light Construction* (September 1992): 28-30.

626 Marcelle Soviero, "The recycled house," *Popular Science* (April 1991): 68.

627 Walter Spurling and others, *Guide to Resource Efficient Building Elements (GREBE)* (Missoula, MT: **Center for Resourceful Building Technology**, 1993).

628 Canada Mortgage and Housing Corp. (CMHC), *Healthy Housing, A Guide to a Sustainable Future* (Ottawa, ON, Canada: CMHC, 1993).

minimizes outdoor pollution, renewable energy sources are best), resource efficiency (building with fewer materials, using materials more wisely, using renewable materials), environmental responsibility (using pollution-free heating methods, recycling scrap materials, using land wisely, disposing of hazardous materials properly), and economic viability (houses must be affordable, buildable, adaptable, and marketable). Popular examples of green building technology include rammed earth, adobe, pumice-crete, and straw bale, but there are others.

A green building isn't always a healthy building. In testing done in Canada, the outgassing of green building materials was compared to the outgassing from conventional building materials.[629] In general, green products were comparable to conventional products, some were more potent outgassing sources, some were less potent. In an unusual situation, it was learned that the reinforcing steel that was used in an office building in Taiwan was contaminated with radioactive material, exposing the occupants to excess radiation.[630] Steel is widely recycled and recycling is generally desirable, but perhaps it isn't a good idea with contaminated raw material. Thus, green builders should select materials carefully in order to be assured of good indoor air quality.

Rammed-earth walls usually consist of a sand/soil mixture that has been packed into temporary forms until it is very dense. Occasionally cement is added to the mixture. The raw ingredients must be selected and mixed carefully. Once the forms are removed, the wall is very durable. Sometimes walls are covered with stucco. The forms can be fairly expensive because they must withstand considerable pressure as the sand/soil mixture is packed between them. Rammed-earth walls are termite resistant, but they tend to be labor intensive. So, unless someone is an owner-builder, these houses can be costly.

Adobe is made from soil having a sufficient amount of clay to hold the wall together well. Adobe is sometimes made stronger with the addition of straw or grass—or cement. The raw materials are not compressed like rammed-earth walls. Adobe walls are traditionally built up from sun-dried blocks. The blocks may require several months of drying time. The blocks are stacked up and held together with a mud mortar, and sometimes "plastered" with additional layers of mud. This type of construction is termite resistant but its use is limited to dry climates such as the southwestern U.S.

Straw-bale construction involves stacking bales of straw to form walls, then plastering or stuccoing the surface. Straw-bale houses are well-insulated, they use renewable resources, and they can have beautiful organic shapes. But, as with most construction techniques, there are disadvantages as well: straw-bake walls must be designed and built with care to allow for settling, stucco tends to be labor-intensive, and stucco can be costly. Tightly packed straw is remarkably fire-resistant and termite resistant. But it can become home to rodents if not properly plastered.

Moisture control is important in all forms of construction—green or otherwise. For example, adobe might not be appropriate in a rainy climate—unless you want muddy

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[629] Canada Mortgage and Housing Corp. (CMHC), *Build green and conventional materials off-gassing tests* (Ottawa, ON, Canada: CMHC, February 1995).

[630] W.L. Chen, C.C. Liao, M.T. Wang, and F.D. Chen, "Preliminary study of dose equivalent evaluation for residents in radioactively contaminated rebar buildings," *Appl. Radiat. Isot.* (December 1998): 1641-1647.

walls. Keeping moisture levels low in a straw-bale wall is very important to minimize decomposition. This isn't to say that green technologies or alternative framing methods are more susceptible to moisture damage or fungal growth—its just that all methods of construction must address a variety of issues (*e.g.* moisture, infiltration, exfiltration, structural support, wind loading, air quality, longevity, *etc.*), and some of those issues may not be obvious to someone who doesn't have an in-depth understanding of a particular system. So, if you are interested an a technology that isn't widely used in your part of the country, you should get some expert advice.

Some green technologies are older methods of building that have been replaced over the years by conventional wood-frame construction, often because of cost—stick building with lumber tends to be less expensive. While some building codes are beginning to address some alternative techniques, they are often ignored in many jurisdictions. Plus, insurance companies, appraisers, and mortgage lenders don't often embrace alternative technologies. And, in general, there is little evidence as to whether any particular approach is tolerated better or worse by chemically sensitive individuals.

Green building is a good idea. However, it's doubtful if some of the green technologies will ever have a significant effect on the housing industry—at least in the foreseeable future. Most people will probably continue to live in conventionally built homes. The focus of this book is on occupant health—the most important of the green building principles—and the concepts discussed in these pages can be applied to any type of construction—green or conventional.

Steel Framing

Steel framing has been widely used in commercial construction and occasionally in multi-family homes. It was first used in pre-fabricated houses in the 1930s, but eventually, wood framing reigned supreme. Today, steel framing is seeing a resurgence in the residential market,. For designers, the **American Iron and Steel Institute** has a *Residential Steel Framing Manual* that is very helpful.[631] Their *Builders' Steel Stud Guide* is an excellent booklet for builders and contractors to learn the basics of steel framing, including a number of tricks to make a job go easier.[632] There is also a trade publication, *Metal Home Digest*, that contains timely articles on steel framing.[633] In addition, **The Steel Alliance** has a good deal of information for both consumers and professionals about the many uses for steel in houses. Because it's often recommended for sensitive individuals, we will discuss steel framing in some depth.

Advantages

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631 American Iron and Steel Institute (AISI), *Residential Steel Framing Manual* (Washington, DC: AISI, 1993).

632 American Iron and Steel Institute (AISI), *Builders' Steel Stud Guide* (Washington, DC: AISI, October 1996) Pub #RG-9607.

633 *Metal Home Digest,* 7450 N. Skokie Blvd., Skokie, IL 60077-3395, 847-674-2200.

Steel framing has several advantages.[634] It's often lighter in weight than wood framing, and it's considerably lighter than other inert materials like concrete or masonry. Quality control is consistently very good, so steel members aren't subject to twisting, shrinkage, or warping. In other words, there is no need to search through a pile of steel studs to find the straight ones.

Steel studs have holes pre-punched in them for electrical wire or plumbing lines. This saves electricians and plumbers time because they do not have to drill holes individually. Steel is non-combustible and some insurance companies provide coverage at less cost. Steel framing is usually galvanized, making it rust resistant. It can accommodate virtually any type of interior or exterior finishing material: plaster, drywall, brick veneer, metal siding, stucco, *etc*.

A significant health advantage to steel is its resistance to fungal attack, and it won't be destroyed by termites and carpenter ants—so it never needs to be chemically treated. For those individuals who are chemically sensitive, it has the additional advantage of being odor-free.

Disadvantages

One of the big disadvantages to using steel is that most builders are unfamiliar with it. It can't be cut with a hand saw or nailed together, so a few specialized tools are needed for assembly. While cutting can be done with a hacksaw, tin snips, or a portable circular saw with a metal cutting blade, for anyone contemplating building an entire house it would be wise to invest in a power cut-off saw. Although the various members can sometimes be welded together, they are more often assembled with self-tapping screws. These can be installed with a power drill, but an electric screw gun will be more efficient. The addition of a few clamps will complete the list of special tools required.

Steel framing behaves differently than wood. Therefore, some special design details are necessary for proper bracing or bridging. Most manufacturers have literature available that describes the various construction techniques.

For someone with sensitivities to petroleum products, steel framing occasionally has a thin coating of oil.[635] This film is picked up during the manufacturing process and can be easily washed off with a heavy-duty cleaner such as a solution of TSP (trisodium phosphate) in water. If the steel has been stored outdoors, most of the oil is removed by exposure to sun and rain.

The most significant disadvantage to steel framing is its lack of energy efficiency. A significant amount of heat is lost through each framing member—enough to degrade the thermal performance of an insulated wall by as much as 35-50%.[636] However, there are a number of things that can be done to minimize this effect (see below).

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[634] "Steel is a solid alternative to wood framing," *Custom Builder* (July/August 1992): 70-72.

[635] Don Ellis, "Safe Homes with Safe Materials," *Environ* #3 (Winter 1985-86): 4.

[636] "Steel studs: Thermal performance," *Energy Design Update* (February 1993): 4-7.

Types of Steel Framing

There are three basic kinds of steel framing. The average person may only be able to think of one: *heavy-gauge steel*. However, *light-gauge steel* is more applicable to residential work—and there are two types of it: *load bearing* and *non-load bearing*.

Heavy-gauge steel includes I-beams and angles—the heavy materials of which skyscrapers are built. Occasionally, a heavy steel beam (or several steel columns) will be used in a basement to support the floor of a house. A wood beam could easily be designed to perform the same function but, because wood is not as strong, a much larger wooden beam might be required—so the use of steel can be space-saving. Most heavy-gauge steel is painted with a primer to protect it from rust. This can sometimes bother paint-sensitive people until it has completely cured.

A few companies specialize in steel-framed houses that use heavy-gauge steel to support the structure. The frame may have the members placed eight feet or more apart. The steel is so strong that closer spacing would be a waste of material. Light-gauge steel is then used to fill in between the heavier members. In most situations, light-gauge steel is better-suited to residential construction than heavy-gauge material, so our discussion will be concerned primarily with it.

Light-gauge steel comes in several shapes, but there are two that form the basic system: studs and channels. When these are assembled, they resemble a standard 2x4 wall more than a skyscraper. The studs come in a variety of sizes and thicknesses. The very thin and smaller sizes are considered non-load bearing and are often referred to as *drywall studs*. They are designed to support only the finishing material such as drywall or plaster, so they are used only for interior partitions. They may be as thin as 26 gauge (0.0168").

Load-bearing light-gauge steel framing will actually hold up the structure, even a several story building. The heaviest framing members are made of 14 gauge (0.0747" thick) steel. The $3^1/_2$"-wide stud is common, and the larger sizes (up to $13^1/_2$" wide) are referred to as joists. Joists can be used in roof and floor systems. Many manufacturers offer standard details for making roof trusses out of light-gauge steel. **Alpine Engineered Products, Inc.** specializes in producing TrusSteel steel trusses.

Cost

Non-load-bearing studs are often cheaper than wood, while load-bearing studs are a little more expensive—but costs vary in different parts of the country. A builder of prefabricated steel houses may be able to erect a lower cost house due to mass-production techniques, but a builder who has never used steel studs before will usually quote a higher cost. Load-bearing studs can generally be placed on 24" centers instead of the common 16" centers used in wood construction, thus helping to lower the total cost.

Assembly

As mentioned above, heavy-gauge and light-gauge framing can be combined. Wood and steel can also be combined in a hybrid approach to framing. With careful design, this can be a reasonable alternative for someone sensitive to softwood odors. For example, all the exterior load-bearing walls of a house can be framed out of wood in the conventional manner. Then the walls and the ceiling can be wired, plumbed, insulated, drywalled and sealed up tightly. Once the wood and the insulation are sealed behind the drywall, the interior partitions can be built with non-load-bearing steel studs. This is how the second house in *Chapter 26, Three healthy houses* was built.

One of the first questions people ask about steel framing is, "How do you fasten everything to it?" Welding can be used with the heavier gauges, but self-tapping screws are much more common. Many of the screws have a small drill bit for a point so they can easily penetrate the thicker steel framing members. Electric screw guns are made by many manufactures. They typically have a magnetic chuck to hold a Phillips screwdriver bit, and a clutch that disengages when the screw is seated.

Drywall or plaster board are attached to the studs with screws as well. Vinyl or metal siding is also attached with screws. Interior woodwork is attached with trim screws. Trim screws look like finish nails with a small head, but they accept a small Phillips screwdriver bit that is driven with a screw gun. Plywood roof decking, or metal roofing, can be screwed down as well.

Most steel-framing suppliers stock a variety of screws as well as the metal framing itself. A mail-order supplier of screws is **Dynamic Fastener**. There are as many different kinds and sizes of screws as there are nails in a conventional house. It is simply a matter of learning to use a screw gun instead of a hammer. The various techniques are not difficult to master and can be easily learned with practice.[637]

Insulation

Steel is a very good conductor of heat, so when used in the structure of a house, a great deal of heat can be lost through each framing member. This is true in any framed wall system—more heat is lost through each stud than through the insulation. As an example, consider a 2x6 wood-framed wall that is insulated with R-19 fiberglass-batt insulation. Each stud has an R-value of a little over 7, so the *average* R-value for a entire wall with 2 x 6 wood studs 16" on center is about 15.1. Because there is so much heat loss through a steel stud, the average R-value for a similar wall framed with steel is only about 7.1.[638]

In the winter, the inside of a steel-framed wall will be cool near each stud. This can lead to a localized area of high relative humidity, or even a microscopic film of condensation.[639] Dust will stick to this damp area, leaving a shadow, and it can lead to mold growth. These *ghost lines* can also occur in a wood-framed house, but usually only when there is a very high relative humidity indoors.

There are several ways to minimize (but not eliminate) the heat-loss problem with

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[637] Steve Mead, "Light-Gauge Steel Framing," *Fine Homebuilding* #32 (April/May 1986): 67-71.

[638] Nadav Malin, "Steel or Wood Framing? Which Way Should We Go?," *Environmental Building News* (July/August 1994): 1.

[639] Henry Spies, "Ghosts from the attic," *Journal of Light Construction* (September 1990): 11.

steel framing.[640] First, walls can be framed differently. For example, steel can be framed on 24" centers (or wider), rather than 16", to minimize the number of studs in a wall, thus the heat loss. Secondly, an insulating foam sheathing can be used. In a steel-framed wall, it will give you more R-value for your money than cavity insulation.[641] Thirdly, you can build a double-wall system.[642] This standard superinsulation technique has been used to minimize heat loss through any type wall. The **American Iron and Steel Institute** has a booklet titled *Thermal Design Guide for Exterior Walls* that can be very helpful in designing steel framing systems for greater energy efficiency.[643]

You can also minimize heat loss by opting for a hybrid approach—using a combination of wood framing and steel framing, wherever each is appropriate.[644] Wood can be used for insulated walls, floors and ceilings, and steel for the non-load-bearing interior partition walls. If the house is tightly constructed, this can be viable for chemically sensitive people who are bothered by softwood framing lumber, because the wood framing (and the insulation) will be separated from the living space.

Manufacturers

Steel framing is being promoted by a number of organizations.[645] [646] The **American Iron and Steel Institute** maintains a roster of producers of various types of galvanized (zinc coated) steel framing. Listings can also be found in the yellow pages under *Building Materials*. Some conventional lumber yards and building-supply centers are now stocking steel studs. Drywall suppliers often stock steel studs because some drywall manufacturers also produce steel framing and other building materials. They should probably be one of the first places to check when looking for a contractor familiar with using steel framing. Some commercial builders listed under *Buildings, Metal* in the telephone book can also be helpful.

A few companies exist that sell prefabricated steel-framed houses. For the most

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640 Bruce Sullivan, “Steel framing: Thermally challenged?,” *Journal of Light Construction* (March 1994): 58-60.

641 “Foam sheathing over steel framing—Does it ‘fix’ thermal bridging?,” *Energy Design Update* (July 1993): 6-9.

642 John Bower, *Healthy House Building for the New Millennium* (Bloomington, IN: The Healthy House Institute, 2000).

643 American Iron and Steel Institute (AISI), *Thermal Design Guide for Exterior Walls* (Washington, DC: AISI, January 1995) Pub. #RG-9405.

644 Tim Duff, “Hybrid framing with wood and steel,” *Fine Homebuilding* (January 1994): 37-40.

645 Metal Lath/Steel Framing Association (ML/SFA), *Lightweight Steel Framing Systems Manual*, 2nd ed. (Chicago: ML/SFA, 1984).

646 Metal Lath/Steel Framing Association)ML/SFA), *Introduction to Steel Framing*, Technical bulletin #131 (Chicago: ML/SFA, 1978).

part, they also use materials such as plywood, partial wood framing, and foam insulations. But with some extra planning, they may be able to supply a shell that could be competed with low-tox materials. **Tri-Steel Structures, Inc.** is one such producer that has distributors nationwide. They have a number of basic plans and can provide custom designs utilizing both heavy-gauge and light-gauge steel framing, and they sometimes offer seminars around the country. A book is available that discusses these houses, as well as steel framing in general.[647] **Classic Steel Frame Homes** offers builders pre-engineered bolt together steel home packages with training classes.

Manufacturers of light-gauge steel framing usually offer technical literature describing their product, such as strength tables. Many companies offer guidance to designers and builders with specific questions, but they generally don't work directly with consumers. They can, however, often recommend contractors in the area familiar with using their products. In addition, **The Steel Alliance** offers a contractor locator on their web site.

There are quite a number of light-gauge steel-framing manufacturers around the country, including: **Allied Studco**, **Dietrich Industries**, **Dale/Incor**, **Harrison Manufacturing Co.**, and **Wheeling Corrugating Co.**

Insulating Concrete Forms

Insulating Concrete Forms (ICFs) come in various styles. Some resemble giant Lego building blocks while other systems use sheets of foam separated by metal or plastic spacers. ICFs have been gaining acceptance among builders in recent years. To use them, a hollow foam wall is created on top of a concrete footing, then the cavity in the center is filled with concrete (usually reinforced with steel). The foam form stays in place to insulate the wall. Costs tend to be a bit higher than conventional wood framing, but ICFs typically result in a stronger wall that is better insulated.

ICFs can be used for both foundation walls and above-grade walls.[648] They must usually be braced with 2x4s to keep the foam forms from moving around while they are filled with concrete. While erecting the forms themselves can go quickly, putting up the bracing can be time consuming. Specific details have been worked out by the various manufacturers for attaching siding and drywall, and for routing plumbing and electrical lines.

Because the foam forms are designed to remain in place, they become an integral part of the wall. This saves the trouble of stripping off reusable forms and then insulating a concrete wall after it's hardened. Foam insulations have some minor outgassing characteristics. However, building codes generally specify that foam insulation be covered up with a material like drywall to prevent a fire from reaching it quickly, and this minimizes occupant exposure under normal circumstances.

There are a number of manufacturers of ICFs around the country. They include **American Polysteel Forms**, **American ConForm Industries**, and **ICE Block Building**

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647 Carl & Barbara Giles, *Steel Homes* (Blue Ridge Summit, PA: Tab Books, 1984).

648 Ralph Woodard, "Building above grade with ICFs," *Journal of Light Construction* (June 1998): 51-55.

Systems.

Summary

There are a variety of alternative ways to construct the support structure of a house, but conventional wood framing will doubtless remain the most popular. Steel framing is probably the most likely alternative to earn converts from conventional builders. The health aspects of the various alternatives aren't significant, but there are definitely advantages and disadvantages. The biggest health advantage to steel framing is its termite resistance, but this advantage is not significant if a low-tox termite-control strategy is used with wood framing.

For someone interested in using an alternative form of building, reading some books on the subject is highly recommended. Alternative techniques often require special knowledge and skills, so an experienced designer and contractor are essential. Some techniques are appropriate for some particular geographic zones but not for others. For example, while it might seem obvious that igloos aren't appropriate in the Midwest, how would an adobe house hold up in New England?

In some ways, alternative construction techniques are experimental—until all the bugs are worked out. It often takes many years before the nuances of building with a new material or technique become well understood. For instance, the first superinsulated houses lead to a very good understanding of how a house functions as a system, but there were mistakes made along the way—some minor, some disastrous. While early users of steel framing didn't realize how much heat loss there was through steel studs, experienced builders now understand how to deal with the issue. If you are interested in any alternative form of construction, be sure to work with a builder or designer who is familiar with it.

14. Roofing

Roofing materials generally have little impact on indoor air quality simply because they are not exposed to the living space. However, there are instances where chemically sensitive people have been bothered by roofing. This often involves a situation where open windows overlooking a hot roof in the summer allow roofing odors to enter the house. Extremely sensitive people can sometimes be bothered by roofing when they are walking on the ground around a house.

Roof Sheathing

A roofing material is usually attached to roof *sheathing*. Most of the sheathing material used today is plywood or oriented-strand board, both of which can emit a small amount of formaldehyde from the phenol-formaldehyde glue. The sheathing is not directly exposed to the living space, so it is usually not a problem—especially in a very tightly constructed house. However, some sensitive people are leery of having *any* formaldehyde sources in their house. If that is the case, a deck of solid 1x8 boards can easily be substituted.

If wood shingles or wood shakes are to be used on a roof, solid boards are often a better choice than sheet materials such a plywood. The boards should be spaced several inches apart to allow for better air circulation underneath the wood roofing. This promotes drying and is called *skip-sheathing*.

Individual shingles are often installed with asphalt-impregnated felt paper (sometimes call tar paper) between them and the sheathing. This material can bother some sensitive people as the asphalt outgases, especially on a hot day. It's sometimes suggested that polyethylene or polyester be substituted to minimize the asphalt odor. However, these alternative materials can deteriorate when exposed to the heat of a roof.

Some sheet-metal roofs are attached to wood or metal purlins spaced 24" to 60" apart. The closer spacing forms a ladder that installers find convenient to use on steep roofs during construction. Wood purlins are usually 2x4s. Metal purlins are made in a variety of shapes and sizes and should be selected for each particular application. Some light-weight sheet-metal roofs need to be installed over plywood, oriented-strand board, or solid-wood decking to provide sufficient support.

If a house is tightly constructed, odors from the roof system will not be able to enter the living space though cracks, electrical outlets, *etc*. In many cases, a roof system is vented to remove excess heat and moisture from the attic space. Both tight construction and roof venting help minimize the chance that roof odors will enter a house. If a house has a general ventilation system, the fresh-air intake should not be located where it can pick up roof odors and being them indoors.

Roofing Materials

There are a variety of different roofing materials available, but asphalt/fiberglass shingles dominate the residential market. Wood shingles, clay tiles, and metal roofing are also used. All types have advantages and disadvantages, some are health-oriented, some are not.

Composition Shingles

Asphalt shingles are more correctly called composition shingles. They are made of asphalt-saturated felt with colored mineral granules embedded in the surface. Fiberglass shingles are composition shingles that are composed of asphalt-saturated fiberglass with a mineral-granule surface. Fiberglass is more widely used than felt, and fiberglass shingles do not contain as much asphalt. Fiberglass shingles are used on 90% of all houses[649] and they're typically nailed or stapled to a roof deck made of plywood or oriented-strand board. An underlayment material, such as asphalt-impregnated felt paper, is usually installed between the deck and the shingles. With asphalt shingles, a heavier shingle is more durable than a lighter-weight shingle, but with fiberglass shingles, tear strength is more important than weight. A good fiberglass shingle should have a tear strength that conforms to ASTM Standard D-3462.[650]

Some sensitive people react to materials containing asphalt when they are warm. A roof can get very hot on a sunny day, so it can definitely outgas some asphalt orders. However, most of the odor from shingles and roofing dissipates upward into the atmosphere and, because they are not directly exposed to the living space, composition shingles are usually tolerated by sensitive people.

Occasionally, a sensitive person will be affected by new composition shingles on a house. For this reason, it's sometimes recommended that sensitive people substitute fiberglass shingles for asphalt shingles because they contain less asphalt. However, if a sensitive person is going to be bothered by asphalt shingles, they will probably also be bothered by fiberglass ones. As all composition shingles age (asphalt or fiberglass), they tend to outgas considerably less.

Wood Shingles and Shakes

Wood shingles are sawn on both sides so they are flat on the top and bottom. Wood shakes are split on one side, so they have a textured, irregular upper surface. Both are popular because of their attractive appearance. They are also more expensive than composition shingles.

A wood roof can be very durable—but only if installed correctly.[651] Some wood roofs last 50 years or more, but others barely last 20 years. The reason has to do with how they are installed. The "wrong" way seems to be the most popular today—installing them on plywood or oriented-strand board sheathing with an asphalt-impregnated-felt underlayment. When this is done, the backs of the shingles don't dry quickly after a rain. If a roof can't dry quickly, it will deteriorate and need premature replacement. The correct

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649 Ted Cushman, "Choosing an asphalt shingle: Organic vs. fiberglass," *Journal of Light Construction* (May 1993): 11-14.

650 Henry Spies, "Shingle differences" (Letter and reply), *Journal of Light Construction* (March 1993): 12.

651 Henri deMarne, "Wood Shakes & Shingles," *Journal of Light Construction* (October 1992): 29-32.

way to install wood shingles is to attach them to skip sheathing.

Cedar is the most widely used wood roofing material because of its natural resistance to insect and fungal attack. Cedar shingles and shakes are available in their natural state or pressure-treated with fire retardants. In order to extend the life of wood shingles, especially in hot, humid climates, it's often recommended that they be treated with wood preservatives containing both water-repellent and fungicidal agents.[652] Not only can these chemicals bother sensitive people, but the strong odor of the cedar itself can be offensive. In a few instances, the strong odor of a new cedar roof has permeated the entire attic space and found its way into the living space.

Southern yellow pine is also being used for shingles. Because it doesn't have the natural decay resistance of cedar, pine shingles must be treated with various chemicals. These chemicals can leach out of the shingles, run off the roof, and contaminate the ground around the building.

Because of the required chemical treatments, or the strong natural odor of cedar, wood shingles are usually not recommended for sensitive people. However, sensitive people often tolerate redwood, and there is one company (**Amarant Wood Products**) that manufacturers redwood shingles.

Concrete and Clay Tiles

Clay roof tiles are often seen in hot climates, especially in Spanish architecture. This is a very healthy material because it outgases nothing. However, a house must be designed to support the extra weight, so it's not always a good choice for retrofits. Clay tiles can be fairly expensive, but they often last for the life of a building. Clay tiles can be the natural color of clay, or manufactured with a baked-on colored glaze.

Concrete tiles are also healthy and they are often seen in hot climates in residential construction. The concrete itself is fairly inert, but concrete is more porous than clay, so it can retain water longer and sometimes be subject to mildew growth. Some concrete tiles are coated on the surface with an acrylic colorant, while others are impregnated all the way through with an iron-oxide pigment to give them color.

Roofing with concrete and clay tiles can be costly but, if installed correctly, these materials should last 50-100 years.[653] Because they are low-outgassing, concrete or clay roof tiles are often recommended for chemically sensitive people. They are available in several styles from the traditional reddish-colored Spanish roll type to contemporary glazed flat tiles or slate-like tiles in a variety of colors. Manufacturers include: **Ludowici Roof Tile**, **MonierLifetile**, **U.S. Tile Co.**, and **Vande Hey-Raleigh Architectural Roof Tile**.

Slate Shingles

Slate is a durable roofing material that is often found on churches, and it's

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652 Red Cedar Shingle & Handsplit Shake Bureau (RCS&HSB), *Recommended Care and Treatment of Red Cedar Shake and Shingle Roofs*, (Belleview, WA: RCS&HSB, n.d.).

653 David Gustafson, "Roofing with concrete tile," *Journal of Light Construction* (May 1990): 13-15.

occasionally seen on older houses, especially in the Northeast. Slate is an inert product and it is well tolerated by most people. Because of its high cost, it's rarely seen in new construction, but it can be cost effective over the life of the building because it generally lasts over 100 years. It's not difficult to install, although most builders will need to do some reading before tackling a slate roof.[654] Slate is very heavy and it requires a framing system designed to support its weight.

Occasionally, used slate roofing can be found at local salvage yards at a reasonable cost. New slate roofing, in a variety of natural colors, can be purchased from: **Buckingham Virginia Slate Corp.**, **Rising and Nelson Slate Co.**, and **Vermont Structural Slate Co.**

Fiber-Cement Shingles

In the past, fiber-cement shingles contained asbestos fibers as a reinforcing material. In those applications, the asbestos was bound up in the Portland-cement, and as long as the material was intact, it was usually not considered a health hazard. However, these products could release asbestos fibers when they were cut during installation or when they are broken during demolition. Homeowner's have unknowingly removed them during remodeling or repair without realizing they contain asbestos. Some asbestos-fiber-cement shingles are composed of up to 20% asbestos fibers.

If older fiber-cement shingles are on an existing house, it should be remembered that the greatest danger is when they are broken. They generally won't release any fibers if in good shape, and left alone. However, one study found that asbestos-cement materials can deteriorate when exposed to acid rain, and asbestos fibers can be released through weathering.[655] If removal is necessary, the precautions required with any asbestos-containing product should be followed. Additional information about asbestos can be found in *Chapter 25, An in-depth evaluation of six common pollutants*.

Today, several companies produce fiber-cement shingles without asbestos. These newer, healthier products are durable and inert, and they often resemble slate shingles or wood shakes, but their cost is typically less than the real thing. Manufacturers include **Certainteed Corp.** (DuraPress Weather Boards), **Eternit** (Thrutone Slates, Stonit Slates, and Alterna Slates each in several styles and colors) and **Slate/Select, Inc.** (8 colors and blends). These products are often factory colored, but some colors will fade with time.

Flat Roofs

Flat roofs often have problems with leaks because they can't shed water as fast as a sloped roof. Actually, in reality, most flat roofs aren't really flat—they generally have a very slight slope. In the past, flat roofs were commonly covered with built-up roofing, but today synthetic membrane roofs are popular. If a flat roof is especially prone to leaks, in some cases it's possible to construct a sloped roof system over the flat roof to better shed water.

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[654] David Heim, "Roofing With Slate," *Fine Homebuilding* #20 (April/May 1984): 38-43.

[655] K.R. Spurny, "On the release of Asbestos Fibers from Weathered and Corroded Asbestos Cement Products," *Environmental Research* 48 (1989): 100-116.

Built-Up Roofs

Built-up roofs are made of alternating layers of hot asphalt, or modified bitumen, and rolled roofing material. They have been used extensively in the past and continue to be popular for flat roofs—especially on commercial buildings. Built-up roofs are not commonly used on residences, but they certainly can be. Because they contain asphalt, they can bother sensitive people—especially during installation when the hot, boiling asphalt is being applied. The odor of hot asphalt can also affect a certain percentage of non-sensitive people. For example, a number of employees in an office building complained of eye and upper respiratory tract irritation after a hot-asphalt roof was applied—resulting in lost attendance and reduced productivity.[656] Sometimes built-up roofs are covered with gravel which can seal in some of the asphalt odor.

Membrane Roofs

Today, synthetic membranes are often used for flat roofs instead of hot-asphalt materials because they are much more durable and easier to apply. The adhesives used in these roof systems can easily bother sensitive people, but they tend to dissipate fairly quickly, so sensitive people often tolerate these roofs better than built-up roofs. There are different membrane materials in use, with EPDM (a synthetic rubber composed of ethylene diene monomer) being one of the most durable. To perform well, these roofs must be installed correctly, preferable by a certified installer who has experience using them.[657]

Innovative Formulations has a liquid membrane Mirrorseal roof coating system that is water-based and low-odor. It is applied in conjunction with a polyester reinforcing fabric that is embedded in the coating.

Metal Roofing

Metal roofing is manufactured from a variety of different materials including copper, aluminum, steel, and stainless steel.[658] Stainless steel and copper are quite expensive and are not often encountered in residential construction. Aluminum and steel roofs usually have a protective coating such as paint, zinc (galvanizing), or terne metal (an alloy of lead and tin). Some products rely on a controlled oxidation process to protect them. This process is chemically similar to rusting but it actually helps to protect the roof.

Steel is the most widely used metal-roofing material, and it is being seen more

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656 R.M. Lynch and H. Kipen, “Building-related illness and lost time following application of hot asphalt roof: a call for prevention,” *Toxicol. Ind. Health* (November-December 1998): 857-868.

657 Joe Bublick, “Installing EPDM rubber roofs,” *Journal of Light Construction* (November 1996): 31-34.

658 J. Azevedo, “Metal Roofing,” *Fine Homebuilding* #24 (December 1984/January 1985): 42-46.

and more on residences.[659] A galvanized-steel roof with a colored baked-on paint can be quite durable and attractive. Metal roofs with baked-on finishes are well tolerated by sensitive individuals and are good choices for healthy houses. There are a number of different paints being used, so extremely sensitive people may want to obtain a sample prior to installation. Because most paints are baked on, outgassing is minimal.

The gentle sound of rain on a metal roof is viewed as a positive point by some people. Others consider the sound to be noise and a drawback. In a well-insulated house, the sound is usually not excessive, but in an *uninsulated* building with no ceiling, the sound of rain on a metal roof can be quite loud.

Sheet Roofing

Long sheet-metal panels that run from ridge to eave are widely available. This type of metal roofing is often used on agricultural and commercial buildings, but it can also be used on houses, and with a little planning, it does not have to look like a barn roof.[660] A striking residential look can often be achieved simply by designing a nice eave detail and selecting an appropriate color. Metal roofing is preferred by many architects and developers because of its long life, aesthetic qualities, and ease of installation.[661]

If you just consider material costs, sheet-metal roofing is generally more expensive than low-cost composition shingles. But, if metal roofing is attached to wood or metal purlins, their cost can be a little less than plywood sheathing. Labor costs to install sheet-metal roofing on a simple rectangular roof can be low. On the other hand, complicated roof designs with many hips and valleys require more labor, and they result in more wasted material, thus a higher cost.

Sheet-metal roofing is available in different configurations or shapes, and it can be installed in several different ways. The best (and most expensive) roofing is the standing-seam roof. A standing-seam roof utilizes hidden fasteners so there are no holes placed in the roof itself. Less-expensive installations utilize nails with rubber washers under their heads which are simply driven through the ribbed roofing into wooden purlins. A drawback to using nails is the fact that they can work their way out slightly, allowing for a possible leak. Using screws with rubber washers under their heads usually doesn't result in leaks. Special flashings are required in some locations where a roof abuts a wall or at plumbing vent stacks.[662] These are generally available from roofing suppliers.

To locate a supplier or installer who is familiar with metal roofing, first check your telephone book under *Buildings—Agricultural*, *Buildings—Metal*, or *Buildings—Pole & Post Frame*. An expensive commercial roof will be heavier and have a better

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[659] Don Vandervort, "Have you considered a metal roof?," Practical Homeowner (March/April 1992): 66-71.

[660] Rob Haddock, "Low-cost metal roofing," *Journal of Light Construction* (June 1992): 19-22.

[661] "Metal Roofing Finds Good Home in Multi-Family Dwelling Market," *Metal Construction News* 6 (August 1985): 1.

[662] Rob Haddock, "Sealing and flashing metal roofs," *Journal of Light Construction* (June 1992 Supplement to "Low Cost Metal Roofing").

coating than a low cost agricultural-grade material. Commercial roofing is often considered *structural*, that is, it's self supporting, and can be placed over widely-spaced purlins.[663] Non-structural roofing is generally placed over a solid deck, or over purlins spaced on 24" centers. Various construction magazines routinely run articles on the finer points of installing metal roofs.[664] When comparing prices, ask your supplier for an expected life. This can be compared to the commonly used fiberglass shingles which last 15-25 years.

Manufacturers of various styles of standing-seam and ribbed sheet-metal roofing include: **ATAS International, Inc.**, **Berridge Manufacturing Co.**, **Georgia-Pacific Corp.**, **McElroy Metal, Inc.**, **Metal Building Components, Inc.**, and **Metal Sales Manufacturing Corp.** They all typically have a number of styles in various colors. In addition, **ATAS International, Inc.**, **Met-Tile, Inc.**, **Metal Sales Manufacturing Co.,** and **Berridge Manufacturing Co.** all have sheet-metal roofing in a variety of colors that is formed to resemble curved clay Spanish tiles.

Most of the companies listed carry nails, screws, plumbing-vent-pipe seals, gaskets, sealing tape, structural support members, and standard trim pieces. Some will also make custom trim shapes.

Individual Metal Shingles

Individual metal roof shingles are available from several manufacturers. **Berridge Manufacturing Co.** offers a variety of individual metal shingles that resemble wood shakes, Victorian metal shingles, Spanish tiles, and fish-scale shingles. These all utilize hidden fasteners and must be mounted over a roof deck of solid boards or plywood, with asphalt felt underlayment.

W.F. Norman Corp. also has metal shingles in several styles, including Spanish Tile, Mission Tile, two Victorian Styles, and a Normandie Style. They also offer interesting trim pieces for the ridge. All are available in galvanized steel (standard), or copper on special request.

ATAS International, Inc. has Castle Top individual diamond-shaped metal roof tiles in painted aluminum or steel, or natural zinc or copper. They also have some other metal shingle styles. These products are attached with hidden fasteners over a solid deck with an underlayment of asphalt-impregnated felt paper.

The metal shingles that resemble rustic wood shakes, and are often seen on fast-food restaurants, are available from **ATAS International, Inc.** (Perma Shake) and **Berridge Manufacturing Co.**

Gutters and Down Spouts

The function of gutters and down spouts is to divert water away from a building. Without them, excess water will run off the roof and saturate the ground. This can result

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[663] William Rose, "Shopping for structural metal roofing," *Journal of Light Construction* (May 1989): 32-34.

[664] Rob Haddock, "Sealing and Flashing Metal Roofs," *Journal of Light Construction* (January 2000): 63-68.

in a wet foundation, crawl space, or basement. Gutters can be a haven for mold because of accumulating leaves and debris. They should, therefore, be cleaned regularly, and perhaps rinsed with a garden hose.[665]

Leaf guards can sometimes be added to gutters to keep out leaves, but they usually don't prevent smaller leaf particles from getting into the gutter. In other words, they can minimize the build-up of organic debris in gutters, but they can't eliminate it.

If the surface of the ground slopes steeply away from a house with a wide overhang, and there is an impervious layer on top of the soil (*e.g.* clay or concrete), there may be little danger of water saturating the ground near the foundation. In this situation, it's possible to eliminate gutters. However, this can lead to erosion of the ground under the eaves. Erosion can be minimized by using a diverter attached to the eaves to break up the water sheet that usually runs off the roof in the rain. One such product, called a Rainhandler is manufactured by **Savetime Corp.** Another solution is to dig a shallow trench under the eaves, line the trench with plastic sheeting, place a perforated plastic pipe in the bottom, then fill the trench with gravel. If the trench is sloped to drain, the force of the water running off the roof will be broken up by the gravel, and it will flow down the pipe in the trench away from the house.

Roof Venting and Moisture Control

Moisture and heat are two things that can shorten the life of a roof and their effect can be minimized by proper venting. Roof venting keeps a roof cooler in summer, thus extending shingle life. Venting can also solve some moisture problems. For example, if excessive water vapor from the living space gets into a roof system, it must be allowed to escape, or it will result in condensation, mold, or rot. One way to vent a roof is to have vents at the eaves and ridge. This allows air to enter at the eaves and rise up through the ridge, removing any excess heat and moisture from the attic space. In order to prevent condensation, the basic rule of ventilation states that the attic temperature should be close to the outdoor temperature at all times.[666]

There are a wide variety of methods used to vent roof systems: louvers, ventilators, fans, grilles, *etc*. Venting is generally done with sloped ceilings as well as attics. Many venting products are sold through local lumber or building materials suppliers. Roofing installers generally stock different types. A rule of thumb states that there should be 1 sq. ft. of venting per 150 sq. ft. of attic floor, and half should be at the eaves and half at the ridge.[667] This is usually sufficient if most of the moisture from the living space is kept out of the attic with tight construction techniques.

Ice Dams

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665 Thomas Sweeney, "Gutter Talk," *Practical Homeowner* (November/December 1991): 16.

666 Giles, *Steel Homes*, 182.

667 Sal Alfano and Clayton DeKorne, "Low-profile ridge vents," *Journal of Light Construction* (May 1992): 17-21.

When a roof is vented, the shingles will be close to the outdoor temperature, so winter snow won't melt on the roof until the outdoor air temperature rises above freezing. However, *ice damming*—which can lead to mold, mildew, or rot—can sometimes occur with vented roofs in the winter. If the attic insulation is packed tightly at the eaves, heat from the living space slowly moves through the insulation and warms the roof deck slightly. The snow directly over the warm part of the roof melts and runs down the slope. When it hits the part of the roof above the overhang, (which is colder) it refreezes, forming an ice dam on top of the roof.[668] This can take place under a blanket of snow, so you may not see it, but the dam can allow melted snow to back up under the shingles, and leak into the attic or living space. Sometimes, ice damming is accompanied by large icicles hanging down from the eaves. The solution is to insert special baffles between the insulation and the roof deck. This allows air to circulate under the deck, keeping it cold and, thus, preventing the heat from the living space from melting the snow. Two types of insulation baffles are manufactured by **Ado Products** (Durovent and proVent). When baffles are in place, heat from the living space still slowly enters the attic, but it dissipates into the attic air, and is carried out through the vents.

Unvented Roofs

Some experts suggest that if a ceiling is tightly constructed, and if it has a diffusion retarder, there won't be any way for moisture to get into the attic, so venting isn't necessary.[669] In fact, sometimes venting actually causes more moist air to enter the attic.[670] Because moisture from the living space is the biggest contributor to moisture in an attic, tight construction is always a good idea to minimize attic moisture problems.[671] Unvented cathedral ceilings are becoming popular, but they must be built tightly—and they must contain enough insulation to prevent ice damming. With too little insulation, an unvented cathedral ceiling will result in a warmer roof, so the snow melts, runs down the slope, then refreezes at the cold eaves. In areas where snow accumulation rarely exceeds 8-9", R-38 insulation in an unvented cathedral ceiling is usually sufficient to prevent ice damming.[672] In climates where more snow is common, venting is probably a good

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668 Julie Wyckoff, "Attic insulation demons," *New Shelter* (September 1984): 78-83.

669 "Attic ventilation," *Solplan Review* (September 1993): 3-4.

670 "Problems with vented cathedral ceilings," *Energy Design Update* (December 1992): 8-9.

671 Don Fugler, "Recent field and test hut research in attics" (Washington, DC: *Proceedings of the Bugs, Mold, and Rot Workshop Sponsored by the Building Thermal Envelope Coordinating Council of the National Institute of Building Sciences*, May 20-21, 1991): 27-34.

672 J.D. Ned Nisson, "Hot debate over hot roofs," *Journal of Light Construction* (June 1991): 39-40.

idea,[673] and if you don't build a tight house, venting is very important.[674]

Attic Exhaust Fans

Although they are widely used, attic exhaust fans that are designed to vent the attic space have been found to cause problems. When they pull air from the attic, they depressurize that space, which often causes air from the living space to leak into the attic. This can depressurize the living space enough to result in backdrafting and spillage of combustion appliances.

During the summer, attic exhaust fans often cool the attic by pulling air-conditioned air from the living space. This is an expensive way to cool an attic, and it can overwork the air conditioner, and lead to an uncomfortable living space.[675]

Mold on Roofs

Moss, algae, mold, and mildew can grow on many types of roofing, especially in damp, shaded locations. This is not only unattractive, but it can shorten the live of many roofing materials. It can also be unhealthy if spores blow down onto sensitive persons. The best remedy is to remove overhanging branches so the wind and sun can keep the roof dry. North slopes are particularly susceptible because they often do not receive much sunlight. The ultraviolet from the sun is especially helpful in combating mold and mildew.

To clean an existing roof, a chlorine bleach solution is often recommended, but it can bother sensitive people, and the runoff can kill grass and landscaping plants.[676] **Verdant brands** has an alcohol-based herbicidal soap called Safer Home, Deck & Patio Moss & Algae Killer that is specially formulated to kill mosses, algae, lichens, and liverworts (but not mold and mildew) on roofs. While it has an alcohol odor when applied, it airs out quickly and isn't as toxic as bleach.

A low-tox method for controlling moss on a wood roof involves stretching bare copper wires across the roof every ten feet horizontally along the butt ends of shingles. The slow normal corrosion of the copper will help to poison the moss. A copper or galvanized ridge cap can also be effective for about ten feet down the roof.[677] **Chicago Metallic Corp.** has a low-tox Shingle Shield product made from zinc that is designed to

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[673] Ted Cushman, "Roof venting: How much is enough?," *Journal of Light Construction* (December 1996): 53-54.

[674] Bruce Sullivan, "Exposing attic ventilation myths," *Custom Builder* (January/February 1994): 84-86.

[675] John Tooley and Bruce Davis, *The Unplanned Impacts on Houses By Powered Attic Ventilators* (Raleigh NC: N.C. Alternative Energy Corp., n.d.).

[676] Henry Spies, "Conquering unsightly roof stains" (letter and response), *Journal of Light Construction* (S eptember 1992): 33.

[677] I.C. MacSwan and M.G. Huber, *Controlling Moss on Roofs* (Corvallis, OR: Oregon State University, Reprinted January 1966). Fact Sheet #FS 10.

be placed under the lower edge of some of the rows of wood or composition shingles. Over time the zinc erodes slightly and zinc oxide, a mild fungicide, washes over the roof and inhibits mold, mildew, and moss. It won't remove moss already on a roof, but it will prevent new moss from growing. In some southern states, composition shingles are available with zinc-impregnated granules to inhibit algae and moss on roofs.

Summary

There are a wide variety of materials used for roofing. Because of their odor, asphalt and cedar products occasionally bother sensitive people but, in most cases, roofing has little effect on indoor air quality. Materials such as slate and clay tile are fairly inert, but they are also higher in cost and they add a considerable amount of weight to a roof. One of the healthier materials that is more cost effective, is a sheet-metal roof. They are being seen more and more as designers realize they can be both attractive and long-lasting.

15. Siding

The siding used on the *exterior* of a wall has less potential to contaminate the inside of a house than the *interior* wall finishing materials simply because the siding is exposed to the outdoors. But while most of the outgassing will be diluted by the outdoor air, some can enter the living space through an open window, or random cracks and holes in the structure, because of air-pressure differences. Outgassing from siding can sometimes be problematic for a sensitive person sitting outdoors near it on a deck or patio. Outgassing tends to be more pronounced when siding is warmed up by the sun.

The sheathing and housewrap used under the siding are also of concern. However, they are neither exposed directly to the outdoors nor the indoors. They are within the wall itself, so they have less potential to affect a sensitive person. Still, if a wall isn't constructed in an airtight manner, air currents flowing through random cracks and gaps can carry pollutants outgassed by these materials into the living space. While this usually isn't a serious concern—unless highly polluting materials are used—it can be minimized by building a tight house.

Sheathing

When 2x4 construction was first developed in the early 1800s, sheathing was not used. As a result, many old buildings have leaned out of square because of a lack of bracing. Without sheathing, houses were less resistant to the wind—it simply blew right through the cracks into the living space. After a while, horizontal boards were used for sheathing. This helped somewhat, but there were still a lot of cracks, and it didn't provide optimal bracing. When builders started attaching the sheathing boards diagonally, the triangular bracing gave a building much more rigidity.

After plywood and other sheet materials were developed, they started to become popular sheathing materials. Their use results in fewer random cracks, thus tighter construction. Some sheet materials add wind bracing and strength to a house, but there are also weaker non-structural sheet materials that are either better insulators or less expensive.

Wood

Solid board sheathing is no longer used because of its high cost. But sometimes a diagonal board is nailed into notches cut in the studs at the corner of a house—for strength—then the entire wall is covered with a non-structural sheathing.

Plywood and oriented-strand board are widely used for sheathing. If nailed properly, they provide the rigidity necessary to brace a house against the wind and keep it square. In many cases, these materials are used only at the exterior corners of a house—for strength—and a weaker non-structural material is used on the rest of the wall.

Both plywood and oriented-strand board contain a phenol-formaldehyde glue that is not considered a significant formaldehyde emitter. Still, many sensitive people are concerned about using such products in the construction of their house.

Fiberboard

Fiberboard sheathing is either black or brown in color. It is composed of various plant fibers held together with an asphalt binder. It provides more insulating ability than plywood or oriented-strand board, and is lower in cost, but it has little strength. If used, there must be a way of providing wind bracing and rigidity to the building. Fiberboard can outgas small amounts of asphalt odor, especially when heated by the sun.

Foam

When the energy crunch hit in the 1970s, insulating foam boards began to replace plywood and oriented-strand board as sheathing. Foam sheathing adds no strength to a wall, so corners must be stiffened with diagonal boards, or wood or metal strapping set into diagonal notches.

Several types of foam boards are being used for sheathing—urethane, isocyanurate, extruded polystyrene, expanded polystyrene. These materials tend to be the most expensive sheathing materials, but they add the most insulating value. All the different foams have some outgassing characteristics, but they don't seem to be significant problems for sensitive people. Some release small amounts of chemicals that can damage the ozone layer.

Gypsum Board

Gypsum-board sheathing is somewhat similar to drywall or plasterboard, but it is designed to be used on the outside of a wall. To withstand the weather, until it is covered with siding, it contains a small amount of asphalt to resist moisture absorption from precipitation. It is not widely used on residences, but can usually be special ordered. Gypsum sheathing will add strength to a wall, but little insulative value. It outgases less than asphalt-impregnated fiber board.

Cardboard

One-eighth-inch-thick aluminum-foil-faced cardboard can also be used for sheathing. Surprisingly, if nailed properly, it can usually provide the strength necessary for wind bracing. It doesn't add much insulating value however, and it's cost is moderate. It outgases very little, but in a few rare cases sensitive people have been bothered by the printing ink on the surface which advertises the manufacturer's name.

Foil-faced cardboard sheathing is made in several styles with either a foil or a poly facing. The product with foil on both sides is the least bothersome to sensitive people. The Thermo-Ply brand is distributed by **Ludlow Coated Products.**

Because aluminum foil is a very good diffusion retarder, foil-faced sheathing is risky to use on the outside of the wall in a cold climate because it can lead to unwelcomed moisture condensation inside the wall cavity. These products are, therefore, most often used in warm climates.

Elimination of Sheathing

Where building codes allow it, in some cases, it's possible to eliminate sheathing.[678] But before you do so, you need to analyze the different functions of

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[678] Nadav Malin, "Assessing sheathing options," *Environmental Building News* (September/October 1992): 1.

sheathing, and make sure you address them in other ways. Sheathing can 1) add rigidity and strength to a wall (wind bracing), 2) add insulative value to a wall, 3) act as a wind barrier to minimize infiltration, 4) act as a stiffener behind thin siding materials (such as vinyl), and 5) it can provide you with a surface to lean a ladder against before the siding is installed.

If the functions of sheathing can be handled by other materials, sheathing is not always necessary. For example, diagonal wood or metal bracing can give a wall sufficient rigidity and strength (but not as much strength as plywood)[679]; if enough cavity insulation is used, insulating sheathing may not be needed; a housewrap (see below) can be used as a wind barrier; some sidings are stiff enough to not require a backing material; and it may not be necessary to lean a ladder against a single-story house that's under construction.

Most sheathings have some minor outgassing characteristics, but they are usually not a problem for sensitive people once covered with siding. For extremely sensitive people concerned with outgassing from sheathing, it can be eliminated—as long as the sheathing's functions are dealt with in other ways.

Housewrap

Many builders are using a housewrap to improve energy-efficiency. There are a number of housewrap manufacturers, and they have slightly different products, but all housewraps have the same function—they keep the wind from blowing into the insulation. If wind gets into the insulation, its R-value decreases.

The use of housewrap can help to tighten the walls of a house—especially if it is well-sealed at all seams, and at doors and windows. But, it can't be used to tighten an entire house. For example, it can't add to the tightness of a floor or ceiling, because it is not used in those locations. The differences in the various manufacturer's products tend to be insignificant as far as their intended function is concerned.[680]

Housewraps are manufactured to allow moisture to pass through them, but not wind. Thus, if moisture gets into a wall cavity, it can escape by passing through the housewrap. Moisture permeability is a good idea in cold climates if moisture enters a wall cavity from the interior in the winter. But in hot, humid climates, a permeable housewrap can allow unwanted moisture from the outdoors to *enter* the wall cavity.

Many housewraps are made of polyethylene. Like other synthetic materials, it can degrade when exposed to very high heat or fire, emitting such things acrolein, formaldehyde, hydrocarbons, carbon monoxide, possible free radicals and soot.[681] However, housewraps don't tend to be strong outgassing sources at normal temperatures,

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679 Paul Fisette, "Braced foam-sheathed walls," *Journal of Light Construction* (April 1993): 32-34.

680 John Andrews, "The Logic of Housewraps," *Custom Builder* (November 1991): 61-64.

681 Helen E. Robinson and others, "The Effects of Fumes from the Thermal Degradation of Polyethylene on Health," *Annals of Occupational Hygiene* 25 (1982): 291.

and they are never directly exposed to the living space.

If a housewrap is used over a sheathing material, much of it is unnecessary. After all, air can only blow through the joints between the sheets of sheathing—not through the solid material itself. So, if you caulk the joints between the sheets of sheathing, and around doors and windows, housewrap won't add anything more to the house's tightness.[682] If you don't seal all the seams between each piece of sheathing, housewrap is generally a good idea as far as preventing wind from degrading the R-value of the insulation.[683]

If a sensitive person decides not to use any sheathing at all, the housewrap should be well-sealed around all the exterior walls to minimize infiltration into the wall insulation. If installed conscientiously, most housewraps will do a good job. It is doubtful if the minor outgassing from housewrap, once covered with siding, will be problematic, but some sensitive people opt for an aluminum-foil-faced product—just to be safe. Several companies make a product called *builders foil*. It's widely used in hot climates as *reflective insulation*, but it can be used in a variety of other ways, such as housewrap. Builders foil is usually made of either Kraft paper or plastic sheeting, with aluminum foil on one or both sides, and it can be purchased with or without hundreds of tiny pin pricks in it.

Builders foil is generally sold in 3- or 4-foot-wide rolls, so when used as housewrap, the seams must be well sealed—usually with aluminum-foil tape. The choice between perforated or non-perforated material depends on the climate. In cold climates, a perforated material should be used as a housewrap to minimize the chance of condensation inside wall cavities. Both versions work equally well as wind barriers. Builders foil is sometimes called "reflective foil insulation" because it can be used to reflect radiant energy in some applications. Manufacturers of builders foil include **Advanced Foil Systems** and **Denny Sales Corp.** The Heatshield product from **Innovative Energy, Inc.** has a polyethylene reinforcing that is bonded between two layers of aluminum foil. This makes it stronger and resistant to tearing. **TVM Building Products** has a similar reinforced foil product. Aluminum-foil tape is usually available locally from heating/air-conditioning outlets and from hardware stores. **Tyco Adhesives** manufactures a Polyken #337 aluminum-foil tape that is often tolerated by chemically sensitive people. It can easily be ordered by mail from **E.L. Foust Co.**

Siding Materials

There are a variety of different siding materials available. They vary in their durability, style, maintenance requirements, and cost. Healthfulness is also an issue, but usually not a significant one.

Older siding that has been painted should be approached with caution, because it's possible it could have been coated at one time with lead-based paint. Thus, before any scraping or sanding is done, you should determine if lead is present. Testing and lead-

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682 Henry Spies, "Air Barrier Basics," *Journal of Light Construction* (July 1991): 14.

683 J.D. Ned Nisson, "Is Housewrap a good investment?," *Journal of Light Construction* (October 1991): 44-45.

abatement options are discussed in *Chapter 25, An in-depth evaluation of six common pollutants*.

Masonry

Concrete blocks, brick, and stone are very long-lasting siding materials. They also tend to be expensive, and they rarely outgas anything. Sometimes mortar will contain chemical additives, but this isn't often a significant issue. Masonry can sometimes be left unpainted to minimize the maintenance requirements. Softer concrete blocks and bricks tend to retain water longer after getting rained on than harder, denser stone. Thus harder materials are less prone to mold growth—especially on shaded, northern facades. For additional information about masonry, see *Chapter 10, Concrete and masonry*.

Wood

Solid-wood siding can be applied either horizontally (clapboards) or vertically (boards and battens), but lapped horizontal siding is superior at shedding rain. Individual wood shingles can also be used for siding. Wood siding is often made of cedar or redwood because of their natural resistance to insect or fungal attack but, for sensitive people, cedar should be avoided because of its strong natural fragrance. Redwood, on the other hand, is often well tolerated. Other woods can also be used for siding, but they are not widely available.

Plywood siding is also being used, primarily because of its low cost or rustic appearance. As with other construction-grade plywood products, the phenol-formaldehyde glue outgases a small amount of formaldehyde. Though not a significant source of formaldehyde, sensitive people generally avoid plywood siding.

Hardboard siding uses less glue than plywood, so it is subject less outgassing. However, it's very susceptible to swelling and moisture damage unless it's primed on all surfaces, including the back—and maintained very well.

The big health drawback to all wood-siding products is the need to paint. Exterior paints generally have more additives (*e.g*. fungicides) than interior paints because they have a tougher job to do outdoors where they are exposed to the weather and ultraviolet light from the sun. In some instances, wood can be left unpainted. In fact, many people prefer the look of weathered wood and, in New England, high-quality radially-sawn clapboards have lasted for over 150 years.[684] For unpainted wood to last, it must be able to dry out quickly after a rain shower. A house shaded from the sun by large trees can remain damp long enough to result in mold or mildew growth, and perhaps decay. This can be a problem in wooded areas where the building site isn't cleared out sufficiently.

Fibrous Cement

Asbestos-cement siding was once a popular material. When undisturbed, and in good shape on the side of a house, it generally remains inert, but sanding and scraping prior to repainting can abrade the surface sufficiently to liberate some asbestos fibers. Similarly, when removing the siding during remodeling, restoration, or demolition, it can become broken, resulting in fibers being released. When working with older siding

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[684] "The quartersawn-clapboard revival," *Traditional Building* (January/February 1991): 25.

containing asbestos, proper respiratory protection is very important.[685]

Today, fibrous-cement siding contains cellulose fibers, not asbestos.[686] Thus, it is a much healthier product. It often resembles horizontal wood siding when installed, but it is resistant to decay, fire, and termites. Manufacturers include **Cemplank, Inc.**, **GAF Materials Corp.**, **James Hardie Building Products** and **MaxiTile.** Most manufacturers offer different styles such as roughsawn, smooth, shingles, scallopped edges, *etc*. These materials are quite inert, so they are often tolerated by sensitive people. However, most products require painting, which can bother some sensitive individuals.

Vinyl

Solid vinyl siding is subject to some outgassing, especially when warmed by the sun. While, the outgassing isn't excessive, some sensitive people are bothered by it. For them, another siding is usually recommended. However, where budgets are tight, vinyl siding is often used on healthy houses because of its low cost. Then, any money saved on siding can be spent on interior finishing materials—materials that have a much more significant effect on indoor air quality.

Stucco

Traditional stucco can be applied as either a two-coat or three-coat system, $^5/_8$" to $^7/_8$" thick. Thinner veneer systems are also available that contain various synthetic resins (see *EIFS siding* below). The traditional mix contains Portland cement, lime, sand, and water. Occasionally, aggregates such as expanded shale, clay, slate, or slag are used instead of sand. Plastic cement, a Portland-cement product containing several admixtures, is used in some parts of the country. Admixtures for stucco have included asbestos, glass fibers, accelerators, retarders, *etc*. If anything other than the basic mixture is proposed, it should be tested by a sensitive person.

Stucco can be applied directly to concrete and masonry surfaces, but only if a sufficient bond can be achieved. If a good bond isn't possible, it should be applied over a layer of expanded metal lath or wire lath. These reinforcing materials are also used when stucco is applied over wood or metal studs, and over some sheathing materials. The texture of the finish coat can be varied to achieve a number of different effects. It can be applied by hand or sprayed on with a machine.

Where stucco is exposed to the weather, cracks can allow moisture to penetrate the wall. For this reason, asphalt-impregnated felt paper is used behind the reinforcing steel as a secondary weather barrier. The felt paper also helps to separate the stucco from the underlying wall, so they can expand and contract at different rates. This minimizes cracking.

Caulking is often required at some stucco joints. Curing stucco is usually accomplished by misting water on the surface, but sometimes admixtures or synthetic resins are used. Admixtures should be avoided by sensitive people.

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[685] Henry Spies, "Patching asbestos siding" (Letter and reply), *Journal of Light Construction* (January 1992): 13.

[686] Nadav Malin, "Fiber-cement siding," *Environmental Building News* (May/June 1993): 5-6.

EIFS Siding

Traditional Portland-cement stucco finishes are usually quite inert. However, the newer synthetic resins, that are now widely being used, have more potential to be bothersome to sensitive people. These systems generally consist of a synthetic stucco mix that is applied over fiberglass mesh on top of foam sheathing. The resin can be bothersome to some sensitive people, but once cured, it's relatively inert. Synthetic-stucco systems are called EIFS (pronounced eeeffs), which stands for *exterior insulation and finish system*. If applied correctly, EIFS can be attractive and long lasting.

If EIFS is installed incorrectly, water can seep behind the stucco and the insulation and result in mold and decay.[687] In humid climates there have been some real EIFS horror stories—and rotting houses—accompanied by millions of dollars in lawsuits and dozens of arguing experts. (There don't appear to be any problems thus far in dry climates such as the U.S. Southwest.) In Wilmington, North Carolina inspections have found moisture problems in 98% of randomly selected EIFS-sided houses.[688] The most critical areas are around windows, where water can seep behind damaged caulking, or through the window jamb itself. So, EIFS manufactures and installers have blamed window makers, and vice versa. The problem isn't with the windows or the siding—it's the way they come together. With most sidings, if a little water gets behind it (*e.g*. around a window, a door, or anywhere else) it can eventually drain out, but with EIFS the water can get trapped inside the wall. As a result of all the problems, manufacturers are changing their installation details.[689] For example, flashing should be used under a window, and it should be designed to redirect any water back outdoors. While EIFS has been marketed in the past as a low-maintenance siding, one manufacturer now recommends regular inspections and replacing damaged caulk every three years.

The most significant advance in EIFS involves the use of insulative sheathing that has drainage built in, such as small vertical grooves. That way, if moisture gets behind it, the moisture can easily drain out.[690] Most EIFS manufacturers now offer a drainable product.

Metal

Aluminum and steel siding are less widely used today than they were in the past. Both horizontal and vertical styles are available in several patterns and colors. The various manufacturers use different types of baked-on finishes that are generally quite inert. Some manufacturers offer more than one type of finish.

Metal siding is easily attached to wood or steel studs with nails or screws. When

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687 Steve Culpepper, "Synthetic stucco," *Fine Homebuilding* (October/November 1966): 66-71.

688 Chris Kidder, "EIFS under scrutiny," *Journal of Light Construction* (April 1996): 7.

689 "Update: U.S. Gypsum pulls EIFS product," *Journal of Light Construction* (July 1996): 13.

690 "Down the Drain," *Building Products* (July/August 1998): 75-78.

attaching aluminum siding to steel studs, cadmium-plated screws should be used to minimize the chance of corrosion between the two different metals. According to the Aluminum Association, corrosion tends to take place only where moisture is present. If the steel is galvanized (most steel studs are) then corrosion is usually not a concern because the zinc coating tends to protect the metal.[691]

Some people have suggested that the beneficial effects of natural background radiation are prevented from reaching the occupants of a house by metal siding.[692] While it may, at first, seem wise to avoid all forms of radiation, research has shown that some forms of radiation are beneficial. For example, one scientist shielded test subjects from all outside influences, including electromagnetic background radiation, and found that their biological rhythms became completely desynchronized. Further experiments determined that the weak background radiation pulsing at 10 cycles per second was a natural biological timer.[693] Other forms of radiation, such as X-rays or gamma rays, should definitely be avoided.

In testing electronic devices, engineers use enclosures called Faraday cages to block all forms of radiation. They must be specially constructed of either metal screen or metal sheets that are well-grounded. A metal-sided house simply doesn't function like a Faraday cage. If it did, it would, indeed, prevent the occupants from being exposed to beneficial background radiation. But to act like a Faraday cage, the individual pieces of siding would need to be soldered together, and very carefully grounded. Furthermore, a metal roof and floor would be necessary, and they would also need to be soldered together and well-grounded. So, in a typical installation, it's virtually impossible for metal siding to block all the beneficial background radiation reaching the occupants. Even if it did, some radiation still passes through windows and doors, and most people occasionally go outdoors where they are routinely exposed to background radiation.

Aluminum and steel siding manufacturers include **Alcoa Building Products**, **Alsco**, **Berridge Manufacturing Co.**, **Edco Products, Inc.**, **Reynolds Metals Co.**, and **Rollex Corp.**

W.F. Norman Corp. has reproduction siding of embossed galvanized steel that can be coated with an oil-based paint, or left plain. Styles include Brick, Pitch-Face Stone, Rock-Faced Brick, and Cluster Shingle.

Columns and Miscellaneous

As with may common building materials, exterior columns and shutters are being made of plastic, a material that can outgas slightly. There are also companies that make these items out of metal. **Moultrie Manufacturing Co.**, and **Reynolds Metals Co.** sell colonial aluminum porch columns, caps, and bases in a variety of sizes with either a

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691 The Aluminum Association (TAA), *Specifications for Aluminum Sheet Metal Work* (Washington, DC: TAA, n.d.).

692 Zamm, *Why Your House*, 75-76.

693 Dana Miller, "Electromagnetic Bodies," *The Human Ecologist* #34 (Spring 1987): 7-10.

primer or a baked-on finish. Wood columns and shutters are also available, but they tend to require regular maintenance in the form of painting which exposes homeowners to paint odors. Aluminum cupolas are available from **Lomanco, Inc.**

Summary

Stucco is usually a well tolerated wall finish, although it can be fairly expensive. Masonry siding is also fairly inert, but it can be costly too. Both stucco and masonry must be installed with care to minimize moisture problems. Wood siding, while popular from an aesthetic standpoint, has the significant drawback of requiring periodic painting. The baked-on finish on metal siding is generally inert, so it can be an attractive, low-maintenance, and well-tolerated product.

Low-cost and low-maintenance vinyl siding has only minimal outgassing characteristics. So, where cost is an important consideration, vinyl has been used in healthy construction. Then, any extra money can be spent on materials directly exposed to the indoors where you will get significantly more improvement in air quality for the same expenditure.

16. Windows and Doors

Windows allow sunlight to enter a room, and they provide a view that helps occupants feel less closed in. The psychological benefits of looking out a window and watching birds, trees, and sunsets can be enormous. When properly designed, windows can allow heat from the sun to keep a house warm in the winter. They can also provide a means of escape in the event of a fire. While windows can be opened for fresh air, mechanical ventilation is often more efficient—especially in harsh climates.

Skylights are simply roof windows. They can admit more light into a room than a wall window, but they are often not as energy efficient, and the extra sunlight may not be welcome on a hot summer day, unless they are tinted or fitted with shades. While many skylights do not offer a very interesting view, on a steeply sloping roof, they can provide both light and a view if placed at a comfortable height. Skylights are often made of the same materials as regular windows, and some can be ordered with multiple panes of glass. While modern skylights are more leak-resistant than older models, anything that penetrates a roof has the potential to leak with resulting mold growth a possibility.

Interior windows between rooms can open up the inside of a house while keeping odors isolated to one part of the living space. For example, a fixed window between a kitchen and family room can make the kitchen seem more a part of the rest of the house. At the same time, it will prevent cooking odors from permeating the other room.

Traditional stained-glass windows are made with lead dividers between the individual pieces of glass. Lead poisoning can be a problem with some craftsmen because lead oxide on the fingers can be ingested when eating, lead fumes can be inhaled when soldering, or lead can be absorbed through cuts in the skin.[694] While these exposures are not problems for homeowners, it's a good idea to wash your hands after cleaning a leaded-glass window. A linseed-oil putty is often used in leaded-glass work to keep the glass pieces from rattling in the dividers. This is something that can negatively affect some sensitive people. Older windows are less likely to be bothersome and, with a new window, you can ask a craftsman not to use putty.

Exterior entry doors provide both access and security, and they are often a focal point for the front of a house. A distinctive door will enhance the appearance of any home. A double-door system, or vestibule, can be used if extra protection from the weather is necessary. A door leading to an attached garage should always be well-sealed with weather-stripping to prevent exhaust gases from entering the house. It can also be a good idea to have an automatic closer on this door so it doesn't stand open for extended periods of time.

Interior doors are primarily installed for privacy. But they can also be used to contain odors in certain rooms—for example, when closets are used for storage of odorous belongings. A door between a kitchen and the rest of the house can prevent cooking odors from permeating the entire living space. Such doors should be tight fitting—in some instances weather-stripping is helpful. Where space is limited, sliding doors, bifolds, or pocket doors are sometimes used.

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[694] Anita & Seymour Isenberg, *How to Work with Stained Glass* (Radnor, PA: Chilton Book Co., 1972): 14-15.

Window and door manufacturers have introduced many technical innovations over the last few decades. Wood is increasingly being replaced with metal or plastic. Frames are being made more energy efficient. Low-E coatings are widely available on glass and multiple glazings and gas fill are common. Although they are not major indoor air pollution sources, in some cases, windows and doors can be problematic.

Window Construction

Windows are manufactured in a variety of styles: single hung, double hung, slider, casement, projected, fixed, *etc*. No one particular style is healthier than another, but casement windows are among the tightest, and traditional double-hung windows the loosest.[695]

In the past, most windows were constructed with a wood frame having a single pane of glass held in place with putty. Today, frames can be either wood, metal, plastic or a combination of materials. Linseed-oil-based putty has been replaced with a synthetic product. Multiple panes of glass provide greater year-round energy efficiency and, occasionally, plastic is used instead of glass. Storm windows no longer need to be put up and taken down seasonally—they are now an integral part of the window unit.

There are a number of ways windows can affect the health of the occupants. For example, wood windows are routinely chemically treated, and plastic or rubber components can outgas slightly. If a window is improperly installed, not very energy-efficient, or if the indoor humidity is high, moisture to condense on cold window surfaces in the winter—resulting in mold growth. Sunlight entering a window can cause synthetic draperies or carpeting to outgas slightly as it warms them. Loose fitting windows can allow unfiltered, polluted, outdoor air to enter a house.

When windows are installed, it's common to use caulking on the outside as a barrier against the weather. The gap indoors—between the rough framing and the window unit—is often stuffed with fiberglass insulation or filled with an aerosol foam insulation. All these materials have been shown to bother some sensitive people when directly exposed to them, but they can usually be isolated from the living space by covering the interior gap between the window frame and the wall framing with aluminum foil tape.

Glass

Window glass is a fairly inert material that is well tolerated by most people. Insulated glass consists of two or more panes spaced $^1/_4$" to $^3/_4$" apart. The spacer separating the panes may be wood, metal, or a synthetic material. Sometimes a drying agent is placed between the panes to minimize fogging. In some windows, a plastic film is suspended between two panes of glass to provide extra airspaces. Multiple air spaces mean greater energy efficiency, and the number of airspaces is more important than the thickness of the airspace. For example, two $^1/_2$" air spaces are more energy efficient than a single 1" air space.

Increasingly, the air between the panes of insulating glass is replaced with an inert

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[695] Gordon Tully, "Choosing windows wisely," *Journal of Light Construction* (July 1992): 8-9.

gas—usually argon, but sometimes krypton. These gases have more resistance to heat flow than air, so they improve the energy-efficiency of the window, often by as much as 15%.[696] If the seal at the edge of a gas-filled window becomes damaged, the inert gas can slowly leak out,[697] but there are no reports of health problems related to such leakage.

Some manufacturers combine a double-pane insulating-glass panel with an additional single-pane storm window. Two panes of glass are quickly becoming the industry standard in many climates, while three panes (and occasionally four panes) are popular in very cold climates. If a multiple-pane window unit is not properly sealed, or is poorly constructed, moisture can leak between the panes of glass and condense.

Coated glass and plastic films are offered by a number of manufacturers to make glass even more energy efficient. Plastic films suspended between two panes of glass are generally not a problem for sensitive people because the units are well sealed, but some of the glass coatings have the potential to outgas depending on their composition. These should be tested by sensitive people prior to use.[698]

Energy-efficient glass with a low-E coating is becoming very popular. There are actually different types of low-E glass, and they have slightly different characteristics.[699] But they all work in a similar manner—they act like a mirror and reflect radiant energy back into a room, thus preventing heat loss to the outdoors in the winter. In hot, sunny climates—or where excessive sunlight can cause overheating of the living space—windows are built with the low-E coating on a different surface of the glass to reflect radiant energy from the sun back toward the outdoors. Thus, windows can be specifically tailored to different climates—and even to different sides of the same house. Low-E coatings block a great deal of the incoming ultraviolet light. This is advantageous for your curtains, because ultraviolet light is responsible for material degradation and fabric fading. There are reports of a few hypersensitive people being bothered by low-E coatings[700] but, fortunately, this is not a common problem.

In some window and door applications, shatter-resistant glass (or plastic) is required to minimize occupant injury. Acrylic and polycarbonate plastic sheets meet this requirement as does tempered safety glass, but the plastic materials are often avoided by sensitive people because of minor outgassing potential.

Seals and Compounds

Glazing compound or putty has been the traditional material to hold glass in a frame. In the past, these materials were linseed-oil based, but today a vinyl-based putty is

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696 “Why should I buy argon fill windows? Isn’t low-E good enough?,” *Solplan Review* (August/September 1993): 15.

697 J.D. Ned Nisson, “Window worries,” *Journal of Light Construction* (September 1991): 50-51.

698 Mary Oetzel, “Selecting Windows,” *The Human Ecologist* #34 (Spring 1987): 29.

699 Marc Rosenbaum, “Choosing a low-E coating,” *Journal of Light Construction*,” (July 1994): 65-66.

700 Virginia Salares, Canada Mortgage and Housing Corp., Personal communication.

widely used. New windows tend to utilize extruded vinyl or rubber-based moldings. For sensitive people, both seals and putties can be problematic, but putties are generally more odorous. In most situations, the putty is applied to the exterior of a window, where it is unlikely to contaminate the indoor air—unless the window is opened. Vinyl and rubber seals are often exposed to the interior where they can outgas slightly, especially when heated by the sun. Although this isn't often a significant outgassing source, a sensitive person who is bothered by seals or weather-stripping can sometimes have them coated with a sealant or clear finish to make them tolerable. The sealant can be applied with a small artist's brush.

Window Frames

Wood, metal, and plastic are the primary materials used in window-frame construction. Sometimes, wood is clad with plastic or metal to increase its durability. Other combinations may also be seen, such as an aluminum window with a plastic track or a wood window with a metal exterior.

Plastic Window Frames

Plastic window-frame components are often avoided by sensitive people because of their outgassing potential. Outgassing is more likely on a hot sunny day—when a window is open in a non-air-conditioned house. This can result in minor odors entering the living space.

Plastic window frames are certainly not the most offensive materials used in house construction, but they *are* exposed directly to the living space, so they can contribute to indoor air pollution. However, their contribution is usually not significant. Solid-vinyl windows are the most bothersome, but plastic parts are difficult to avoid completely in wood and metal window construction. In general, harder plastics tend to outgas less than soft plastics, and all outgassing will decrease with time.

Wood Window Frames

Wood window frames have been the traditional choice for residential windows. In fact, for years, they were the only choice. The majority of the wood windows manufactured in the U.S. meet a standard set by the **National Wood Window & Door Association**. This requires that all wood parts (except interior trim) be treated with a water-repellent preservative to reduce water absorption and attack by mold or mildew. There are currently several possible chemicals that can be used, including Bis(Tri-N-butyltin)Oxide (TBTO), and 3-ido-2-propynyl butyl carbamate (IPBC),[701] both of which are toxic to fish, wildlife, and domestic animals. Overexposure to these chemicals in the

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[701] *Hallmark Certification Program, Water-repellent preservative treatment, Formulations tested through NWWDA* (Des Plaines, IL: National Wood Window and Door Association, n.d.).

workplace can result in eye or skin irritation, nausea, dizziness, or headache.[702] [703] Chemically treated wood windows can be bothersome to some sensitive people, and some individuals are intolerant of the natural odor of the softwood lumber from which wood windows are made. However, if sensitivities aren't severe, a paint or clear finish can often be used to successfully seal a wood window frame.

Wood windows that are not chemically treated can sometimes be special ordered from a window manufacturer. Small, local companies are easier to deal with in this regard than large firms. While softwoods are almost universally used in window construction, a manufacturer willing to use untreated wood may also be willing to use a hardwood of your choice. Of course, this type of special handling will usually result in a significant cost increase—and perhaps delays in shipping. If a wood window is properly installed, painted, and maintained, there should be no real need for it to be chemically treated. However, the paint could be bothersome to some sensitive people.

Wood windows made of pine are widely available from local lumber yards and building-supply centers. **Loewen Windows** uses Douglas fir lumber, rather than pine, that is somewhat less bothersome to chemically sensitive people. Their windows are well made and energy efficient.

Metal Window Frames

Metal window frames are most often made of aluminum, although steel-framed windows are available. When metal frames are cold in the winter, and the indoor relative humidity is high, moisture can condense on the cold surfaces. This often leads to mold growth or, in severe cases, adjacent wood materials can rot. Most metal-window manufacturers offer a frame with a *thermal break* that effectively insulates the indoor portion of the frame from the outside of the frame, thus minimizing condensation or sweating. Thermal breaks greatly improve the energy efficiency of metal window frames. The material used for the thermal break is usually a synthetic rubber or plastic that can theoretically outgas and bother sensitive people. However, thermal breaks are generally not directly exposed to the living space, so outgassing is minimal. Because of potential condensation problems, thermal breaks are desirable features in cold climates where condensation is likely, but they are less important in mild climates.[704]

Most residential aluminum windows are available with a white or brown baked-on finish that is usually well tolerated. Some frames are anodized in various colors by an electrolytic process that is also well tolerated. There are a few people who have metal sensitivities to aluminum. For them, a baked-on finish may be sufficient to prevent a reaction to the aluminum itself. In general, aluminum-framed windows are reasonably priced, and well tolerated.

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702 *Product Data sheet* #SWC 1407 R00 8407 for "Tribucide P-75", (St. Louis, MO: Koppers Company, Inc.).

703 *Product Data sheet* #PPD 1257 8602 for "Woodtreat MB", (St. Louis, MO: Koppers Company, Inc.).

704 Alex Wilson, "Window technology update," *Journal of Light Construction* (December 1991): 18-21.

Aluminum windows are made by many different companies. Most producers distribute regionally, and not to all parts of the country, so it's always a good idea to check local suppliers to see what's available in a particular area. Manufacturers include **Alenco Windows**, **Capitol Windows and Doors**, **Fleetwood Aluminum Products, Inc.**, **Gapco Windows**, **Summit Window and Patio Door**, and **Traco**.

Screens

Many manufacturers are supplying fiberglass screens with their windows. Sometimes these are well tolerated by sensitive people because fiberglass, like glass, is relatively inert. However, fiberglass screens are occasionally treated with a chemical to make them less appetizing to insects, and some have a very strong odor.

In 1997, the Michigan Department of Community Health (MDCH) issued an alert that some vinyl-coated window screens were reported to cause some adverse health effects.[705] This alert was based on complaints from a number of households about vinyl-coated screening that was manufactured by one particular company. The company has since changed their formulation and no additional complaints have been reported to the MDCH.[706]

Sensitive people should obtain a sample of screen from their window supplier to test for tolerability. If a fiberglass or vinyl-coated screen is offensive, the frames can often be ordered with a different screen material. Treated screen can be easily replaced by most glass shops. Aluminum screen is readily available, and sometimes galvanized-steel screen can be found. At a substantially higher cost, copper or brass screen can be special ordered, but in most cases untreated fiberglass or aluminum screen will suffice.

Wrisco Industries, Inc. manufactures an attractive aluminum-framed screen-room kit in white or brown. It can be purchased in a variety of sizes, with or without an aluminum roof. Fiberglass screen is usually furnished, but the kit can be purchased without screen and metal screen can be substituted. A similar product is available from **Alumet Building Products, Inc.**

Window Locations

In cold climates, it's a good idea to have a large percentage of windows on the south side of the house to take advantage of the free solar heat. If the roof overhang is properly designed, the south-facing windows can be shaded in the summer and exposed to the sun in the winter. In air-conditioning climates, windows often need to be shaded year round.

Bedrooms should have at least one window that can be used as a means of fire escape. Multiple bedroom windows on different walls can be opened to allow fresh air to easily pass through the room on nice days. This should not be a substitute for mechanical ventilation because windows are rarely open all the time. For example, windows are kept closed during periods of harsh weather, or to make a house secure against burglars.

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705 "Window screens in Michigan," *Our Toxic Times* (March 1997): 12.

706 Kirpal S. Sidu, Michigan Department of Community Health, personal communication.

Building codes usually don't require a bathroom window if an exhaust fan is used. However, it can be a good idea to have a window in every room of a house so, if unusual odors are generated—say, from painting—a window fan can be used to pull air through the room until the outgassing is complete.

Where possible, windows should be located away from kitchen, dryer, or ventilation-system exhausts. They should not be placed near plumbing vent stacks, garages, or parking areas because of the danger of pollutants entering the house when the windows are open. An asphalt roof near a dormer window can allow undesirable odors to enter the house if the roof heats up during the day and outgases. With a knowledge of the local wind directions, it should be possible to locate windows so that a gentle breeze will flow through the house when they are open.

Window Coverings

Synthetic curtains and draperies can outgas when heated by the sun. Natural fabrics such as cotton or linen are less prone to outgassing and can easily be substituted. As they deteriorate over the years, fabric curtains (natural or synthetic) generate dust that bothers some sensitive people. Linen is less likely to break down in sunlight than cotton. A well-designed window may not require curtains to dress it up, so they aren't always necessary in all rooms.

Metal blinds are available that provide privacy while being relatively inert. They have the advantage of not *generating* dust, but they can *collect* dust that already exists in a room. This can be easily removed by periodic vacuuming. They are often available in department stores. Discount mail-order suppliers include **Baron's Window Coverings** and **National Blind & Wallpaper Co.** Solid-wood interior shutters can also be used for privacy. **Pinecrest** offers them in a variety of styles and sizes made of pine, knotty pine, or poplar.

Curtains or draperies that are kept closed in the winter, to keep heat from escaping, can result in a moisture problem. This is because the airspace between the window and the curtain will be colder than the rest of the room. When moisture-laden indoor air moves behind the curtain it can condense on the colder glass, resulting in a potential mold problem. If this is a possibility in your climate, curtains should be kept open in the winter. To minimize condensation potential, energy-saving window coverings should contain a diffusion retarder and be securely sealed at all edges.[707] This prevents excess moisture from getting between the covering and the glass. A commercial producer of such coverings is **Window Quilt**.

Interior Doors

Interior doors are typically made of wood, manufactured-wood products, metal, or plastic in various combinations. All have certain outgassing characteristics, but some choices are less offensive than others. Doors are generally hinged on one side, but sliders, pocket doors, and bifolds are also available.

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707 William K. Langdon, *Movable Insulation* (Emmaus, PA: Rodale Press, 1980): 57-59.

Solid Wood

Solid-wood interior doors are usually made in a frame-and-panel design, and they are available in several different styles. Most building-material suppliers either stock them, or they can easily be ordered. The majority of solid-wood doors are made of softwood, generally pine, but less-odorous fir or hemlock doors can often be special ordered. For individuals sensitive to all softwoods, or for those who prefer the appearance of hardwoods, it is usually possible to order solid hardwood doors out of oak or poplar. Some doors have the look of solid wood but, on close examination, they are veneered, so if you are after solid wood, look closely. The glues used to assemble wood doors are sometimes formaldehyde based, but very little glue is required in a panel door, so outgassing is often minimal. Some manufacturers use less bothersome water-based glues.

Most woodworking shops can make doors to your specifications—out of any type of wood or glue you prefer. Sometimes the cost is less than that of a factory-made door that must be special ordered. Less-expensive hardwoods such as poplar can be used instead of more costly woods such as walnut or oak. A simple style can be selected to reduce labor costs, making custom-made doors even more affordable.

Another source to consider for interior wood doors is the local salvage yard. Used doors and antique doors are available in many different styles and woods. Older softwood doors are not as offensive for sensitive people as new doors. By having each door in the house a different style, each room can have its own character. For example, a beveled glass door can be used for the dining room, French doors for the family room, and various paneled doors for bedrooms. If a salvage yard has all of the doors from a school or a hotel, matching doors can be used throughout the house. It may not be possible to choose from a wide variety of sizes, so when building a new house, the doors should be selected before rough framing the openings so they will fit. If it's necessary to remove the finish from an old door, care should be taken to use a less-toxic stripper. Old doors could be coated with lead paint.

The **Combination Door Co.** offers solid-wood interior doors in a variety of styles. They can be made of a number of different hardwoods (walnut, mahogany, ash, oak, cherry, hickory, birch, poplar, pecan or maple) or softwoods (hem-fir, pine, knotty pine, or Douglas fir). **Madawaska Doors, Inc.** also offers a wide variety of solid-wood doors in many styles and species of wood. So many, in fact, that they advertise "any size, any design, any wood, any time." For a different appearance, **Alternative Timber Structures** makes attractive bead-and-batten doors in a variety of hardwoods and softwoods. They offer several standard styles as well as bifolds, doors with arch tops, and custom designs. **Pinecrest** primarily manufacturer exterior doors (which are $1^3/_4$" thick), but most of their designs can also be ordered as interior doors (which are $1^3/_8$" thick). They have a very wide selection of door styles in a variety of woods, some highly ornate and carved.

Koetter Woodworking, Inc. and **Hardwood Wholesale Supply and Mill Work, Inc.** distribute solid-hardwood paneled doors in the Midwest. **Simpson Door Co.** and **Woodgrain Millwork, Inc.** produce solid-wood (softwood) interior doors in a variety of styles that are distributed nationally.

Manufactured Wood Products

Hollow-core wood interior doors are common in residential construction because of their low cost. They are available in flush styles that have a thin skin of plywood or hardboard over a core of a resin-coated honeycomb-paper material. Others are molded of hardboard to resemble a paneled door. Some hollow doors are said to have a solid core. Some of these cores are solid wood, but many are solid particle-board, which can outgas a considerable amount of formaldehyde. In general, doors made of manufactured-wood products should be avoided in healthy houses.

Plastic

Doors that appear to be wood can, in fact, be made of a plastic skin with a wood-grained finish. Plastic doors vary in their outgassing potential, depending on what material is inside them—a resin-coated honeycomb material or particleboard. Those with a particleboard core are more offensive, but all are usually avoided by sensitive people.

If both a plastic-skinned door and a plywood-skinned door have a particle-board core, the plastic-skinned door will usually outgas less formaldehyde from the particle-board core. This is because the plastic is a better diffusion retarder than the plywood, so it blocks more of the particle-board emissions.

Metal

Hollow metal interior doors are commonly used in commercial applications. They can be hung in either metal or wood frames. Some have a corrugated fiber core that adds rigidity to the door and can contain a formaldehyde-based glue. Others contain fiberglass or foam insulation, or they might have an asphalt-based soundproofing sprayed inside the door.

Because metal is an excellent diffusion retarder, the material inside a door generally doesn't outgas a great deal into the living space. Still, sensitive people will want a door that is as inert as possible. Metal doors are usually shipped with a primer finish, but they can sometimes be ordered with a factory-applied finish coat. Baked-on finishes are the best tolerated. Sometimes doors are available with a galvanized finish or made of stainless steel.

Steel interior door manufacturers include **Curries Co.**, **Republic Builders Products**, and **Steelcraft**. The **Emerson Engineering Co., Inc.** specializes in commercial doors of stainless steel.

Metal bifold doors are available from **Slimfold Products** in six styles including louvered, raised-panel, or flush designs. These are well-suited for closets. They are made in several different widths and heights, have a factory-applied finish (white or tan), and are available with a textured, leather-like finish (like many refrigerator doors). **Arthur Cox & Sons, Inc.**, **Fleetwood Aluminum Products, Inc.**, and **Stanley Works** offer mirrored sliding bypass doors or bifold doors for closets, all with metal frames.

Exterior Doors

Exterior doors are usually thicker, sturdier, and better insulated than interior doors because they must withstand a harsher environment of temperature extremes, precipitation, and sunlight.

Wood

Flush exterior wood doors are similar in construction to flush interior doors. They have a core of either wood, particle board, or corrugated fiber and a thin plywood skin—all held together with a formaldehyde-based glue.

Most solid-wood exterior paneled doors are made of softwood—usually pine—and they meet the **National Wood Window and Door Association** standards which requires treatment with the same chemicals as wood windows. Local lumber yards and building-materials suppliers often stock solid-wood exterior doors in different styles and woods. Manufacturers include **Madawaska Doors, Inc.** (they advertise "any size, any design, any wood, any time."), **Nord** (oak, fir, and hemlock), **Pinecrest** (very wide selection in a variety of woods, some highly ornate carved doors), and **Simpson Door Co.** (Douglas fir or western hemlock).

Because of exposure to temperature and weather extremes, exterior wood doors are subject to dimensional changes and warping at different times of the year. Therefore, they often don't always seal well, and paints or finishes must be reapplied regularly. Some wood doors are made of a combination of solid wood, wood veneer, plywood, metal, and insulation, so if you are after a true solid-wood door, look carefully.

Metal

Most exterior metal doors are insulated for energy efficiency, usually with polyurethane or polystyrene. A metal door tends to seal in any outgassing from the insulation fairly well, especially if there is metal on the faces and also on the four edges. Even though the insulation might be problematic for a very sensitive person when exposed directly, once sealed inside a metal door it is often well tolerated. Many metal doors use some wood or plastic at the edges to act as a thermal break, reducing the likelihood of sweating. However, condensation is less a problem with insulated doors than it is with windows.

Metal doors can be embossed to resemble panel doors, or they can have moldings attached for decoration. The moldings are often plastic, and they have the potential to outgas—but not significantly. Moldings around the glass in metal doors are also typically plastic. Residential, steel entry-door manufacturers include **Castlegate Entry Systems**, **Ceco Door Products** (commercial doors, some of which are stainless-steel), **General Products Co., Inc.** (Benchmark), **Johnson Door Products** (Premdor), **Pease Industries, Inc.** (Ever-Strait, Homestead, Trooper), **Perma-Door** (Royal, Regency), **Stanley Works**, and **Taylor Door**.

Residential exterior doors are usually hung in softwood frames while commercial door frames are generally metal. **Castlegate Entry Systems** and **General Products Co. Inc.** make steel residential doors for new construction with all-metal frames. **General Products Co., Inc.**, **Johnson Door Products**, **Pease Industries, Inc.**, **Perma-Door**, and **Stanley Works** have residential replacement doors made with metal frames that slip into existing wood frames.

Steel doors are usually galvanized with a primer finish sprayed on in the factory. Most manufacturers do not apply a finish coat, so they must be painted prior to installation. For paint-sensitive people, doors should be purchased and painted early in the construction process so they can have sufficient time to outgas. An automotive finish is sometimes used on metal doors. It can be quite durable, and some automotive body shops can bake on finishes. Aluminum sliding-glass patio doors are often finish coated or anodized in the factory.

Plastic

Fiberglass entry doors are very durable and long-lasting. To manufacture fiberglass, glass fibers (in either a chopped form or woven of strands) are saturated with a polyester resin and cast in a mold, where the resin hardens. The finished side (which is against the mold) usually has less odor than the unfinished side but, actually, neither side is very bothersome. In a fiberglass door, which is hollow, the two unfinished sides face inward toward each other, and the two finished sides face outward. Thus, the less bothersome sides are all that are exposed to the occupants.

Like metal doors, fiberglass doors should be painted early in the construction process so the paint can have time to outgas. Manufacturers include **Castlegate Entry Systems** and **Pease Industries, Inc.** In addition, **Pease Industries, Inc.** has some of the most durable doors available in their Pease Carbon Door line, which use carbon fibers instead of glass fibers.

Other Exterior Doors

Garage doors can be made of the same materials as other doors: plastic, softwood, hardboard, *etc*. All-steel overhead garage doors are available from **Clopay Corp.**, **Raynor Garage Doors**, **Taylor Door**, and **Wayne-Dalton**. Most manufacturers offer garage doors that are either uninsulated, or insulated with a foam core. All are available in a variety of styles and sizes. Some are prefinished with a baked-on paint.

Bilco Company manufacturers a steel outdoor hatch-type basement door in a variety of sizes. These are weatherproof and secure, and they have a baked-on primer finish. They are uninsulated.

Weather-Stripping

Most weather-stripping today is made of some type of synthetic material such as vinyl, foam, or fabric pile. The purpose of weather-stripping is to control air infiltration and rain penetration. This limits the amount of undesirable outdoor odors, pollens, and mold spores entering the house. Steel doors often utilize a magnetic, vinyl-covered material similar to a refrigerator door that makes for a very tight seal. Most weather-stripping is on the exterior (outdoor side) of a door, so it usually doesn't have much effect on the indoor air. But some very sensitive people have had to coat weather-stripping with a clear sealant to make it tolerable. Others have had to remove the synthetic material and replace it with a metal product. Brass or stainless-steel "Spring Weatherstrip" is manufactured by **Pemko, Inc.** and is available in some hardware stores.

Tygon tubing is manufactured by **Saint-Gobain Performance Plastics Corp.** and, although it is a plastic product, it is often well tolerated by sensitive people. Available in many sizes and grades, it can be slit and tacked in place for use as weather-stripping. It's available from laboratory supply houses, and small quantities can often be purchased through individual laboratories. This material is not designed to be weather-stripping, so it often functions imperfectly.

Thresholds can be made of wood (usually oak), metal (usually aluminum), or plastic. Most exterior steel doors are supplied with aluminum thresholds. These should have thermal breaks in cold climates to prevent moisture from condensing on them. Thresholds are often adjustable so, if a house settles, they can be readjusted to maintain a seal.

In order to provide a seal, thresholds are usually fitted with vinyl weather-stripping. **Pemko, Inc.** makes aluminum "Interlocking Thresholds" that utilize metal hooks or spring seals but they usually aren't stocked by local hardware stores.

Summary

Windows and doors can cause a variety of health effects because of outgassing from the various materials. Most of the outgassing is minor, so the health effects only affect extremely sensitive people. Of course, no window or door is 100% inert—all have some drawbacks. For most people, aluminum windows with insulating glass are the best choice from a health standpoint, although there may be some minor outgassing from the seals. Window technology has changed radically over the last couple of decades, primarily in the area of energy efficiency.

Designers and builders interested in detailed information about energy-efficiency features of windows should consult a book titled *Residential Windows*.[708] Because there are so many different window styles and glass options, it can be difficult to compare the energy efficiency of different products, but comparisons are possible by using the **National Fenestration Rating Council**'s *Certified Product Directory*.[709] With this directory, you can compare the efficiency of a particular style of window from one manufacturer to a different style from another manufacturer.

Metal or solid-hardwood interior doors are healthier choices than softwood doors or hollow-core doors. Exterior insulated steel doors are fairly well tolerated because they tend to seal well, and there is little outgassing from the insulation, but in mild climates an exterior hardwood door can be a good choice.

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708 John Carmody, Stephen Selkowitz, and Lisa Heschong, *Residential Windows* (New York: W.W. Norton & Co., 1996).

709 National Fenestration Rating Council (NFRC), *Certified Product Directory* (Available from **National Fenestration Rating Council**).

17. Insulation

Insulation is used in a variety of locations in houses: inside walls and roof systems, under floors, and around foundations. Water heaters and ductwork are also commonly insulated. Insulation is required in warm climates to keep the heat outside and in cold climates to keep the heat inside. There are a variety of different types and forms of insulation available. Some are suited for use in specific parts of a house. Nearly every type of insulation has been implicated in some health problem yet, with care in installation and material selection, a healthy house can contain insulation.

Background

All materials resist the flow of heat to some degree. Dense, solid materials such as steel and concrete resist the flow of heat, but they do a poor job of it. Insulating materials tend to resist the flow of heat very well. Most insulating materials do so by trapping tiny multiple pockets of air within their structure.

Insulations are compared by their R-value (Resistance-value). The higher the R-value, the better the insulating ability. A common brick has an R-value of 0.20 per inch while fiberglass batt insulation has an R-value of 3.17 per inch. Both materials can be used to insulate a house, but fiberglass does a much better job, in fact it's over 15 times as effective. Insulating houses in a very good idea because, according to the North American Insulation Manufacturer's Association (NAIMA), spending $1 on insulation will save $12 in energy costs.[710]

Historically, natural materials were used as insulations. Such things as cotton, straw, sawdust, feathers, moss, and cork were common. Today, most commercially available insulations are man-made. Rock wool and fiberglass were two of the first to be developed. These were followed by perlite, cellulose, and various plastic foams. Asbestos was used in the past in some insulations.[711] It was not as widely used in residences as in commercial buildings, nevertheless, asbestos can be found in some houses, especially around older heating systems.

Health Problems

Of all the health problems related to building materials, insulation seems to have gotten the most press coverage. This dates back to the energy crisis of the 1970s when urea-formaldehyde-foam insulation was responsible for elevated formaldehyde levels in some homes. As a result of health complaints, this particular product was banned from being used in houses. While the ban is no longer in effect, urea-formaldehyde-foam insulation has virtually disappeared from the market. But, since that time, the press and the public have been very interested in the negative health effects of all forms of

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[710] Glen Wilkinson, "Beyond R-Value—Insulating for the Environment," *Environmental Design & Construction* (January/February 1999) 26-41.

[711] CPSC, *Asbestos in the Home*, 8.

insulation.

There are actually a variety of health problems associated with the many different insulating materials now on the market.[712] Some illnesses have been found in factories where insulation is manufactured, and sensitive individuals report symptoms related to outgassing. Other problems are related to the release of tiny fibers. Some products are more offensive than others, but none seem to be as bad as urea-formaldehyde-foam insulation. Different insulating materials have different health effects, but most of today's insulations can be used safely in a tightly constructed house where the insulation is well-separated from the living space.

Many synthetic foam insulating materials release extremely toxic gases when heated and burned. This is one of the reasons fire fighters routinely wear oxygen masks when entering a burning building. For the occupants of a burning house, oxygen masks are rarely available. To them, smoke inhalation means toxic gases. In most fires, deaths are due to carbon monoxide and other toxic gases—not flame contact.[713] Building codes require flammable foam insulation to be separated from living spaces by fire-resistant materials such as drywall or plaster.

When installed improperly, insulation can cause some electrical fixtures to overheat and start a fire. This is especially true when recessed ceiling lighting fixtures are covered with attic insulation. Instructions supplied with insulation typically specify the proper clearance that must be maintained between the insulation and lighting fixtures, furnace flues, water heaters, *etc*. If a device isn't specifically designed to be in direct contact with insulation, three inches of clearance should be provided to minimize the chance of fire.[714]

Energy conservation—and insulation in particular—has often been blamed for indoor air pollution and, consequently, ill health. Ill health is not so much due to the insulation itself, but to a failure to design and build the house as a system. Excessive tightening is not a problem—in fact, tight construction is very desirable—as long as the interior of a house is built with low-tox materials, and air is exchanged mechanically.

Batt Insulation

Batt or blanket insulation is very widely used today. It is a fluffy product that can be purchased in different colors, depending on the manufacturer, and in different thicknesses and widths. There are three basic types available for residential use: fiberglass, rock wool, and cotton. Other specialized batts are used in industrial applications. While rock wool was very popular before World War II, fiberglass is now more popular in residential construction. Both are considered man-made mineral fibers and are referred to as mineral wool. Cotton-batt insulation is a relatively new product,

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712 John Bower, "The hazards of insulation," *East West* (September 1989): 44-49.

713 Georg Kimmerle, "Toxicity of Combustion Products With Particular Reference to Polyurethane," *Annals of Occupational Hygiene* 19 (1976): 269.

714 Consumer Product Safety Commission (CPSC), *Home Insulation Safety* (Washington, DC: CPSC, July 1980). Product Safety Fact Sheet #91.

designed to appeal to environmentally conscious individuals.

Residential batt insulation is usually sold either without any facing, or with an asphalt-coated Kraft-paper facing. In addition, some manufacturers also offer plastic or aluminized-paper facings. These facings are designed to act as diffusion retarders. In some cases, builders will install a separate diffusion retarder over unfaced batt insulation.

Installers of both rock wool and fiberglass often complain of itching and tiny cuts in the skin due to the fibers. Itching can also result from an allergic reaction to the binder used to hold the insulation together.

There has been a great deal written about the health effects of fiberglass. As early as 1955, researchers were seeing respiratory problems and death attributed to inhaling fiberglass.[715] One of the first reports to gain widespread attention was presented to a World Health Organization symposium in 1986.[716] The report found that workers in fiberglass manufacturing companies suffered more lung cancer than other workers. Other reports have also indicated that man-made mineral fibers such as rock wool and fiberglass can cause cancer in production workers.[717] [718] The illnesses reported include cancer of the upper respiratory system, alimentary tract, and digestive system, as well as non-malignant respiratory disease. Production workers are usually exposed to higher concentrations over longer periods of time than homeowners. Insulation installers can be exposed to levels even higher than production workers because they often work without respiratory protection.

Some people believe the increased cancer risk is due to short, small-diameter fibers that are inhaled—fibers that are similar in size to asbestos fibers.[719] One report suggests that these man-made mineral fibers "appear to be more potent than asbestos with regard to chronic pulmonary disease." [720]The U.S. National Toxicology Program's *Seventh Annual (1992) Report on Carcinogens*, said that fiberglass is "reasonably

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715 G.W.H. Schepers and Anthony Delahunt, "An experimental study of the effects of glass wool on animal lungs," *A.M.A. Archives of Industrial Health* 12 (1955): 276-279.

716 "Fiberglass insulation and cancer," *Energy Design Update* (February 1987): 4-8.

717 Cynthia F. Robinson, J.M. Dement, G.O. Ness, and R.J. Waxweiler, "Mortality Patterns of Rock and Slag Mineral Wool Production Workers: an Epidemiological and Environmental Study," *British Journal of Industrial Medicine* 39 (1982): 45-53.

718 Jean J. Moulin and others, "Oral Cavity and Laryngeal Cancers among Man-Made Mineral Fiber Production Workers," *Scandinavian Journal of Work and Environmental Health* 12 (1986): 27-31.

719 Mearl F. Stanton, and others, "Carcinogenicity of Fibrous Glass: Pleural Response in the Rat in Relation to Fiber Dimension," *Journal of the National Cancer Institute* 58 (1977): 587-603.

720 John R. Goldsmith, "Comparative Epidemiology of Men Exposed to Asbestos and Man-Made Mineral Fibers," *American Journal of Industrial Medicine* 10 (1986): 543-552.

anticipated to be a carcinogen."[721] Fiberglass insulation now carries a warning label stating that it is a possible carcinogen. Manufacturers recommend the following work practices: wear a respirator; avoid contact with skin and eyes; wear long-sleeved clothing, gloves, and eye protection; wash with soap and water after handling; wash work clothes separately from other clothes and wipe out the washing machine.[722]

Fiberglass manufacturers point out that fiberglass and asbestos are chemically different, and that when asbestos gets into the lungs, it remains unchanged and stays there forever, but that fiberglass eventually dissolves in body fluids.[723] Richard Munson, a vigorous opponent of fiberglass (and a proponent of cellulose insulation) says that when fiberglass dissolves in the lungs, the decomposition produces silicic acid, which is a cytotoxin.[724] Cytotoxins kill living cells.

There are a number of situations where homeowners have had their health destroyed by fiberglass insulation. In one case, fibers were distributed throughout the house during a remodeling project. Everything in the house was contaminated, and the residents complained of an unbelievable list of symptoms: conjunctivitis, dermatitis, intestinal and urological disorders, immunological imbalances, chronic chemical sensitization, heart irregularities with accompanying chest pain, acute nervous teeth causing temporal mandibular joint syndrome, acute sinus headaches, migraine headaches, tracheitis, tonsillitis, sinusitis, tachycardia, acute eczema and psoriasis, acute depression, anxiety, and tension. Another case involved fibers migrating into the living space from blown-in attic insulation.[725]

It's been found that when moisture is present in mineral-wool insulation, the resin binder can break down and release aliphatic aldehydes, and residents can complain of odors.[726] Moisture in insulation can also lead to biological growth and reduced insulating ability. When done properly, tight construction minimizes these hidden moisture problems.

The negative health effects related to fiberglass insulation have been widely disseminated by a group called **Victims of Fiberglass** (**VOF**). While there is some good scientific evidence regarding negative health effects and fiberglass, **VOF** has often taken an alarmist view, suggesting that fiberglass is worse than asbestos, and should be removed from all houses. Yet, in many houses, the migration of fibers into the living space is negligible. In tightly constructed houses, the insulation, no matter what kind it is,

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721 "The Fiberglass Threat," *Our Toxic Times* (July 1995): 16.

722 Owens-Corning Fiberglass Corp., Package warning label.

723 Ken Roberts, Johns-Manville Corp., Personal communication.

724 Richard Munson, Victims of Fiberglass, Personal communication.

725 John Bower, "Use fiberglass with caution," *Environ* #9 (1989): 17-20.

726 Jan F. van der Wal, Andre Moons, and Ronald Steenlage, "Thermal insulation as a source of air pollution" (Berlin: *Proceedings of the 4th International Conference on Indoor Air Quality & Climate, Vol. 1, Volatile Organic Compounds, Combustion Gases, Particles and Fibers, Microbiological Agents*, 1987): 79-83.

is well-separated from the occupants.

Fiberglass

Fiberglass insulation is manufactured by melting inorganic materials—often sand—and spinning them into glass fibers. The fibers are usually held together in batt form by a formaldehyde-based binder. Fiberglass is generally contaminated with fewer impurities than rock wool and its cost is somewhat less.

Most of the fiberglass insulation manufactured today is either pink or yellow in color, and the batts contain approximately 5% of the resin binder. The pink variety contains, in addition, less that 1% dye to give it the pink color. The yellow insulation has been recommended for chemically sensitive individuals,[727] because of an intolerance to the coloring dye. This seems to be a reasonable precaution—avoid as many unnecessary pollutants as possible—however, the formaldehyde binder is more problematic than the dye. With age, outgassing from the binder will diminish, and if the insulation is well separated from the living space (by using tight construction techniques), neither odors nor fibers will reach the occupants.

Pink fiberglass insulation is manufactured by **Owens-Corning Fiberglas Corp**. The yellow variety is manufactured by several companies, including: **Certainteed Corp.**, **Johns-Mansville Corp.**, **Knauf Fiber Glass**, and **Georgia-Pacific Corp.** Even though there are minor differences between their products, the negative health effects are similar.

Owens-Corning Fiberglas Corp. introduced a fiberglass insulation called Miraflex in late 1994 that seems to have some health advantages when compared to conventional fiberglass batts.[728] Miraflex is produced by fusing two different types of glass into long strands that are more resistant to breakage—and no formaldehyde binder is used. In addition, this insulation is wrapped with a layer of perforated polyethylene. The wrapping minimizes fiber release when handling. The wrap is perforated to prevent trapping moisture in the insulation. Miraflex is less of a problem than more conventional products, but it only comes in a few standard sizes, so it cannot be used in all residential applications. However, the manufacturer is adding new sizes to the line occasionally.

Johns-Manville Corp. has a fiberglass insulation called Grid-SHIELD Rx that uses an acrylic resin, rather than a formaldehyde-based resin.[729] It is wrapped with a perforated polyethylene, which can minimize the release of fibers in applications such as above dropped ceilings. However, the fibers themselves are similar to conventional fiberglass products, so they can be broken off and abraded during handling and cutting. Grid-SHIELD Rx is only available in limited sizes, it's being marked primarily for commercial applications, and it's more costly than conventional fiberglass. They also have a similar product called ComfortTherm that is marketed for residential applications.

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[727] "Label This Building Very Healthy," *The Human Ecologist* #31 (Winter 1985-86): 8.

[728] "The white panther strikes back," *Environmental Building News* (January/February 1995): 8-9.

[729] "Formaldehyde-free fiberglass batts," *Environmental Building News* (November/December 1996): 9-6.

During a fire, the fiberglass itself is fairly inert, giving off little in the way of toxic gases. The resin, however, can decompose in a fire and produce small amounts of ammonia, carbon dioxide, carbon monoxide, carbon particulates, and traces of hydrogen cyanide. The Kraft-paper facing material can produce oxides of sulfur, carbon, and nitrogen.[730] If a plastic facing is used, it too can give off toxic gases in a fire.

It's very important to keep fiberglass insulation well separated from the living space. One report found that nearly all of 13 workers in an office reported various symptoms related to glass fibers entering the air due to improper construction methods. Symptoms included: itchy rash, burning eyes, sore throats, coughing, and malaise. Eye complaints made it impossible to wear contact lenses. After the insulation was sealed behind plastic foil, the health complaints ceased.[731]

Rock Wool

Rock wool is produced by heating natural basalt rocks or industrial steel-mill slag in a furnace. As the material melts, it is drawn out into fibers and formed into felts, blankets, or batts. Today, rock wool has been generally replaced in residential construction with fiberglass insulation. While rock wool is better at reducing sound transmission and has better fire resistance, it is generally more costly than fiberglass.[732]

Rock wool is often contaminated with lignite, a type of coal, and mineral oil, to control dust. It is typically bound into batt form by the use of a phenolic resin. These materials can be bothersome to sensitive people if exposed directly.

Cotton

The cotton insulation currently being manufactured by **Inno-Therm Products, LLC** is actually a blend of cotton and polyester fibers.[733] (This was formerly made by a company called Greenwood Cotton.) The polyester acts as a binder, holding the fibers in batt form. The cotton insulation manufactured by **Bonded Logic** uses a thermoplastic resin to hold the fibers together. A binder is necessary to give the fibers a springiness. Neither company uses a formaldehyde-based resin. Much of the cotton for insulation comes from recycled jeans, so it has a bluish color.[734] The cost is similar to fiberglass—but only if you live near the manufacturer. If cotton insulation must be shipped across the country, it will be somewhat more expensive than fiberglass. Cotton insulation is available in several standard sized batts, but not as many sizes as fiberglass or rock wool.

Although cotton insulation is billed as a healthy product—and it's certainly much

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730 Knauf Fiber Glass GmbH, *Material Safety Data Sheet, Kraft Faced Fibrous Glass Insulation*, (Shelbyville, IN: Knauf Fiberglass GmbH, 1985): 2.

731 S.J.A. Verbeck, E.M.M. Buise-van Unnik, and K.E. Malten, "Itching in Office Workers From Glass Fibers," *Contact Dermatitis* 7 (November 1981): 354.

732 "Rockwool batts," *Energy Design Update* (June 1993): 12-14.

733 "Move Over Fiberglass?," *Environmental Building News* (May/June 1994): 9.

734 "Recycled Cotton Insulation Coming Back," *Energy Design Update* (March 1994): 4.

better than fiberglass or rock wool—it isn't perfect. In order to get building-code approval, it's treated with something like boric acid to make it flame resistant. Placing a sample up to your nose an inhaling can result in burning sinuses because of the boric acid.

Workers who inhale cotton dust in cotton-processing industries are at risk of contracting byssinosis, which is also known as brown lung disease.[735] [736] Although there is no evidence that cotton insulation installers would also be at risk, respiratory protection is recommended.

In the U.S., almost half the pesticides used in agriculture are applied to cotton—far more than any other crop.[737] Some of this residue remains in the cotton after processing, so it could result in some minor contamination of cotton insulation. Pesticide residues may explain why some chemically sensitive people must wear clothing made from organically raised cotton.

Even though it is not ideal, cotton insulation is a relatively healthy product. However, to be safe, it should be well-separated from the living space, just like man-made mineral fiber insulation. And, of course, tight building techniques have other advantages, as discussed in *Chapter 9, Tight construction*.

Loose-Fill and Blow-In Insulation

Loose-fill and blow-in insulations come in several forms. Some can be simply poured out of a bag while others are blown through a specially designed machine, then through an applicator hose. Cellulose and chopped fiberglass are the most common. Both are generally blown in place but they can also be poured out and placed by hand.

Sometimes, the only way to insulate the walls of an existing house is to drill holes in the walls and blow some type of insulation into the wall cavities. Existing attics can be insulated in a variety of ways, but blow-in insulations are often quicker are cheaper to install than batts. Some lumber yards rent blowing machines to do-it-yourselfers. When carefully blown into sidewalls, insulation can help to tighten a house, thus minimizing infiltration, and maximizing energy efficiency and comfort.[738]

For new construction, there is a Blow-In-Blanket system (BIBS), licensed by **Ark Seal International**, that uses either cellulose or chopped fiberglass. With this approach, a mesh is stapled up over the studs, on the interior—after the wiring and plumbing are in place, but before the drywall. Then cellulose insulation (or chopped fiberglass) is blown

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[735] D. Fishwick and others, "Lung function in Lancashire cotton and man-made fibre spinning mill operatives," *Occupational and Environmental Medicine* 53 (January 1996): 46-50.

[736] D.C. Christiani and others, "Cotton dust exposure, across-shift drop in FEV1, and five-year change in lung function," *American Journal of Respiratory and Critical Care Medicine* 150 (November 1994): 1250-1255.

[737] Gene Bruce, "The Bedroom Goes natural," *East West* (March 1987): 56-59.

[738] Jim Fitzgerald, Gary Nelson, and Lester Shen, "Sidewall Insulation and Air Leakage Control," *Home Energy* (January/February 1990): 13-20.

into the stud cavities. This will fill voids quite well around electrical boxes and plumbing pipes, and it is often faster than using batts.

Cellulose and chopped fiberglass are widely used in wood frame construction. Vermiculite, perlite, and polystyrene beads are more often found in masonry construction. They can simply be poured into the inside of a concrete block wall as it is being built. Materials like shredded tree bark and sawdust have been used in the past as loose-fill insulation, but they are very susceptible to insect attack and fire, so they are almost never used today.

Cellulose

Cellulose insulation is a very popular product today. It is made by chopping old newspapers into a fine, fluffy material. Because newspapers are very combustible, and they can be eaten by insects, fungi, or bacteria, and they can be used as nesting material by rodents, cellulose insulation must be chemically treated. Approximately 20% of the final product consists of additives such as borax, boric acid, ammonium sulfate, aluminum sulfate, lime, ammonium phosphate, mono- and diammonium phosphate, aluminum hydrate, aluminum trihydrate, and zinc chloride.[739] If used in improper amounts, these chemicals may not adequately control flammability, and they can corrode any metal they come in contact with. In attic areas, roof trusses are often held together with metal plates. Corrosion of these plates could eventually lead to a collapse of the roof system.[740] Cellulose insulation standards today take these potential problems into consideration, but many older products could contain flammable or corrosive material. A sample of the insulation can often be obtained from the attic and placed near a flame to test for flammability, and an examination of any exposed metal will reveal any corrosion.

From a health standpoint, the various chemical additives can cause reactions in some sensitive occupants.[741] Symptoms reported after the installation of cellulose insulation include: severe rashes, hair loss, digestive and respiratory disorders.[742] Individuals with an intolerance to newspapers (either to the printing ink or to the paper) can easily be bothered by this insulation. Because cellulose insulation is so finely ground and powdery, it can filter through very small openings into the living space, resulting in symptoms that require costly removal.[743] Installers who don't wear protective clothing or

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739 Brookhaven National Laboratory and Dynatech R/D Co., *An Assessment of Thermal Insulation Systems for Building Applications* (Washington, DC: U.S. Department of Energy, June 1978). # BNL-50862, 84.

740 Ned Nisson, "Cellulose Insulation—Why Not?," *Journal of Light Construction* (July 1990): 38-39.

741 David Buscher, "Problems with Cellulose Insulation," Presentation given to the 16th Advanced Seminar in Clinical Ecology at Banff, Alberta, Canada on October 5, 1982.

742 "Insulation Attacks Woman, Son, Dog," *The Reactor* (Newsletter published by the Environmental Health Association of San Francisco) (November/December 1987): 4.

743 Zamm, *Why Your House*, 148.

respiratory protection can experience red and sloughing skin, lung irritation, coughing, bronchitis, and pneumonitis.[744]

A 1993 paper (which was funded by the fiberglass-insulation industry)[745] found few research reports directly related to health effects of cellulose insulation.[746] However, some indirect evidence was reported. For example, excess cancers and pulmonary disease have been seen in paper-mill workers[747] [748] and cellulose insulation is made from paper. Sub-lethal doses of boric acid have caused symptoms of abdominal pain, and liver, kidney and lung dysfunction.[749] An experimental study in which rats inhaled cellulose insulation, resulted in pulmonary damage.[750]

Cellulose insulation is often installed in existing wall cavities through small holes drilled in the exterior siding, which are plugged after the cavity is filled. There are some real horror stories of applicators working their way around the outside of houses without realizing they were blowing large amounts of insulation into the interiors. In older houses, remodeling over the years may have left openings in the walls of closets, above dropped ceilings, or behind kitchen cabinets. As a result, a house can have clouds of insulation floating around inside—unknown to the applicators outdoors. Small gaps around electrical outlets can be easy pathways for insulation to enter the living space of a house. Because of this, it's always a good idea for someone to be inside the house while the material is being installed. That way, any problem will be noticed immediately—before an extremely difficult clean-up job is necessary.

There are a number of cases where homeowners have experienced a wide variety of negative health effects related to cellulose insulation. This is usually the result of the dry insulation migrating into the living space because of sloppy installation.[751].

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744 Hank Spies, "Insulation Hazard (letter & response)," *Journal of Light Construction* (October 1989): 14.

745 "More mud in the attic," *Energy Design Update* (June 1993): 1-2.

746 J.M.G. Davis, "Forum," *British Journal of Industrial Medicine* 50 (1993): 187-190.

747 R.A. Rinsky, *Hazard evaluation and technical assistance report 1990* (Cincinnati: NIOSH, 1990). # HETA-89-020-L2070.

748 B. Jarvholm and others, "Lung function of workers exposed to soft paper dust," *Journal of Occupational Medicine* 31 (1989): 627-630.

749 American College of Toxicology, "Final Report on the Safety Assessment of Sodium Borate and Boric Acid," *Journal of the American College of Toxicology* 2 (1983): 87-125.

750 J.G. Hadley, P. Kotin, and D.M. Bernstein, "Subacute (28 day) repeated dose inhalation of cellulose building insulation in the rat," *The Toxicologist* 12 (1992): 225 (abstract).

751 John Bower, "Cellulose insulation: Handle with care—if at all," *Environ* #11 (1991): 11-14.

Symptoms of breathing difficulties, rash, skin turning yellow, hair falling out, bronchitis, sore throat, mood swings, suicidal depression, bleeding gums, and abdominal pain have all been reported. Tropical fish have died, house plants have suffered, and a dog has gone into convulsions—all after cellulose insulation was poorly or improperly installed.

In most cases, cellulose insulation is installed conscientiously and it remains inside building cavities, so it presents no health problems to the occupants. However, small amounts (sometimes large amounts) *can* be blown into the living space of an existing house during installation, and installers must be careful to minimize such occupant exposure, and then clean up thoroughly.[752] New houses can also be insulated with cellulose, and if they are constructed tightly, the insulation won't be able to migrate into the living space. There are many manufacturers of cellulose insulation, and it can be purchased through many lumberyards or insulation contractors.

Chopped Fiberglass

This material can be installed in a manner similar to cellulose. It is composed of small fibers of glass, similar to fiberglass batt insulation, but in a loose form, so it can be blown into wall cavities or attic spaces. Glass is inherently non-combustible and is not subject to being eaten, so it does not need to be chemically treated like cellulose.

Several manufactures make a chopped fiberglass blowing insulation. **Certainteed Corp.** has a widely used product, called Insulsafe, that contains approximately 1% mineral oil and silicone to control dust. This is the least chemically contaminated mineral-fiber insulation available today for the residential market. For many sensitive people, this is a positive point, but it must be weighed against the possible long-term cancer risks. If it is adequately separated from the living space using tight construction techniques, the risk will be minimal for the occupants.

Much of the concern over the cancer causing ability of man-made mineral fibers relates to very small diameter fibers. Insulsafe, in particular, is reportedly more problematic than other products because of its small fiber size.

Rock Wool

Many older homes are insulated with loose rock wool, primarily in their attics. Installed by simply pouring it in place, its use today in the residential market is considerably less than it was in the past. It can be contaminated with the same materials that rock-wool batts contain, with the exception of the resin binder. Sensitive people should be concerned about its presence, but should keep in mind that old insulation will have outgassed over the years and may no longer be a outgassing problem. However, inhalation of the loose fibers can still be a cancer risk.

Vermiculite and Perlite

These materials are usually poured-in-place, sometimes in attics, but more often inside hollow concrete blocks. Vermiculite is a mica-like mineral that contains both free and chemically bound water. When heated, it expands due to steam being driven off. This puffed-up product is then used for insulation. It's naturally resistant to fire, rot, vermin

[752] John Bower, "Feedback on cellulose" (letter), *Environmental Building News* (November/December 1993): 2-3.

and termites, but is sometimes treated chemically to make it water repellent.

There is some concern about vermiculite containing small amounts of asbestos,[753] [754] however, the temperatures used in heating and puffing it up may cause the asbestos to decompose, yielding a less-toxic product.[755] Still, it has been reported that one particular vermiculite mine produced vermiculite with up to 5% asbestos. It is estimated that 70% of the vermiculite in use today came from this single mine, with the asbestos-contaminated product being installed in 940,000 homes.[756] Fortunately, this particular mine was shut down in 1990. The **EPA** suggests that vermiculite should be treated like any other asbestos-containing material.[757]

Perlite is a naturally occurring silicate volcanic rock. When heated, it expands, like vermiculite, because of a small amount of water turning to steam. Perlite is also fireproof and resistant to vermin. It is a very dusty material, and is often treated with silicone to control the dust. Its use in attics is often discouraged because the dust can filter down into the living space through light fixtures or other small openings. This dust can be problematic to an asthmatic, as can the silicone to chemically sensitive individuals. There is the possibility of silicosis due to long term breathing of dust containing silica, but this is a remote possibility outside of a perlite-producing factory.

When these products are used inside masonry walls, there is little chance of them or their contaminants reaching the living space—unless the walls have cracks in them and air-pressure differences cause air to move through those cracks. Unfortunately, older masonry walls are often cracked. In older attics, there are even more possibilities that they can get into the living space, because older attics are often not sealed particularly well. In new construction, extra care should be taken to insure that they stay inside building cavities and remain well-separated from the living space.

Polystyrene Beads

Polystyrene beads, which are often used as stuffing in bean-bag chairs, can also be used as a loose-fill insulation. The beads, when expanded, are approximately $^1/_8$" in diameter. As with many synthetic foam insulations, they are flammable and must be protected from fire. Like vermiculite and perlite, they are primarily used to insulate inside masonry walls—although they can also be used in attics and in other locations. Health concerns are similar to polystyrene board products (see below).

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753 H.E. Amandus and others, “The Morbidity and Mortality of Vermiculite Miners and Millers Exposed to Tremolite-Actinolite, Part 1, Exposure Estimates,” *American Journal of Industrial Medicine* 11 (1987): 1-14.

754 “Vermiculite insulation cited as possible cancer risk,” *Energy Design Update* (July 1987): 1.

755 Stephen B. Hayward and Glenn R. Smith, “Asbestos Contamination of Vermiculite” (letter), *American Journal of Public Health* 74 (1984): 519-520.

756 “Asbestos risk in vermiculite,” Environmental Building News (March 2000): 4-5.

757 “Asbestos-contaminated vermiculite may put remodelers at risk,” *Journal of Light Construction* (May 2000): 20.

Board Insulations

There are a number of different insulating boards. Those commonly used in residential applications include: polystyrene, polyurethane, isocyanurate, cellular glass, rock wool, and glass fiber. Cork, phenolic foam, and rubber foam are occasionally used.

One of the biggest issues with the synthetic foam insulations has to do with the gases used to manufacture them. In the past, some of these products used chemicals called chlorofluorocarbons (CFCs) that were found to damage the ozone layer.[758] [759] Today, manufacturers have switched to less-damaging HCFCs. Although not as bad as CFCs, HCFCs still damage the ozone layer.[760]

Most board insulations are available in a variety of thicknesses and sizes. Four-foot by eight-foot sheets are common. They are often used as sheathing, underneath the siding of a house, or as foundation insulation.

Polystyrene

Polystyrene foam insulation is made in two types, expanded and extruded. Expanded polystyrene consists of small beads fused together inside a mold. It is often called beadboard. Extruded polystyrene is made by pushing a chemical mixture through a rectangular die. Upon cooling, it is cut into sheets. Both types of polystyrene will deteriorate when exposed to ultraviolet light, so they must be protected from sunlight. Both can emit noxious gases when burned.

Expanded polystyrene insulation has never used either CFCs or HCFCs. Instead, it uses pentane in the manufacturing process. Pentane doesn't damage the ozone layer, but it does contribute to smog.[761] Beadboard's R-value is slightly lower than extruded polystyrene and it is not as sturdy.

Extruded polystyrene is foamed by the use of the pressurized gas, usually a type of fluorocarbon. After foaming, it will contain, within its pores, both air and the fluorocarbon gas. CFCs, which are implicated in damaging the ozone layer in the upper atmosphere, used to be widely used, but most manufacturers are now using a less-damaging HCFC gas.

Both types of polystyrene insulation are commonly available at lumber yards. Styrofoam is a particular brand of extruded polystyrene that is manufactured by **Dow Chemical Corp.**

Polyurethane and Polyisocyanurate

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758 Alex Wilson, "Foam insulation and the CFC problem," *Journal of Light Construction* (May 1988): 70-72.

759 J.D. Ned Nisson, "Foam insulation: Is there life after CFCs?," *Journal of Light Construction* (December 1989): 36-37.

760 Alex Wilson, "Rigid foam insulation and the environment," *Environmental Building News* (July/August 1992): 1.

761 "Reduced pentane emissions from EPS production," *Environmental Building News* (January/February 1993): 4.

The basic ingredients of polyurethane foam are isocyanates, polyol resins, and an amine catalyst. Other additives can be used. A blowing agent causes the mixture to expand, creating a foam. Polyurethane can be made into flexible foam, as used in upholstery, or a rigid foam, as used in insulation, depending on the type of isocyanate used.

Health effects in factories that produce polyurethane include: blurred vision, skin, eye and respiratory tract irritation, asthma, chest discomfort, *etc*. Some of the chemicals causing these symptoms outgas rather quickly, but others do not. Isocyanates are sensitizers. This means that they can sensitize a person and, once sensitized, that person will react to lower levels with a symptom such as asthma.[762] Once these foams are cured, they no longer act as sensitizers.

Polyurethane is flammable and must be separated from the living space by drywall or plaster. It burns rapidly and releases carbon monoxide, oxides of nitrogen, and hydrogen cyanide. Hydrogen cyanide is lethal (it's used in gas chambers) but so much carbon monoxide is released in a fire that it's of more concern.[763] A group of firemen, who were exposed to isocyanates, reported numerous neurological symptoms such as: euphoria, headache, difficulty concentrating, poor memory, and confusion.[764]

Polyurethane insulation has a higher R-value than some other insulations because of the blowing agent trapped in its pores. Other insulations use trapped air to retard the flow of heat, but the gas used in polyurethane functions as a better insulator. However, as the material ages, the gas slowly escapes and is replaced with air. This results in a lower R-value as the insulation gets older. The escape of gas can be largely prevented by coating the polyurethane with a dense skin, or a layer of metal foil. Polyurethane used, for example, inside a sealed steel entrance door, would probably allow little gas to escape.

Polyurethane will degrade and fall apart in sunlight unless ultraviolet inhibitors are used in the formulation. It will also take on water when in a damp environment or used underground, so it must be adequately protected with a suitable diffusion retarder.

Polyisocyanurate foam insulation is very similar to polyurethane, but is slightly more stable. It, too, must be protected from sunlight and moisture and it has similar characteristics when burned. It is often supplied with a foil facing to protect it from degradation.

While workers in manufacturing plants can be exposed to a variety of chemicals, polyurethane and polyisocyanurate insulations are fairly inert once cured. Thermax and Tuff-R are both polyisocyanurate insulations manufactured by **Celotex Corp.**

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762 Carl U. Dernehl, "Health Hazards Associated with Polyurethane Foams," *Journal of Occupational Medicine* 8 (February 1966): 59-62.

763 A.R.D. Lambert, "Foamed Polyurethane Insulation," in *Energy Conservation and Thermal Insulation*, ed. R. Derricott and S.S. Chissick (New York: John Wiley and Sons, 1981): 445.

764 Pamela M. LeQuesne and others, "Neurological Complications after a Single Severe Exposure to Toluene Di-isocyanate," *British Journal of Industrial Medicine* 33 (1976): 72-78.

Cellular Glass

Cellular glass insulation is a commercial product, and is rarely used in residential applications because of its increased cost. It's mentioned here because it will not burn and it's moisture resistant. It can be used in roof and wall systems as well as underground. Various thicknesses are available. Foamed glass is basically composed of glass—it has no fillers or binders—however it is not 100% safe. During the foaming process, carbon-monoxide and hydrogen-sulfide gases are trapped in each cell of the foam. Theoretically, they will not be released because each cell is totally surrounded by glass. But whenever the surface is scratched, or the material is flexed sufficiently, the characteristic rotten-egg odor of hydrogen sulfide can by released. Once incorporated into a building, it is doubtful if this will ever become a problem because, when installed, it's generally not subjected to abrasion, and most buildings do not flex enough to allow the release of gas. Cellular glass costs approximately two to three times more than other foam insulations, and it has a lower R-value. It's manufactured under the name of Foamglas by **Pittsburgh Corning Corp.**

Rock-Wool and Glass-Fiber

These insulation board products have the same basic health advantages and disadvantages as their batt counterparts. They are denser and more-rigid, but are made of the same materials as rock wool and fiberglass batts, although they may contain more resin binder.

Cork

Cork insulation is made by grinding up the outer bark of an evergreen oak tree that grows around the Mediterranean Sea. It is one of the few all-natural insulations still readily available, but it is often processed into sheets by adding a resin to hold the particles together. Sometimes instead of using a resin, manufacturers steam-bake the cork in molds. In this process, the natural resins in the cork hold the particles together, but the sheets end up with a burnt odor.

Sensitive people can react to cork held together with a resin or to steam-baked cork, but most healthy people aren't negatively affected by either. It is sometimes possible to special order unprocessed raw cork granules directly from the tree, but the price can be high. The granules can be used as a pour-in-place insulation. Because there are only so many cork trees in the world, there is a limited supply of cork insulation.[765] Cork can cost ten times as much as fiberglass. Manufacturers of cork insulation include **Technicor International** (Rector brand), and **WE Cork**.

Spray-In-Place Insulation

There are several types of spray-in-place insulation available. The foam products tend to be about the consistency of shaving cream when applied. They can be injected through small holes in walls, like blow-in insulations, or they can be sprayed onto open

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765 Alex Wilson, "Insulation that won't make you sick," *Journal of Light Construction* (June 1987): 54.

walls or attic surfaces.

Urea-Formaldehyde Foam

In the 1970s, urea-formaldehyde-foam insulation (UFFI) was installed in approximately 500,000 homes in the U.S. and there were no reported negative health effects among the majority of the occupants.[766] There were, however, many instances where negative health effects were recorded.[767] So many, in fact, that the **CPSC** banned its use in residences and schools in 1982. Even though the ban was overturned by a Court of Appeals, the **CPSC** feels that the decision was based on legal and factual errors, and they continue to warn consumers about its dangers. Even though it is again legal to use UFFI, it's rarely installed today. In fact, it's considered such a liability in houses that some real estate agencies require that its presence be disclosed to prospective buyers.

The primary problem with UFFI is that, if mixed incorrectly, it released excessive amounts of formaldehyde gas into the living space. This occurred more often in warm weather or in hot attics. Other gases given off included: benzene, benzaldehyde, acetaldehyde, cresol, methylnaphthalene, acrolein, ammonia, and phenol.[768]

Health effects included: eye, nose and throat irritation, cough, headache, dizziness, bronchopneumonia, pulmonary edema, asthma, dermatitis, rhinitis, conjunctivitis, and allergy. Some people were sensitized to many other chemicals as a result of the formaldehyde exposure, leading to a wide variety of symptoms.

The story of the Leyda family relates how they were driven from their home after it was insulated with UFFI. Early symptoms included chest problems: colds, bronchitis, and coughs, then later included red, watering, and painful eyes. Mrs. Leyda became very weak and dizzy and began having irregular heartbeats. Her doctor suspected multiple sclerosis. By the time the problem was related to formaldehyde outgassing, Mrs. Leyda had become hypersensitive to a wide variety of everyday chemicals. They borrowed $15,000 to have the insulation removed, but because of her newly acquired sensitivities, Mrs. Leyda still could not tolerate her home. The formaldehyde had sensitized her so much that the family was forced to abandon their home. Mrs. Leyda now has MCS and must avoid many things that the rest of the population takes for granted.[769]

Individuals interested in having UFFI removed from their homes are advised that it's very expensive and time consuming, involving major demolition and remodeling.

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766 Formaldehyde Institute, *UFFI Questions and Answers: Urea Formaldehyde Foam Insulation* (Scarsdale, NY: Formaldehyde Institute, n.d.).

767 Lester Levin and P. Walton Purdom, "A Review of the Health Effects of Energy Conserving Materials," *American Journal of Public Health* 73 (June 1983): 683-690.

768 Small, *Susceptibility Report*.

769 Nancy Pappas, "The House on Pickerel Lake Road," *Northeast/Hartford Courant* (December 8, 1985): 14

Two Canadian publications are available describing the necessary procedures.[770] [771] Because it has been so long since UFFI has been in use, it is doubtful if any early applications are still problematic. Most of the formaldehyde has probably long since dissipated.

Polyurethane

Polyurethane insulation is sometimes sprayed in place in residences, but it is more often used in commercial applications. Disadvantages are similar to polyurethane board insulation. Most of these spray-in-place urethane foams use a chemical known as MDI (diphenylmethane diisocyanate). MDI should be treated with respect.[772] It can sensitize a person by inhalation or skin contact, so it should be used with adequate ventilation, respiratory protection, and gloves. Once cured, products containing MDI are fairly inert and are often well tolerated by sensitive people.

There's a *modified* urethane spray-in-place insulation that uses MDI but it's a water-blown product (rather than CFC blown). Called Icynene Insulation, it's produced by **Icynene, Inc.** and licensed to contractors throughout North America. It is sprayed onto wall surfaces as a two-part liquid before the drywall is installed. They also have a version that can be injected into existing wall cavities.[773] The two components react, forming carbon dioxide, which expands the foam.[774] If mixed and installed correctly, it sticks to everything and expands to fill all gaps and openings.[775] Once the foam cures, the surface is trimmed flush with the wall studs and the drywall is installed over it. Once completely cured, this material is often tolerated by chemically sensitive people, and after 30 days there are no detectable emissions. Icynene costs roughly twice as much as fiberglass batt insulation, but it requires no diffusion retarder, and it results in a fairly tight structure. Installing Icynene correctly requires training, skill, and care. One contractor has described sloppy installations where wall cavities were not filled completely—leaving

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770 G.A. Chown, R.P. Bowen, and C.J. Shirtcliffe, *Urea-Formaldehyde Foam Insulation: Building Practice Note No. 19* (Ottawa, ON, Canada: Division of Building Research, National Research Council of Canada, April 1981).

771 R.P. Bowen, C.J. Shirtcliffe and G.A. Chown, *Urea Formaldehyde Foam Insulation: Problem Identification and Remedial Measures for Wood Frame Construction* (Ottawa, ON, Canada: Division of Building Research, National Research Council of Canada, August 1981). Building Practice Note #23.

772 R.A. Bilan, W.O. Haflidson, and D.J. McVittie, "Assessment of isocyanate exposure during the spray application of polyurethane foam," *American Industrial Hygiene Journal* 50 (1989): 303-306.

773 "Non-CFC cavity-fill foam insulation," *Energy Design Update* (July 1994): 9.

774 Richard Harrington, "New from Canada: Icynene Insulation," *Journal of Light Construction* (June 1991): 31-33.

775 Alex Wilson, "Cavity fill insulation: Alternatives," *Journal of Light Construction* (September 1988): 73-74.

large uninsulated voids.[776] But with a competent installer, Icynene can be a healthy choice.

Aerosol cans of single-component polyurethane insulation are widely available in hardware stores and lumber yards for general purpose use in houses. These products use MDI and cure by reacting with moisture in the air. They can be used to fill gaps around window or door jambs, and holes drilled for electrical wires or plumbing lines.[777] This material does outgas MDI for a short period, so respiratory protection, ventilation, and skin protection are recommended.[778]

Single-component urethane has been used successfully in healthy-house construction in a number of applications. For example, the gap between a window frame and the rough framing of the house can be filled with single-component polyurethane then, once the insulation is cured, and any excess is trimmed off with a knife, aluminum-foil tape is applied over the foam as a diffusion retarder to prevent any residual minor outgassing into the living space. This approach helps make the house airtight, and protects the occupants from minor outgassing.

Many builders use canisters of a two-component urethane foam to fill gaps and cracks when they seal up a house. These products also use MDI, but they cure differently than single-component urethanes. They cure by means of a chemical reaction, rather than by reacting with the moisture in the air. Thus, they actually cure somewhat faster than single-component products. They are also often well tolerated by sensitive people after curing.

Some of these foams expand considerably when they cure—so much that they can warp a window or door jamb. Because of this, some window and door manufacturers don't recommend them. There are two solutions. You can partially fill a gap, let the foam cure, then fill the gap a little more, allow that to cure, and so on, until the gap is filled. This must be done with care to avoid excessive expansion. Or you can use a foam that doesn't expand very much.

Aerosol foam manufacturers that offer minimal-expanding products include **Convenience Products** (Touch 'n Foam for consumers, Touch 'n Seal single- or two-component foams for professionals), **Fomo Products** (Handi-Foam, in a variety of container sizes—some smaller throw-way sizes, some larger refillable contractor sizes with application guns, both single- and two-component foams.), **Flexible Products Co.** (Insta-Seal, a single-component foam in containers ranging from 12 oz. aerosol cans up to 12 lb. contractor-sized containers with application guns), and **Macklanburg-Duncan** (Polycel, in both consumer and contractor sizes). These manufacturers also offer expanding foams. Most of these products are generally well-tolerated by sensitive people once cured. Foam sealants and guns can be mail-ordered from **Shelter Supply.**

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776 Fred Lugano, Lake Construction, Personal communication.

777 Alex Wilson. "User-friendly foams," *Journal of Light Construction* (September 1988): 65-66.

778 National Institute for Occupational Safety and Health (NIOSH), *Request for assistance in preventing asthma and death from diisocyanate exposure* (Atlanta, GA: NIOSH, March 1996), DHHS (NIOSH) Publication No. 96-111.

Air-Krete

Air-Krete has been widely reported to be a non-toxic insulating material.[779] [780] It is a foamed-in-place product and it must be installed by trained technicians[781] because, if mixed imperfectly, it can shrink, reducing its insulating effectiveness. If installers are not careful, there can be uninsulated voids inside the walls.

The main ingredients in Air-Krete are magnesium oxychloride (a cementitious material), and sodium silicate (water glass). Both are fairly inert. Fluorescent dye is used to give it a pink color. Compressed air is used on the job to cause the liquid material to become a foam.[782] Air-Krete contains no formaldehyde or asbestos and it has more insulating ability than fiberglass or cellulose.

In new construction, Air-Krete is installed in walls before the interior drywall or plaster is attached. In existing buildings, it is foamed into the wall cavities through holes drilled in either the exterior siding or the interior wall surface. The holes are then plugged or repaired. Attics and masonry walls can also be insulated. After installation, Air-Krete becomes semi-rigid within seconds. Final drying takes two to four weeks.

While Air-Krete seems to be one of the least toxic insulating materials on the market today, there are some sensitive people who report a minor odor—even after several weeks. One extremely sensitive person had to resort to having the Air-Krete removed when she couldn't tolerate it.[783] Most chemically sensitive people, however, tolerate Air-Krete quite well and report little or no odor after curing. Air-Krete was developed by **Air-Krete Inc.** and there are several licensed installers around the country.

Fiberglass and Cellulose

In new construction, chopped fiberglass or cellulose insulation can be mixed with a tiny amount of water or glue and sprayed into open wall cavities.[784] [785] Then, after a brief drying period—usually a few days—the walls are enclosed in a normal fashion. Fiberglass and cellulose dust can be a significant problem when these products are applied as *blow-in* insulations. But, because the insulation is slightly damp when *sprayed*

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779 Peter Fossel, "Sick Home Blues," *Harrowsmith (U.S.)* #11 (September/October 1987): 46.

780 "The All-Natural House," *Everything Natural* (September/October 1986): 10-13.

781 Marylee MacDonald, "Filling cavities: Retrofit foam update," *Journal of Light Construction* (August 1989): 18-20.

782 "Nontoxic insulation business reaches out to schools," *Informed Consent* (November/December 1993): 35.

783 Irene Greenlee, Personal communication.

784 J.D. Ned Nisson, "Wet-spray cellulose for houses," *Journal of Light Construction* (July 1989): 42-43.

785 Chuck Reiss, "Wet-Spray Cellulose Insulation," *Journal of Light Construction* (August 1994): 24-27.

in place, dust is not a problem. Thus, this is a healthier method of applying these materials.

One of the concerns with this *wet-spray process* of installing insulation is that the added moisture can sometimes result in mold growth. In some worst-case installations, there have certainly been serious problems, but in research carried out in Canada, there haven't been any moisture problems as long as installers use the proper amount of water.[786] Drying of the insulation begins immediately, but complete drying typically takes several months.

Reflective-Foil Insulation

Radiant energy can be reflected back where it came from by means of a shiny foil. The foil doesn't need to be exposed directly to the radiant source—it can be placed inside a wall cavity and still function. For example, radiant heat can pass through drywall, strike the foil and be reflected back where it came from. The only requirement is that there be an air space in front of the foil.[787] A layer of reflective aluminum foil inside a wall with a $^{3}/_{4}$" air space in the summer can have an R-value of 3.28 compared to 0.91 for a $^{3}/_{4}$" air space without aluminum foil. Some of the claims for much higher insulating values are based on theory, and can be difficult to achieve with conventional construction tolerances and practices.[788]

Reflective-foil insulation is also called *builders foil*. As an insulation, it is only of minimal value in cold climates[789] but it can be cost-effective in hot climates to keep the radiant solar energy out of attics and air-conditioned spaces.[790] [791]

Reflective foils are made of a variety of shiny metals including: aluminum foil, stainless steel, and foil-coated paper. They only reflect radiant energy when they are shiny; so they will not function when covered with dust. The dust factor can be difficult to determine when the foil is hidden inside the structure of the house. Dust is more of a problem in floor systems than in walls or ceiling systems, but it can coat a reflective foil in any location.

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786 Hank Spies, "Is the insulation dry yet?" (letter and response), *Journal of Light Construction* (October 1991): 10.

787 Philip Fairey, *Designing and Installing Radiant Barrier Systems* (Cape Canaveral, FL: Florida Solar Energy Center). #FSEC-DN-7-84.

788 J.D. Ned Nisson, "Bubble, Bubble, Foil and Trouble," *Journal of Light Construction* (July 1991): 47-48.

789 *EEBA Alert: Radiant barrier installation in attics*, (Minneapolis, MN: Energy Efficient Building Association, November 22, 1988).

790 Philip Fairey, *Radiant Energy Transfer and Radiant Barrier Systems in Buildings* (Cape Canaveral, FL: Florida Solar Energy Center). #FSEC-DN-6-84.

791 Steve Andrews, "Do radiant barriers save energy?," *Journal of Light Construction* (October 1991): 35.

Reflective foil can function as a diffusion retarder, even when dusty. In such an application, it's generally called builders foil. Some reflective-foil-faced cardboard sheathing materials can function both as a sheathing material, a diffusion retarder, and as reflective insulation.

Reflective-foil products are sometimes lightly perforated to allow moisture to pass through. The perforated products will function as reflective insulation, but not as a diffusion retarder. Moisture migration is an important issue with reflective-foil insulations because, if you chose the wrong product for a particular application, you can end up with a moisture-condensation problem hidden inside a wall cavity.[792]

These materials rarely pose any health problems, but some reflective foils are made of aluminized Mylar or aluminized polyethylene which could outgas slightly. On rare occasions a sensitive person will be bothered by printing ink from advertising that is printed on a reflective foil product, but in most installations, they are isolated from the living space.

Reflective insulations come in a variety of forms. The lightest-weight products consist of Kraft paper with aluminum foil on one or both sides. One manufacturer of a light-weight foil/Kraft-paper product is **Denny Sales Corp.** (Denny Foil). These types of materials are often not very sturdy, and they can get torn in some applications. **Innovative Energy, Inc.** has a very durable Heatshield product that is reinforced with plastic fibers, as does **TVM Building Products**. In addition, **Advanced Foil Systems** offers a durable Aluma-Foil product that is a light-weight foil-faced paper, and an Aluma-Foil Plus that is thinner but has a nylon reinforcing. **Parsec** has an aluminized mylar product.

Innovative Energy, Inc. (Astro-Foil), **Reflectix**, and **TVM Building Products** (rFoil) have foil-faced insulations that resemble bubble-pack packaging material. These products can be used in a variety of insulating applications, including around water heaters, pipes, and ducts.

Summary

Because there are no 100%-safe insulations available, care should be taken to insure that they are well separated from the living space. Diffusion retarders help in this regard as far as outgassing is concerned, but tight-construction techniques are the most effective means of separation—to prevent both gases and particles from entering the living space.

Of the readily available products, the foam insulations on the market today are often tolerated by sensitive people, especially Icynene and Air-Krete—but they can be expensive, and they must be installed conscientiously. For someone with severe sensitivities, most insulations can be bothersome when in direct contact—but tolerable when well-separated from the living space. This has been demonstrated in a number of healthy houses in which fiberglass was effectively isolated from the occupants.

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792 Ingrid Melody, *Radiant barriers: A question & answer primer* (Cape Canaveral, FL: Florida Solar Energy Center). #FSEC-EN-15-87.

18. Flooring

When choosing a flooring material, keep in mind the fact that the square footage of floors in a house is second only to walls and ceilings in the amount of surface area exposed to the inhabitants. So, there are hundreds—sometimes thousands—of square feet of flooring within the living space of a house that are directly exposed to the occupants. If the floor covering material is very unhealthy, it can easily be responsible for illness. But even if it is only slightly unhealthy, it can still have an impact on health—simply because there is so much of it.

Preliminary Considerations

The structure of the house can have an impact on your choice of flooring. For example, a concrete slab can easily be covered with ceramic tile, but a wooden subfloor is easier to cover with solid-wood flooring. While there are ways to attach ceramic tile to a wooden subfloor, or hardwood to a concrete slab, they tend to be more work—and they cost more.

In an existing house, some floor-covering materials may be more suitable than others. For example, existing floor joists may not be designed to support the extra weight of ceramic tile, or the floor system may not be stiff enough to prevent ceramic tile from cracking. Some floor coverings can add enough thickness that the bottoms of doors will need to be cut off for proper clearance. Ceramic tile can add between $^1/_4$" and $1^1/_2$" in thickness and hardwood can add between $^3/_4$" and $2^1/_4$". The bottom of a wooden door can be easily sawn off, but it's not always possible to shorten a metal or fiberglass entry door. So, if flooring is going to add considerable thickness, and a metal door is involved, it may be necessary to remove the trim and frame, and raise the whole door assembly.

When planning a new house you should choose a finish flooring at the same time you select the subfloor or foundation system. That way, the entire system will be more economical and structurally sound.

Many floor systems require both a subfloor and a finish floor. Generally, floor systems over vented crawl spaces, outdoor spaces, or over soil, should be tightly constructed, and have a diffusion retarder, to prevent the transmission of moisture or pollutants through the floor assembly. Floors between living spaces (*e.g.* between a second floor bedroom and a main-level living room) generally don't require tight construction or diffusion retarders.

Subflooring

A subfloor is attached to the top of floor joists to add strength and rigidity to the floor system, and to provide a solid surface for attaching finish flooring. In residential construction, subflooring is usually plywood or oriented-strand board, both of which contain phenol-formaldehyde glue. In the past, subflooring was simply nailed to the joists, but many contractors now also use construction adhesive. This minimizes squeaks, and adds strength to the assembly.

It's possible to avoid manufactured wood products by using solid-wood boards for a subfloor. This usually involves 1x8s, laid diagonally, and nailed at each joist. Sometimes, the 1x8s are tongue-and-grooved along their edges, but more often they are simply square-edged boards. They should be installed with a small amount of space between each board. This will allow for expansion if the subfloor gets rained on while a house is still under construction.

There are a variety of ways to make subflooring airtight. The easiest is to use plywood or oriented-strand board that has tongue-and-grooved edges, and apply construction adhesive to the joists and to all the joints between the sheets. This not only yields an airtight floor, but it also makes the entire floor assembly very rigid and sturdy. With a solid-wood subfloor of 1x8s, you must install a separate material on top of the subfloor that is airtight. This can be something as simple as plastic sheeting, paper, or cardboard—if all the seams are sealed with tape or glue. Cardboard is sturdier and less likely to be damaged than paper. Foil-faced products also give you a diffusion retarder. Any holes cut in the floor later (for plumbing, wiring or ducts) must be sealed with an appropriate material.

A well-sealed plywood or oriented-strand-board subfloor makes for the strongest and most air-tight installation. While the amount of formaldehyde released from these construction-grade materials isn't significant, it can bother some sensitive people. But there is a way to isolate such a subfloor from the living space—place a diffusion retarder on top of it to minimize upward outgassing. If the subfloor is already airtight, the diffusion retarder itself doesn't need to be. Builders foil works well if the finished floor is going to be hardwood. With glazed ceramic tile, the glass-like surface of the tile is itself a diffusion retarder. (The grout between the tiles isn't a very good diffusion retarder—but if the subfloor is airtight, the diffusion retarder can be imperfect.)

A diffusion retarder installed under a wood finish floor (*i.e.* close to the interior) isn't recommended in some applications in hot, humid climates. For example, if a floor system over a crawl-space in a hot, humid climate has a diffusion retarder on top of the subfloor, close to the living space, moisture can condense on the underside of the retarder if it is cool—and it will be cooler than the outdoors if the house is air conditioned. In such a climate, a concrete slab floor system may be a better choice.

If a multiple-story house has plywood or oriented-strand-board subfloors, a diffusion retarder (say, builders foil) can be placed on top of the upper level's subfloor (under the finished floor) to prevent outgassing upward. However, it won't prevent outgassing downward. You could attach a diffusion retarder to both the top and the bottom of the subfloor, or you could attach a diffusion retarder to the top of the subfloor and the bottom of the joists (before the ceiling is installed). This can be a reasonable solution—sometimes. Multiple diffusion retarders in the same building assembly can be problematic if moisture gets trapped between the two retarders. It's common, during the construction process, for building materials to get rained on. If this happens, and they're covered on both sides with a diffusion retarder before they have a chance to dry completely, there is a danger of mold growth or rot. Or, if there is a plumbing leak, building components between two diffusion retarders won't be able to dry easily.

Underlayment

Some floor installations use an intermediate material between the subfloor and the finished floor—an underlayment. Underlayment can serve several functions. It can add stiffness. Particle board has been widely used as an underlayment over plywood with a finished floor of carpeting. Particle board is such a potent formaldehyde emitter that this can result in a formaldehyde level in a home that is twice that found in homes insulated with urea-formaldehyde foam insulation—and the high level can last for years.[793]

Underlayment can also be installed to minimize the transmission of sound through a floor. A 440 Sound Barrier underlayment is sometimes used under carpet for this purpose. Manufactured by **Homasote Co.**, it contains no asbestos or formaldehyde, but it is made from recycled paper (like cellulose insulation) so it could bother some sensitive people. Their Carpet Board product is treated with paraffin wax to resist moisture absorption, and with aluminum sulfate to resist termites, rot, and fungus attack. A similar product is made by **Bonded Logic**.

Maxon Underlayment (formerly called Gyp-Crete) is a fairly inert plaster-based product that is mixed with sand and water on the job. It's primary use is as an underlayment under carpeting or ceramic tile. Installed as a slurry, and quickly leveled by trained workers, it hardens rapidly. Old, uneven floors can be easily leveled with a layer of this material, and it is a component of some radiant-floor heating systems. It is fire and crack resistant and tends to seal small gaps in an existing floor, plus it seals around the perimeter of a room. It is manufactured by **Maxxon Corp.** and is available through a number of installers throughout the country.

Finish Flooring

The finish flooring is the material that is actually exposed to the living space, so it must be chosen with more care than subflooring and underlayment. Finish floors vary as to their durability, comfort, beauty, ease of maintenance, and cost.

Wall-To-Wall Carpeting

Wall-to-wall carpeting is an unhealthy flooring material for a number of reasons.[794] [795] When new, it often outgases a wide variety of chemicals into the indoor air. In addition, wall-to-wall carpeting cannot be removed for an occasional beating outdoors, so we don't realize what a huge quantity of filth it contains. In fact, the ability of carpet to *hide* dirt fools us into believing we have a clean house. If an adhesive is used to attach a carpet, it can also be a source of emissions. Because carpet is directly exposed to the living space, so widely used, and so often the source of health complaint—some quite serious—it will be discussed in more depth than some other building materials.

Cleaning

People who have rented a water-extraction/vacuum cleaning machine from their local grocery or drug store, are often shocked to see how much dirt is removed from their

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793 Fossel, "Sick Home."

794 John Bower, "The Floor Plan for Health," *East West* (July 1989): 55.

795 Francis V. Silver, "On the Carpet," *The Human Ecologist* #20 (Winter 1982-83): 2-3.

wall-to-wall carpet. The nozzle on these machines is often transparent, so you can watch the dirt being pulled out. In many cases, you can go over the same area again, and again, and again—and still see more dirt being removed. Carpet holds a tremendous amount of debris—much of it highly allergenic—that cannot be removed completely by routine cleaning.

Cleaning a carpet doesn't always improve the situation—sometimes it makes it worse. Carpet shampoos can be bothersome to sensitive people because of the cleaning agents involved. Some carpet-cleaning solutions contain tri-chloro-ethylene, a dry-cleaning solvent. It is a suspected carcinogen and should be avoided.[796] Insecticides and fungicides are sometimes added by professional rug cleaners.[797] In addition, carpet cleaning has been suspected of causing Kawasaki syndrome, possibly because of an infectious agent becoming airborne during the cleaning process. This is a systemic illness in children, characterized by a high fever. Symptoms have been reported 16-25 days after cleaning.[798] In one study, 24% of those affected reported that there was rug cleaning within one month of symptoms developing, and there was a higher incidence in middle and upper socioeconomic classes.[799] In an analysis of a 1984-85 Colorado outbreak, researchers found that 62% of affected children were exposed to carpet cleaning.[800]

Actually, any damp cleaning or shampooing process results in wet carpet which allows mold, mildew, and dust mites to proliferate. Dr. Clare Dykewicz, who is with the **Centers for Disease Control** in Atlanta, advises keeping young children away from newly cleaned carpet for at least several hours.[801]

After having her carpet cleaned professionally, one woman developed multiple chemical sensitivity. Her initial symptoms included dizziness, headache, and upset stomach, then her legs went into spasms, her toes went numb, her fingers went numb, and she began gasping for breath.[802] Because there were so many chemical compounds involved, the precise cause of her health problems won't ever be known. It could have

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796 Gary Mayk, "A License To Spill," *Practical Homeowner* (May/June 1986): 66-71.

797 June Larson, "Pesticides in New Nylon Carpets and in Carpet Cleaning Services," *The Human Ecologist* #31 (Winter 1985-86): 31.

798 Peter A. Patriarca, "Kawasaki Syndrome: Association with the Application of Rug Shampoo," *The Lancet* (September 11, 1982): 578-580.

799 Nunzia Fatica, "Rug shampoo and Kawasaki disease," *Pediatrics* 84 (August 1989): 231-234.

800 Alan Rauch, "Outbreak of Kawasaki syndrome in Denver, Colorado: Association with rug and carpet cleaning," *Pediatrics* 87 (May 1991): 663-669.

801 Tracey Ann O'Shea, "Wall-to-Wall Worries," *Practical Homeowner* (October 1991): 22-24.

802 Charlotte Sutton, "Price of Progress: Chemicals Make Life Miserable for Many," *St. Petersburg Times* (February 9, 1992): A1-A2.

been the cleaner itself, or a complex reaction between the cleaner and the carpet, the pad, or the adhesive. In another case, a carpet deodorizer caused an otherwise healthy woman to experience acute chest pain, nausea, and lethargy within a few hours of being exposed.[803] In yet another instance, a woman's five-year-old cat died of pulmonary edema (a known allergic reaction to formaldehyde) after her carpet was shampooed. After obtaining a Material Safety Data Sheet for the shampoo, she found that it contained formaldehyde.[804]

The moisture added by carpet cleaning can also affect the materials and furnishings inside the living space. The Earl L. Long Library in New Orleans had their carpet cleaned, and then the library was closed over a long weekend with the air conditioning shut off—before the carpet had a chance to dry completely. As a result of the excess moisture, almost a million books were contaminated with mold. Clean-up costs were estimated at over $1.5 million.[805]

Most portable residential vacuum cleaners have very inefficient filters. So, whenever you vacuum your carpet, a great deal of the very fine dust passes through the filter and is blown back into the room. This airborne dust often bothers allergic or asthmatic individuals, and it isn't good for anyone to breathe. Some specialty vacuums, and some commercial vacuums, use very efficient filters to capture more of the dust. But there can be gases that aren't highly volatile clinging to carpeting that can also become airborne when vacuuming.[806] A central vacuum system can be a good solution—as long as it has an outdoor exhaust to expel all the fine dust, and any gases, from the living space to the outdoors. Built-in central vacuum cleaners are discussed further in *Chapter 24, Central vacuums*.

There are increasing numbers of complaints about carpet staining. Generally, dark stains show up on light-colored carpet around the perimeter of a room or under closed doors. What is happening is this: 1) there is an air-pressure difference causing air to move through the small invisible gap between a wall and the floor (or under a closed door), 2) the moving air contains pollutants, and 3) the pollutants get deposited in the carpet. In effect, the carpet is acting like a filter. This effect is often tied to burning candles indoors, particularly scented ones, and it is the candle soot that gets deposited on the carpet.[807] However, this staining can also be due to other air contaminants—such as outdoor pollutants being sucked indoors.

Outgassing

Some new synthetic carpeting can outgas more than 200 chemicals for weeks

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803 Dominick Shelton, Bruce Urch, and Susan Tarlo, "Occupational asthma induced by a carpet fungicide—tributyl tin oxide," *Journal of Allergy and Clinical Immunology* (August 1992): 274-275.

804 "Carpet shampoo takes all 9 lives," *The Reactor* (January/February 1988): 10.

805 "Three libraries clean up mold infestations," *ACTS Facts* (June 1999): 3.

806 "Analyzing Carpet Chemicals," *Indoor Air quality Update* (October 1980): 7-9.

807 "Carpet Staining," *Solplan Review* (July 1998): 8.

after installation.[808] This outgassing can be due to the carpet itself, chemical additives (such as pesticides, mothproofing, fungicides, stain guards, or soil repellents), the dye, the backing, the padding, the adhesive, or the subfloor. The outgassing of formaldehyde, toluene, and xylene can be very bothersome. A complete list of chemicals typically given off by new carpeting can sound very frightening but it would take a chemist to fully understand it. Such compounds as methyl methacrylate, ethylbenzene, hexamethylene triamine, 1-chloronaphthalene, 2-methylnaphthalene, and 1-phenylcyclopentanol can be given off by new carpeting.[809] The carpet industry has said repeatedly that formaldehyde is not used in the manufacturing of carpet, yet laboratory analysis has shown that it can be released from carpeting—probably as a by-product.[810]

There can even be chemical reactions taking place between the different chemicals in carpeting. One study found that alcohols were given off when humidity from the air combined with calcium oxide in the carpet and resulted in hydrolysis of the phthalate plasticizers in the carpet.[811] Many of the chemicals dissipate with time as the carpet ages but, in some cases, older carpet can also be problematic. Sunlight falling on carpeting can hasten its deterioration and increase its outgassing rate. Neurological symptoms, such as headache, dizziness, slurred speech, and forgetfulness, have been related to carpeting.

Two significant occurrences have been responsible for increased concern about carpeting in recent years: 1) health problems attributed to new carpeting in the **EPA**'s headquarters and 2) mice dying after exposure to carpeting in a laboratory. The **EPA** problem dates back to 1987 when 27,000 yards of new carpeting were laid in their Waterside Mall complex. Almost immediately, some employees started complaining of various health problems including: eye and respiratory-tract irritation, chills, wheezing, cough, fever, joint pain, numbness, blurred vision, dizziness, nausea, difficulty concentrating, memory problems, depression, menstrual disorders, headache, and disabling multiple chemical sensitivity (MCS).[812]

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808 Cindy Duehring, "Carpet toxicity associated with MCS and chronic illness in humans," *Our Toxic Times* (February 1999): 13-14.

809 Glenn Beebe, *Toxic Carpet II* (Cincinnati: **Toxic Carpet Information Exchange**, n.d.).

810 A.T. Hodgson, J.D. Eooley, and J.M. Daisey, "Emissions of volatile organic compounds from new carpets measured in a large-scale environmental chamber," *Journal of the Air and Waste Management Association* 43 (March 1993): 316-324.

811 Phylis McLaughlin and Rosemarie Aigner, "Higher alcohols as indoor air pollutants: Source, cause, mitigation" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 3, Characteristics of Indoor Air*, 1990): 587-591.

812 Bill Hirzy and Rufus Morison, "Carpet/4-Phenylcyclohexene Toxicity: The EPA Headquarters Case," (San Francisco, CA: *Paper expressing the views of the authors and the National Federation of Federal Employees Local Union 2050, Presented to the Society for Risk Analysis*, October 30, 1989).

At first, the **EPA** did almost nothing, prompting the employees union (which counts a number of Ph.D. researchers as members) to petition **EPA** Administrator William Reilly to take action.[813] In the meantime, the union was flooded with requests for information from the media, and from private citizens who had health problems related to their own carpet. For passing on letters of support and requests for information, the union was told "You guys are really in trouble now that we have evidence of all this illegal activity."[814] Surprisingly, the **EPA**'s solution to a health problem was to gag and slander the victims. The union was told to cease responding to citizens requests for information[815] but, finally, $3^{1}/_{2}$ years after the carpet was laid, the union was told that they could again respond to inquiries from the public and the press.[816]

Eventually all of the problem carpet was removed from the **EPA**'s headquarters, but not before over 1,000 employees had health complaints. It's been estimated that more than 40% of the employees suffered sick-building symptoms[817] and, even today, some are 100% disabled. In trying to determine which particular outgassed chemical caused the problem, early focus was on a compound called 4-phenylcyclohexene (usually shortened to 4-PC), which was released by the latex backing on the carpet.[818] [819] Made from styrene and butadiene, 4-PC is often responsible for the characteristic "new-carpet" smell. It now appears that, while 4-PC may not be a good thing to breathe, it probably isn't the single problem chemical. Research sponsored by the Styrene Butadiene Latex Manufacturers Council found no serious adverse health effects related to 4-PC.[820] Rosalind Anderson,

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813 Bill Hirzy, *Citizen's Petition. Re: Control of Risk Associated with Certain Carpeting*. (Washington, DC: National Federation of Federal Employees local union #2050, December 4, 1989). Petition revised on January 11, 1980.

814 Bill Hirzy, Vice President of the National Federation of Federal Employees local union #2050. Letter to "Friends." July 1, 1991.

815 Bill Hirzy, President of the National Federation of Federal Employees local union #2050. Letter to "Friends." April 23, 1991.

816 Bill Hirzy, President elect of the National Federation of Federal Employees local union #2050. Letter to "Friends." June 26, 1992.

817 "Chemical; Sensitivities Considered; Would Protections Hurt Business?," *Indoor Pollution News* (July 25, 1991): 7.

818 M.D. Van Ert and others, "Identification and Characterization of 4-Phenylcyclohexene—An Emission Product from New Carpeting" (Montreal, PQ, Canada: *Abstract #28 from the American Industrial Hygiene Conference*, May 1987).

819 I. Vogelman and others, "Evaluation of 4-Phenylcyclohexene Concentrations in Home and Chamber Environments" (San Francisco, CA: *Abstract #83 from the American Industrial Hygiene Conference*, May 1988).

820 K.D. Nitschke and others, "Dermal Sensitization Potential and Inhalation Toxicological Evaluation of 4-Phenylcyclohexene," *American Industrial Hygiene Association Journal* 52 (May 1991): 192-197.

Ph.D. doesn't believe one single chemical is responsible. "Everyone would like to find a 'bad guy'," she said, "I have a feeling we are looking at an unfortunate combination of medium guys that are terrible when put together." [821]

Dead Mice

On October 29, 1992, as fallout from the **EPA**'s carpet problems was beginning to dissipate, two national news programs added a significant amount of new fuel to the carpet debate. Both CBS's *Evening News* with Dan Rather and *Street Stories* with Ed Bradley had major reports on how mice had actually died in a laboratory setting after a relatively brief exposure to carpeting.[822] The reports centered on Rosalind Anderson's work at **Anderson Laboratories, Inc.** in New England, where she performed a simple experiment. She placed a carpet sample in a glass chamber (an aquarium) with a small heating pad under it. Then she blew air through the chamber into a second chamber containing white mice. The mice were exposed to the chemicals outgassed by the carpeting for one hour, twice a day, for two days—a total of 4 hours over a 48 hour period—and many died. The procedure (ASTM-E981) was originally developed in the 1960s to test nerve gas.

Critics of Anderson's work said the carpet was heated to abnormal temperatures,[823] but the temperature used was about 37°C (body temperature), a temperature carpeting often reaches when the sun is falling on it, when it's near a heater, when there's a heating duct under it, or when installed over a radiantly heated floor.

In a paper presented to an international conference in Belgium, Anderson reported on test results using carpet samples sent in by individuals who felt their carpet was responsible for health complaints.[824] Performing the simple experiment, her lab found sensory irritation, pulmonary irritation, and striking neuromuscular effects. One carpet sample caused severe convulsions after the second hour of exposure, and overall, 17 of the 50 mice exposed to the carpet samples died. Anderson's work was big news, and the **EPA** quickly dispatched a team of scientists to New England to look at her work. While there, they performed the experiment themselves with the same results[825]—mice exhibited symptoms of gasping, turning blue, paralysis, lung hemorrhaging, and death. About this same time, the **Carpet & Rug Institute** commissioned Yves Alarie, Ph.D. at

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821 Marie McCullough, "In small-scale tests, fumes killed mice. Study raises worries of illness from carpet," *Philadelphia Inquirer* (August 26, 1992).

822 Steven Taylor, "Media Reports Spur Further Demands for EPA Probe of Carpet-Health Hazard Link," *Indoor Air Review* (December 1992): 1.

823 Nadav Malin, "Carpeting, Indoor Air Quality, and the Environment," *Environmental Building News* (November/December 1994): 1.

824 Rosalind Anderson, "Toxic Emissions From Carpets" (Brussels, Belgium: *Paper presented to the Building Design, Technology & Occupant Well-Being in Temperate Climates International Conference*, February 17-19, 1993).

825 "'EPA Mouse' Dies in Government Carpet-Health Tests," *Indoor Air Review* (February 1993).

the University of Pittsburgh to try to duplicate Anderson's results.[826] Alarie, who actually developed the ASTM-E981 procedure, got the same results in his own lab—four times.[827] Anderson has since tested hundreds of carpet samples and found serious problems with samples as much as 12 years old.[828]

Politics Enter the Picture

When the **EPA** scientists returned to their lab in Research Triangle Park, NC, they repeated the test—but they changed it slightly. This time, they increased the humidity in the carpet-holding chamber. At the higher humidity, not much happened to the mice. This was an important clue—the problem chemical might be water soluble. But, instead of trying to get to the bottom of the problem, they said they couldn't duplicate Anderson's results—in spite of the fact that Anderson had them on video tape doing just that in her lab.[829] Soon, the **Carpet & Rug Institute** started saying that no one could get the same results—even though Alarie had also done so. (The **EPA** did find pesticide residues, micro-biological flora, and over 200 VOCs in carpet.[830])

By now, the carpet debate was more political than scientific. A congressional hearing was convened to look into the matter. Anderson testified that high humidity affected her results also, but that the problem wouldn't go away when drier air was used. She noted that the **EPA**'s test had so much humidity that they described it as a "rain forest."[831] When the **EPA** was asked if they had, in fact, replicated Anderson's results, a representative at first said "We did not replicate the severe toxicity described by Anderson Laboratories."[832] It took a great deal of Congressional cross-examination for them to finally admit that they had changed the protocol, and that they did get the same results

826 Yves Alarie, Testimony to the Subcommittee on Environment, Energy, and Natural Resources, House of Representatives, Committee on Government Operations, June 11, 1993.

827 "Carpet Industry Agrees to New warning Labels at U.S. House Hearing, Sanders Criticizes Environmental Protection Agency for Dragging Its Heels." Press release from Rep. Bernard Sanders, June 11, 1993.

828 "Problem Carpets Spur Calls for Action, EPA Research Program." *Indoor Air Quality Update* (February 1993): 1-6.

829 "Toxic Carpet Debate," *Our Toxic Times* (July 1993): 4.

830 "Results of EPA carpet emission tests," *Inside IAQ* (Fall/Winter 1993): 3. #EPA/600/N-93-021.

831 Rosalind Anderson, Testimony to the Subcommittee on Environment, Energy, and Natural Resources, House of Representatives, Committee on Government Operations, June 11, 1993, Amended June 23, 1993.

832 Victor J. Kimm, Acting Administrator for Prevention, Pesticides, and Toxic Substances, EPA, Testimony to the Subcommittee on Environment, Energy, and Natural Resources, House of Representatives, Committee on Government Operations, June 11, 1993.

while in New England.

The **Carpet & Rug Institute**, sensing economic problems for their many carpet-manufacturing members, quickly issued an over-reactive press release stating that the tests "are tantamount to lacing up a human being in a strait jacket and repeatedly choking him for two days." [833] New York State Attorney General Robert Abrams took the matter more seriously. On April 11, 1991, he petitioned the **Consumer Product Safety Commission (CPSC)** to require a health warning on carpeting, stating that new carpeting and installation materials "contain as many as 120 chemicals—some of them are toxics and carcinogens." [834] Abrams noted that the **CPSC** had received 500 complaints about carpet and had done virtually nothing. (Actually, by the fall of 1991, the **CPSC** had received 6,151 complaints about carpeting.[835]) When his petition was denied and being appealed, 25 additional States' Attorneys General wrote to the **CPSC** asking for their names to be added to Abrams' petition.[836]

The Carpet Policy Dialog

While all this was going on, the **EPA** was involved in a "Carpet Policy Dialog" with policy makers, scientists, and carpet-industry representatives.[837] Surprisingly, two of the leading players, Anderson and Alarie, were not a part of the discussion. After about 16 months of debate over what to do, the **EPA** released a watered-down brochure titled *Indoor Air Quality and New Carpet* that downplayed what many people believed was a very serious problem. Among other things, the brochure says "…there is no link between adverse health effects and the levels of chemicals emitted by new carpet." [838] Also as a result of the Carpet Policy Dialog, the **Carpet & Rug Institute** voluntarily began a consumer information program, including a new carpet label that is worded surprisingly stronger than the **EPA**'s brochure. It states that "Some people experience allergic or flu-like symptoms, headaches, or respiratory problems which they associate with…

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833 "CRI Calls for Meaningful Indoor Air Quality Research." Carpet and Rug Institute press release, June 11, 1993.

834 "Chemicals in New Carpets Pose Potential Health Hazard." Press release from Robert Abrams, New York State Department of Law, April 1991.

835 Noel Cohen, "Carpeting Standards, Labeling Under Fire," *AGES Magazine* (Spring 1994): 13.

836 Letter to Jerry Thorn, General Council for the CPSC, from the Attorneys General of Texas, Alabama, Arizona, Connecticut, Florida, Iowa, Kansas, Massachusetts, Minnesota, Missouri, Nevada, New Jersey, New Mexico, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee, Utah, Vermont, Washington, West Virginia, and Wisconsin.

837 "Carpet Emissions Reduction; Policy Dialogue," Federal Register, Vol. 55. No. 150, Friday, August 3, 1990.

838 Environmental Protection Agency (EPA) *Indoor Air Quality and New Carpet* (Washington, DC: EPA, March 1992).

carpet."[839]

The new brochures and labels did nothing to address the severe symptoms some individuals were reporting with new carpet. Kevin and Jocelyn McIvers' 10-month old son Christopher began having seizures within a few days of having new carpet installed. After a battery of tests ruled out multiple sclerosis, muscular dystrophy, and tumors, someone suggested that it might be the carpet because the symptoms lessened when Christopher was away from home. When the McIvers asked Monsanto Co., the manufacturer of the carpet, if anyone had ever complained of a neurological or neuromuscular reaction to carpet, the reply was "We have not heard of any reactions similar to what you describe."[840] Then, the McIvers saw CBS's *Street Stories* episode on carpeting. "So we had our carpet tested and sure enough, the mice were rolling over and shaking just like our son did. We were horrified."[841] They immediately removed the carpet, pad, and adhesive, and Christopher's symptoms soon stopped.

Blaming the Innocent

About 16 months after Monsanto's not-very-helpful letter to the McIvers, Monsanto employee Dallas A. Meneely discussed, in an internal memo, a Fleishman Hillard report that was submitted to the **Carpet & Rug Institute** for public-relations purposes. According to Meneely, "The Fleishman thrust is two-fold…to publicly refute Anderson's research and repair damage to the image of carpeting."[842] Commenting further on the report, Meneely added, "p. 4—Last paragraph, last sentence—'The key is to discredit her methodology, results and motives' We need to be careful of this tactic. It may be necessary to publicly discredit and disgrace her but this can be a risky endeavor. Even if we can prove she is incompetent, consumer advocates generally are difficult to discredit and we would run the risk of turning her into a martyr. That's not to say it shouldn't be done, but we should be on very strong footing if we go this route,"[843] No mention was made in the memo of improving the safety of carpeting or addressing the health complaints with compassion.

Now that much of this has become old news for the national media, little has been done to improve the safety of carpeting. Many researchers continue to use the **EPA** protocol of using humid air in their experiments—and reporting that their test mice show no ill effects—rather that trying to replicate Anderson's original experiment. And for good reason, if they buck the system, they run the risk of being "publicly discredited."

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839 Cindy Duerhing, "Carpet Concerns, Part Three: New Carpet label Receives Mixed Reviews," *Informed Consent* (March/April 1994): 40-45.

840 Letter to Jocelyn McIvers from Lori Grant, Monsanto Co., July 18, 1991.

841 Cindy Duehring, "Carpet, Part One: EPA Stalls and Industry Hedges while Consumers Remain at Risk," *Informed Consent* (November/December 1993): 6.

842 Cynthia Wilson, "EPA Report and Monsanto Memos Shed Light on Toxic Carpet Controversy." *Our Toxic Times* (August 1994): 14-15.

843 Cindy Duehring, "Industry Strategizing Memorandum Comes to Light," *Informed Consent* (September/October 1994): 44-48.

For example, it's been suggested that Anderson's laboratory—which has had an excellent reputation—uses disease-ridden mice with weakened resistance,[844] in spite of the fact that Anderson's control mice are fine. Rosalind Anderson, who holds a Ph.D. from the Yale Medical School in physiology, and has received many years of additional training in toxicology, is still being published at respected international conferences[845] [846] where she is told by other researchers, from around the world, that they too are seeing health problems related to carpeting.

When asked if she would go public again if she'd fully known the repercussions of doing so, Anderson replied, "The attacks we've had from industry have been viscous and clearly show the issues are not technical, they're political. Still, if I'd seen the same toxicity, I'd have to act on it. I couldn't live with myself if I'd have tried to cover it up knowing that real lives were at stake. If there's one thing I've learned in all my years of toxicity testing, it's that when you have the bad luck of finding really serious data, you have to follow it through to the very end."[847]

Despite the good scientific evidence of a serious health problem, individuals who have had their health destroyed by carpeting are being labeled crazy. A 1995 study at Cornell University concluded there was no evidence of any negative health effects associated with carpet, but odors from new carpet might trigger anxiety- and stress-related symptoms.[848] Yet, a 1997 paper reported on the results of a questionnaire sent out by **Anderson Laboratories, Inc.** to families with carpets that they (Anderson) had found to be toxic. Of the 110 families who received a questionnaire, 51 households responded and there were 78 individuals who described an average of 17 symptoms that developed after the carpeting was installed. The most commonly reported symptoms were severe fatigue, eye, nose or throat irritation, head, trunk or limb pain, difficulty concentrating or short-term memory loss, difficulty breathing, and tremors and weakness.[849]

The Green Label

One of the more recent developments is a "green label" program started by the

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844 Jason Fry, "Carpet Study Questions Health of Anderson Mice," *Indoor Air Review* (June 1994): 1.

845 Rosalind Anderson, "Toxic Emissions from Carpets" (Helsinki: *Proceedings of the 6th International Conference on Indoor Air Quality & Climate, Vol. 1, Health Effects*, 1993): 651-656.

846 Rosalind Anderson, "Bioassy of Irritant Chemicals in Indoor Air" (Helsinki: *Proceedings of the 6th International Conference on Indoor Air Quality & Climate, Vol. 2, Chemicals in Indoor Air, Materials Emissions*, 1993): 327-332.

847 Duehring, "Industry Strategizing."

848 Jason Fry, "No Health Effects from Carpet, Cornell Study Concludes," *Indoor Air Review* (February 1995): 3.

849 Julius Anderson, "Reactions to carpet emissions: A case series," *Journal of Nutritional & Environmental Medicine* 7 (1997): 177-185

Carpet & Rug Institute.[850] The program is voluntary, but it allows manufacturers to have their carpet tested, and if it meets **Carpet & Rug Institute** standards, they can attach a label to the carpet stating it has been tested. According to New York Attorney General Abrams, "The carpet industry has mounted a massively deceptive merchandising campaign that intentionally misleads the public by implying that all carpets with the green tag have met safety standards."[851] Abrams further points out that there are no recognized standards for carpet safety, the **Carpet & Rug Institute** set it's own arbitrary standards, and the program is inadequate because it only measures a few chemicals. Other critics point out that some carpet samples that have made people ill actually qualify for a green label.[852] [853]

Carpet Workers

Workers who lay carpet for a living seem to be particularly at risk. Those exposed to solvents, glues, and adhesives have a higher-than-normal incidence of neuro-psychiatric illness.[854] [855] A study of carpet and textile workers in Georgia found a higher incidence of death due to lymphocytic leukemia and testicular cancer.[856] Another study found an increased risk of oral pharyngeal cancer among male carpet layers.[857] And a Russian study stated that the central nervous system is most sensitive to chemical exposure in the carpet industry.[858]

Carpet installer David Beuchler knows the risks. He experiences hoarseness,

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[850] "Carpeting Industry Begins Testing, Labeling Program to Meet Consumer Concerns on Indoor Emissions," *Indoor Air Review* (August 1992): 5.

[851] "Green Carpet Label Makes Officials See Red," *Green Alternatives* (October/November 1993): 6-7.

[852] "Carpet Chemicals May Pose Serious Health Risks," *Public Citizen Health Research Group Health Letter* (March 1993): 1.

[853] Rosalind Anderson, Personal communication, March 17, 1997.

[854] K. Ekberg and others, "Chronic and Acute Effects of Solvents on Central Nervous Function in Floorlayers," *British Journal of Industrial Medicine* 43 (1986): 101-106.

[855] O. Axelton, M. Hane, and C. Hogstedt, "A Case-Referent Study on Neuropsychiatric Disorders Among Workers Exposed to Solvents," *Scandinavian Journal of Work Environment & Health* 2 (1976): 14-20.

[856] T.R. O'Brien and P. Decoufl, "Cancer mortality Among Northern Georgia Carpet and Textile Workers," *American Journal of Industrial Medicine* 14 (1988): 15-24.

[857] W.W. Huebner and others, "Oral Pharyngeal Cancer and Occupation, A Case-Control Study," *Epidemiology* 3 (1992): 300-309.

[858] G.I. Rumiantsev and others, "Experimental Studies of the Combined Effect of Styrene in General Vibration," (in Russian), *Gig Sanit* 9 (1990): 32-36.

shortness of breath, and clogged sinuses every time he lays carpet, and says "I don't know any other carpet layers whose health isn't affected by the job in some way."[859] He says insurance companies require a tough physical for carpet layers before they will give them life insurance.

Gerald Schmidt laid carpet for 26 years before having to quit when his symptoms became disabling. He, too, knows other carpet layers who are suffering, and feels abandoned by an industry he supported most of his life.[860] Some carpet dealers remember when carpet warehouses had a terrible problem with mice nesting in carpet rolls. No more—the mice are smarter today, and they nest elsewhere.

Carpet in Schools

One of the more interesting carpet-related issues to evolve has to do with carpeting in schools, where young children could be exposed to dangerous outgassing. In Vermont, two high-school students suffered flu-like symptoms—lingering fatigue, headache, nausea, burning air passageways—due to new carpet, and had to be transferred to another school.[861] Other students were also affected, although to a lesser degree. Partially as a result of this incident, the State of Vermont will no longer purchase carpet containing 4-PC.[862]

In North Dakota, high-school senior Karla Knudson experienced a wide range of neurological problems when carpet was glued down in her school. Among other symptoms, she had problems with concentration, slurred speech, coordination, and headache. Her immunotoxicologist recommended she not return to the school. Other students also had symptoms—three had a high level of trimetallic anhydride in their blood and evidence of auto immunity.[863]

Responding to a variety of issues, the Dade County (Florida) School Board has recommended that the use of new carpeting be restricted in their schools.[864]

Environmental consultant Mary Oetzel has pointed out to schools, who are conscious of costs, that when you factor in material, installation, and maintenance expenses, over a floor covering's expected life, carpeting costs about twice as much as

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[859] Cindy Duering, "Carpet Concerns, Part Two: Carpet Installers Speak out As the Medical Evidence Mounts," *Informed Consent* (January/February 1994): 8.

[860] *Ibid*.

[861] Yvonne Daley, "Emissions from carpets spurn concern in Vermont," *The Boston Globe* (August 22, 1992): 65-66.

[862] Annie Berthold-Bond, "Risks from carpets too high for schools," *Green Alternatives* (December/January 1993-94): 29-30.

[863] Eline Knudson, "Carpet in schools," *The Reactor* (July/August 1989): 5.

[864] Janet R. McAiley, Chairperson, "Carpeting in Schools," Letter to Office of School Board Members, Board Meeting of February 17, 1993. Dade County, Florida School Board.

terrazzo or vinyl composition tile.[865] An analysis of residential installations, also shows a higher life-cycle cost for carpet when compared to wood or quarry tile.[866]

Lawsuits

Glenn and Sharon Beebe got involved in the carpet issue in May 1980, when 79 yards of new carpeting were laid in their business office. They developed a wide variety of symptoms (headaches, respiratory problems, muscle and joint pain, weakness, fatigue, throat irritation, burning of the nose and eyes, inability to concentrate, affected nervous system, jerking in sleep, high blood pressure, chest pain, sensitivity to light, numbness, tingling of skin, heightened sense of smell, and multiple chemical sensitivity), they found dead spiders on the carpet, and leaves on their plants turned black.[867] They had inspections done by local contractors, the board of health, the National Institute of Occupational Safety and Health, and an independent testing laboratory. After receiving a chemist's report showing toxic chemicals, they had the carpet removed. The installer and the manufacturer (Burlington) refused to replace the carpet so, seeking to be reimbursed, the were forced to sue. They learned the hard way how time-consuming and costly a lawsuit can be. It took until 1989 for their case to go to trial. They lost, and were faced with tremendous legal and medical bills. Their story is a nightmare, and it has radically affected their lives. Their story is fully documented in *Toxic Carpet III* and, today, the Beebes act as a clearinghouse for people experiencing health problems related to carpeting. For information, contact the **Toxic Carpet Exchange**.

By the beginning of 1995 there were as many as 20 lawsuits filed against the carpet industry, with at least one being a class-action suit.[868] A significant case in Vermont was settled out of court in 1994. A congressional aide following the case speculated that the defendant (Dorsett Carpet Mills) wouldn't have settled "unless they thought there was information that's better not brought before a jury."[869] In Louisiana, Andre Caubarreaux won what is believed to be the first case against a carpet manufacturer (E.I. DuPont de Nemours) in 1996. Caubarreaux was awarded a total of $4,226,963.92.[870]

As a part of their Consumer Information Initiative, the **Carpet & Rug Institute**

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865 Mary Oetzel, *School Districts Pay a High Price for Carpeting* (Austin, TX: Environmental Education and Health Services, Inc., n.d.)

866 John Bower, "Carpeting: Wall-to-Wall Problems," *Better Building* (October 1993): 1.

867 Glenn Beebe, *Toxic Carpet III* (Cincinnati: Glenn Beebe, P.O. Box 399086, Cincinnati, OH 45239, 1991).

868 John Bower, "Carpets Can be Toxic" (letter), *Environmental Building News* (January/February 1995): 2-3.

869 "Out-of-Court Settlement Ends Vermont Carpet Case," *Building Environment Report* (December 1994): 11.

870 Cindy Duering, "Plaintiffs Win Toxic Carpet Suit," *Our Toxic Times* (March 1997): 7-9.

has assembled “response teams” to investigate carpet complaints. Attorney Kevin McIvers, who’s son was made ill by carpeting, asks “How could the CRI possibly do an objective evaluation when they don’t even believe carpet makes people sick in the first place?” He feels their underlying motive may be to obtain prediscovery information about the house and the victim—before they’ve hired an attorney. Says McIvers, “from a lawyer’s perspective, I wouldn’t let them anywhere near a client of mine.” He’s understandably skeptical because, before assembling the response teams, he says “they lied to us and misled us, and as a result, our little boy was exposed to toxic carpet more than a year longer than he needed to be.” [871]

In 1993, it was estimated that 25% of random off-the-shelf carpets were problematic.[872] Is the problem going away? Not according to **Anderson Laboratories, Inc.** They continue to test carpet for individuals every week and see no reduction in potency. While they generally only evaluate carpet already suspected of causing health problems, about 85% of what they test is problematic.[873] This certainly doesn’t mean the majority of carpeting is capable of killing mice, because that simply doesn’t appear to be the case. However, there is no easy way to determine what is safe and what isn’t when you walk into a carpet store.

Biological Pollutants

Even when outgassing isn’t a problem, the tremendous reservoir capacity of carpet means it contains not only large quantities of dirt, but food particles and crumbs as well. This results in a breeding ground for mold, mildew, bacteria, *etc*. As you walk across carpeting, each footstep creates an invisible cloud of allergenic material. The cloud is four to six feet from a standing adult’s nose, so the symptoms you experience may not be immediate, or severe. However, a child’s nose is much closer to the floor because they’re shorter. They’re also more likely to be laying or playing on the carpet with their noses directly exposed to this reservoir of allergens.[874] Air samples over carpets are literally “flooded” with spores.[875] With the popularity of wall-to wall carpeting, it’s no wonder the incidence of childhood asthma increased 29% from 1980 to 1987.[876]

We all shed a certain amount of dead skin every day that contributes to house dust and finds its way into the carpet—and human skin flakes are the primary food of dust mites. It’s been shown that carpeting can contain tens-of-millions of microscopic

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[871] Cindy Duering, “Carpet Industry Response Team: A Lawyer’s Perspective,” *Informed Consent* (March/April 1994): 44-45.

[872] “Mouse-killing carpets,” *Environmental Building News* (March/April 1993): 3.

[873] Rosalind Anderson, Personal communication, March 17, 1997.

[874] “Carpets and indoor air quality,” *Solplan Review* (March 1996): 10-11.

[875] “Bioaerosols can cause ‘very, very serious building-related illness’,” *Indoor Pollution News* (June 27, 1991): 4-5.

[876] Environmental Research Foundation (ERF), *Publication #218* (Washington DC: ERF, January 30, 1991).

organisms in every square foot.[877] In fact, it's possible for a gram of house dust to contain 1,000 dust mites, and 250,000 of their fecal pellets.[878] It's these tiny fecal particles that become airborne easily, and trigger symptoms in allergic people. Dust-mite fecal pellets can remain airborne for 10 minutes after being disturbed, and it's estimated that 10% of the population is allergic to them, and 45% of young people with asthma are bothered by them.[879]

Carpet is often installed over a concrete floor slab. If the slab has no diffusion retarder or capillary break between it and the soil, dampness can rise up through the concrete and provide enough moisture for mold, dust mites, and other microorganisms to thrive in the carpet. Even with a diffusion retarder, an uninsulated slab is often cooler than the air temperature in most of the room. Carpet on top of the slab acts like insulation, causing its temperature to be lower yet. This results in a microclimate of higher relative humidity near the floor—and biological growth in the carpet.[880] This can be especially problematic in hot muggy weather.[881] To minimize the problem, ventilation and air movement will help raise the temperature near the floor to dissipate some of the humidity. It's been shown that a radiantly heated floor has a lower relative humidity near it, resulting in lower dust-mite and mold populations.[882]

The airborne concentration of dust mites is higher in rooms with wool carpets than with synthetic carpets—even though the total amount of dust in the carpets is similar.[883] It's been suggested this may be due to a static charge in the synthetic carpet which holds the particles in the carpet and prevents them from becoming airborne.

Commercially available acaricidal powders and sprays can be used to control dust mites. These anti-mite preparations can apparently reduce mite populations and

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[877] Roger L. Anderson, "Biological Evaluation of Carpeting," *Applied Microbiology* 18 (August 1969): 180-187.

[878] Robert Wilmott, "Interrelationship of Allergy and Asthma" (Louisville, KY: *Paper presented to the Louisville Area CME Consortium*, March 13, 1992).

[879] American College of Allergy and Immunology (ACAI), *Advice from your allergist* (Palatine,. IL: ACAI, n.d.).

[880] Joe Laquatra, "Is carpeting safe?," *Home Energy* (March/April 2000): 6.

[881] Harry F. Ulrey, *Questions and Answers for Carpenters and Builders* (Indianapolis, IN: Theodore Audel & Co., 1966): 184.

[882] M. Schata, J.H. Elixmann, and W. Jorde Gesellschaft, "Evidence of Heating Systems in Controlling House-Dust Mites and Moulds in the Indoor Environment" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 4, Building and System Assessments and Solutions*, 1990): 577-581.

[883] Jill Price and others, "Measurement of airborne mite antigen in homes of asthmatic children," *The Lancet* 336 (1990): 895-897.

allergenicity[884] but these products should be used with care, especially with sensitive people. In one case, a severe, suffocating odor was released after an application.[885] The manufacturer speculated that there was an unusual reaction between the powder and a previously used cleaning chemical. An application of liquid nitrogen has also been found effective in controlling dust mites.[886] Wet cleaning processes result in a short-term reduction in populations but, soon afterward, there is an increase in mite larva due to the residual moisture in the carpet.[887]

Designers of the Audubon Society's headquarters in New York were dedicated to using low-tox and sustainable building materials wherever possible, so they chose 100%-wool carpeting. Within three years, the carpet became infested with moths, and workers inadvertently carried moths home on their clothing.[888] After evaluating several less-toxic control methods, they decided to apply isopropyl alcohol over ten consecutive weekends, but it doesn't seem to be working. They may need to re-consider some of the other less-toxic control strategies they rejected earlier—such as releasing lizards into the building to eat the moths.

Pesticides and Other Contaminants

One study found high levels of pesticides, polynuclear aromatic hydrocarbons (PAHs), lead, and other metals in carpeting.[889] PAHs are by-products of incomplete combustion, and it's speculated that all these pollutants are tracked indoors on shoes. According to the study, house dust in carpeting can contain "sand, clay, soil organics, bacteria, molds, allergens, smoke residues, pesticides, asbestos, rug and clothing fibers, paint fragments, solvents, flame retardants, cleaners, building products, and pollutants created by activities in the home or carried in from road dust, soil, or work sites." This study found 7 potential carcinogens in house dust.

According to a respected environmental physician, "one of the dangerous things about carpet is that children crawl and play on it, so they have a much greater breathing

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884 W.F. Green and others, "Reduction of house dust mites and mite allergens: effects of spraying carpets and blankets with Allersearch DMS, an acaricide combined with an allergen reducing agent," *Clinical and Experimental Allergy* 19 (March 1989): 203-207.

885 Stanley Wolfe, "Suffocating Odor and Asthma After Acarosan-Powder Carpet Treatment," *Journal of Allergy and Clinical Immunology* (February 1992): 637-638.

886 G. Schober and others, "Comparative efficacy of house dust mite extermination products," *Clinical and Experimental Allergy* 22 (1992): 618-626.

887 Euan Tovey and Lindy McDonald, "Carpet Cleaning," *The Medical Journal of Australia* 158 (April 19, 1993): 579.

888 "Audubon House Provides Good Moth Habitat," *Environmental Building News* (November/December 1996): 4-5.

889 John Roberts and others, "Chemical Contaminants in House Dust: Occurrences and Sources" (Helsinki: *Proceedings of the 6th International Conference on Indoor Air Quality & Climate, Vol. 2, Chemicals in Indoor Air, Materials Emissions*, 1993): 27-32.

and dermal exposure than adults."[890] Pesticide concentrations in house dust found in carpeting often exceed the concentrations found in soil. An **EPA** study suggests that when pesticides are found indoors, they are protected from degradation by sunlight, moisture, temperature, wind and rain dispersal, and the higher bacterial action in the soil.[891] This study also suggests that house dust is a significant contributor to the load of chemicals children are exposed to. Another study noted that the smallest sized particles of house dust collected from a residential cleaning service's vacuum cleaners have the highest concentration of pesticides.[892] These fine particles can easily become airborne, and they can be inhaled deeply into the lungs. They also adhere readily to the skin, so they can be transferred to foods, toys, and the mouths of children.

Fried Dust

Carpeting can actually generate its own dust. As it ages and becomes worn, fibers can break off and become airborne. Most carpeting is made of synthetic materials, so it generates synthetic house dust. This can be picked up by circulating air and find its way into a heating system, where it can burn on hot surfaces inside the furnace. This results in small amounts of various toxic gases being released as combustion by-products. See also *Fried dust* in *Chapter 7, Heating and cooling*.

Solutions

From a health standpoint, there is no perfect carpet, but several companies manufacture 100%-wool and 100%-cotton carpeting. This is often an improvement over synthetic carpeting, but individuals with conventional allergies can be bothered by these natural fibers, and wool carpeting is often treated with toxic mothproofing chemicals. Cotton carpet can have residues of pesticides that were originally sprayed on the cotton crop. As was stated earlier, of all of the pesticides applied to crops in the U.S., almost half are applied to the cotton crop, and they are not all removed during processing. Cotton and wool can both can be dyed with bothersome dyes, or they can have an intolerable backing of latex or some other material. In Germany, 50% of the complaints of odorous carpet involve wool or wool/synthetic blend carpets.[893] Untreated 100% nylon carpeting with a

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[890] Cindy Duehring, "Carpet Concerns, Part IV: Physicians Speak Up As Medical Evidence Mounts," *Informed Consent* (May/June 1994): 12-16.

[891] Environmental Protection Agency (EPA), Science advisory Board, *Reducing Risk: Setting Priorities and Strategies for Environmental Protection* (Washington, DC: EPA, 1990). #EPA SAB-EC-900-021.

[892] R.G. Lewis et. al., "Distribution of pesticides and polycyclic aromatic hydrocarbons in house dust as a function of particle size," *Environmental Health Perspectives* 108 (September 1999): 721-726.

[893] E. Schroder, "Textile floor coverings and indoor air quality" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 3, Characteristics of Indoor Air*, 1990): 719-723.

natural jute backing is reportedly less offensive than other types.[894] To minimize dirt buildup in carpeting, you should develop the habit of removing your shoes as you enter the house.[895]

Unlike wall-to-wall carpeting, natural-fiber area rugs are relatively easy to clean. Large rugs can be taken outdoors for beating (be sure to wear a dust mask) or vacuuming, and smaller rugs can be machine washed. Many discount and department stores carry woven natural-fiber rugs in a variety of sizes and styles. Untreated Oriental and Navajo Indian rugs are also available.

If you decide to purchase new synthetic carpeting, choose a product with little odor. This is imperfect advice, because some of the outgassed chemicals have no odor. You can also air out new carpet in an unused room or garage before having it installed to allow the major contaminants to outgas. New York State Attorney General Robert Abrams recommends airing for 2-4 weeks with the windows open and fans running.[896] This is best done when the weather outdoors is mild, perhaps while you are on vacation. (Be aware that open windows are an invitation to burglars.) If odors persist, water/vacuum cleaning sometimes helps, but many of the chemicals involved are not water soluble.

It's generally believed that outgassing from carpet decreases with time but, because of the wide variation between manufacturing processes, materials, and treatments, it's impossible to say how long it takes outgassing to dissipate completely. However, a few manufacturers offer low-emission carpeting. Some can be quite expensive—often exceeding the cost of a ceramic-tile or hardwood floor. If you're interested in such a product, you may decide to have a sample tested by **Anderson Laboratories, Inc.** to see how it affects mice. That way, you'll know how toxic or healthy it actually is—without having to rely on a manufacturer's claims.

Natural-fiber carpet, usually wool, can be generally obtained locally through carpet stores or interior decorators. There are a number of manufacturers, including **Bellbridge, Inc.**, **Carousel Carpet Mills Inc.**, and **Tintawn Carpets**. Keep in mind the fact that wool carpet is often treated with mothproofing chemicals. If not, it can be subject to moth damage.

There are various producers of carpet that is more environmentally conscious, some of which is sometimes called "low emission" carpet; some of which is made from natural or recycled materials. While some of these carpets may have lower emissions than some other carpets, they may not be suitable for chemically sensitive people. And it should be remembered that all carpet has the capacity to become a reservoir for all kinds of polluting debris, including mold, dust mites, and whatever you tracked in on your shoes. Following are some sources for more environmentally conscious carpet. Many of these carpets are made from natural fibers such as wool, sisal (from the agave plant), coir (from coconut husks), jute, various grasses, or recycled plastics. If you are considering a

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894 Mary Oetzel, "Build for Health," *The Human Ecologist* #21 (Spring 1983): 2-7.

895 "Carpet Toxins: What You Can Do About Them," *Safe Home Digest* (May 1991): 4-5.

896 "Chemicals in New Carpets."

carpet made of a natural material, be sure to ask about specific cleaning instructions.

Collins & Aikman manufacturers a Powerbond RS carpet with ER^3 (Environmentally Redesigned, Restructured, and Reused). This carpet has a 100% recycled backing, and you can return the carpet to the company for recycling after it is worn out, to help preserve landfills. It has a self-stick back, so no other adhesives are needed for installation.

Colin Campbell and Sons has a product called Nature's Carpet that is made in Europe of wool that has never been exposed to toxic chemicals. The carpet is bound to a jute or jute/cotton backing with a natural latex rubber, and it is available in a range of natural, undyed, wool colors. It is also available colored with vegetable dyes. Samples of this carpet have been tested by **Anderson Laboratories, Inc.** and they produced no sensory or pulmonary irritation in test mice.

Design Materials Inc. has woven carpeting made from sisal, seagrass, mountain grass, coir, and jute, as well as tufted wool carpeting. Some products are available in a natural color, while others are dyed. A rubber compound and urethane cushion are used on the back. There are a wide selection of edge bindings available for non-wall-to-wall installations.

Earth Weave Carpet Mills, Inc. produces a Bio-Floor carpet in a Dolomite and Pyrenees style for those who are chemically sensitive and/or environmentally aware. This carpet is made with all-natural wool that has no dyes, pesticides, mothproofing, stain protections or other synthetic components. It has a jute/hemp/cotton/natural rubber backing. (Hemp is naturally mold resistant.) This product is 100% biodegradable when eventually placed in a landfill.

Fibreworks Corp. offers a variety of patterns, colors, and styles of both natural-fiber rugs and broadloom carpets. The choice of fibers include sisal, jute, seagrass, and coir, and there are a number of edge treatments available.

Family Heir-Loom Weavers have attractive woven wool stair runners in traditional designs (mothproofed). They can assemble two or more runners to make wider pieces for use as carpeting.

Mohawk Industries manufacturers, among other products, an Image carpet made from PET (polyethylene teraphthalate) beverage bottles that have been recycled by consumers. They estimate that this use prevents over 200 million pounds of bottles from going to landfills each year. PET fibers are naturally resistant to most household stains, including mustard.

Merida Meridian manufactures attractive, woven, natural-fiber carpet and area rugs in over one hundred styles, designs, and weaves (plain, basket, twills, herringbone, Jacquard, *etc*.). There are also over 200 edge finishes, including leather. Fiber choices include sisal, coir, sisal/coir, sisal/wool, seagrass, paper, and paper/sisal. Colors range from neutral and muted to bold and bright.

Natural Home by Natürlich is a retail and mail-order source for a number of different types of natural-fiber carpeting (and other floor coverings) from a variety of different manufacturers. They regularly deal with chemically sensitive people.

Alison T. Seymour Inc. offers floor coverings in a variety of natural fibers. Their jute product has a loose weave and is made in Ireland, while the sisal has a much tighter weave and is made in Mexico. The coir (from India) is thicker and resembles the material used for door mats, while the wool product has short loops like a conventional carpet. All these floor coverings are available in either 12- or 13-foot widths, and they have a backing to provide stability.

Talisman Mills manufactures commercial carpeting from recycled plastic PET bottles. Testing has shown that their carpet wears considerably better than nylon, and they note that bottle-grade PET resins are of higher quality than virgin carpet PET resins. They offer over 1,800 custom patterns as well as solid colors.

Woodard & Greenstein have several attractive styles of stair runners hand-crafted of 100% cotton. They recommend dry cleaning—if you launder their runners in a washing machine, the colors may bleed somewhat.

Carpet padding can also be a source of outgassing.[897] Natural-fiber carpet padding, made from materials such as jute and animal hair, is available from **Bellbridge, Inc.**, **Colin Campbell and Sons** (#NH 40 of jute/hair), **Dixie Manufacturing** (Nature's Best of jute in different densities), **Earth Weave Carpet Mills, Inc.** (untreated wool pad, natural latex rug gripper) and **Natural Home by Natürlich** (retail supplier of several products). An alternative to conventional padding is an aluminum-foil-faced bubble-pack insulation. **Innovative Energy, Inc.** (Astro-Foil), **Reflectix**, and **TVM Building Products** (rFoil) are three popular brands. According to **Innovative Energy, Inc.**, they don't advertise their product as a carpet pad, but they have used it as such in their own offices. The main drawback is the fact that high-heeled shoes or small-diameter furniture legs can pop some of the bubbles. Carpet can be installed without padding, but it may not wear well or last as long.

If you install carpet with tack strips, you can often avoid using adhesives. Tack strips are generally made of thin pieces of plywood, which can outgas some formaldehyde, but the overall outgassing will likely be less than with an adhesive-covered floor. If an adhesive must be used, choose a low-odor, water-based product. **TacFast Systems** produces a hook and loop system (somewhat like Velcro) for installing carpet to the subfloor without either adhesives or tack strips. With this product, the carpet backing is specially manufactured with "loops" on the back and it sticks to the "hooks" on a special tape that is adhered to the floor.

In wider rooms, and where two or more sections of carpet must be joined, the seaming process can sometimes release undesirable odors. With narrower rooms, seaming is often not necessary.

For carpeting that is odorous, or suspected of causing health problems, there is product called SafeChoice Carpet Guard (**AFM**) that is tolerable for some sensitive people. It is sprayed or sponged onto carpeting to seal in the outgassing. For added sealing, you can also apply a coat of **AFM**'s Lock Out. This has helped in some situations—but not always. Sealants tend to be imperfect, and if carpeting is suspected of causing illness, by far the best thing to do is have it removed.

Resilient Flooring

Resilient flooring is used under foot in more houses than anything but carpeting, generally because of its relatively low cost. The most commonly encountered materials contain vinyl or asphalt, either as individual tiles, or in rolls for a seamless installation.

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[897] "What do you do if you want carpet?," *Informed Consent* (November/December 1993): 32-33.

Sometimes cork, linoleum, and rubber are seen. They can be composed of a wide variety of fillers, pigments, binders, gums, plasticizers, and resins. Many resilient floors require a potentially bothersome wax or clear finish. In general, resilient flooring is not well tolerated by sensitive people because of the outgassing potential, however, it is usually not as offensive as carpeting. As resilient flooring ages and the outgassing lessens, it can better tolerated. So, by the time the material is worn out, it may be perfectly tolerable from an outgassing standpoint.

In the past, asbestos was found in some, but not all, vinyl- and asphalt-based resilient-flooring products. It was either in the surface layer or a part of the backing. If an asbestos-containing flooring becomes worn, it can release asbestos fibers into the air[898] although this usually isn't considered a serious problem. When old floors containing asbestos are removed, the fibers can be released as the flooring is broken, scraped or sanded. Sometimes, the best solution is to leave such a material in place and cover it with a more inert product. Testing laboratories can usually determine whether or not asbestos is present in a flooring sample. While there is no law that prohibits the use of asbestos in flooring, it has not been used since the 1970s. See *Chapter 25, An in-depth evaluation of six common pollutants* for more information about asbestos.

Linoleum and Cork

Linoleum is a material that is sometimes recommended as being healthy. It's made from natural materials—linseed oil, pine resins, and wood flour on a jute backing—and is available in several solid, or marbleized, colors. Linoleum is advertised as containing "no harmful by-products, toxins, carcinogens, fumes, gases, *etc*." However, it does have an odor that can bother some chemically sensitive people. While the particular chemicals are different, its outgassing rate may be similar to vinyl flooring.

Linoleum is also very susceptible to moisture and fungus attack and cannot remain damp for extended periods. If installed on a concrete floor slab over soil, special installation requirements are necessary to prevent moisture damage. Because new concrete takes some time to lose its moisture, some people suggest that linoleum shouldn't be used over a concrete slab unless the concrete is at least 2 years old. Linoleum requires a wax or protective finish that can be bothersome to sensitive people.

Cork flooring is a little more resilient than linoleum, and is available unfinished, waxed, or with a polyurethane finish. It's made from the ground bark of cork trees and can have an odor. The only maintenance required is occasional cleaning with a mild detergent, but care must be taken in kitchens and bathrooms to prevent water damage. Periodic waxing and buffing is recommended for waxed floors. Furniture legs can indent cork, so leg rests are necessary.

Both cork and linoleum must be installed with an adhesive, but water-based versions are available. Linoleum and cork flooring are available from a variety of outlets, including **Bangor Cork**, **Dodge-Regupol, Inc.**, **Forbo Industries**, **Natural Home by Natürlich** (a retail supplier of various flooring products), **Technicor International** (Rector brand), and **WE Cork**.

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[898] P. Sebastien, J. Bignon and M. Martin, "Indoor Airborne Asbestos Pollution From the Ceiling and the Floor," *Science* 216 (June 1982): 1410-1413.

Vinyl

Linoleum was once widely available, but today, it has been largely replaced with vinyl. There are a number of chemicals outgassed from vinyl flooring, but chemicals called plasticizers are often particularly bothersome. They are used in vinyl flooring to make it more flexible. One of these substances is butyl benzyl phthalate, which can emit benzyl chloride and benzal chloride into the air. Some plasticizers irritate the eyes and respiratory mucosa and some are carcinogenic. The half life for some of the chemicals in vinyl flooring has been estimated to be 100-200 days, meaning that it takes that long for half the chemicals to dissipate.[899] A Swedish study found that emissions of the plasticizer TXIB (2,2,4-trimethyl-1,3-pentanediol-diisobutyrate), which can be released by some vinyl flooring, can be "remarkably high after several years."[900]

Because exposure to chemicals can increase the risk of asthma, recent research is looking at the link between the plasticizers used in vinyl flooring and wall coverings, such as di(2-ethylhexyl) phthalate (DEHP), and asthma. A study in Norway found that in houses with vinyl flooring and wall coverings, young children were more likely to suffer from bronchial obstruction.[901] A Danish study found that, as the DEHP is released from vinyl, it is adsorbed onto house dust and airborne particles. This study found that a person inhaling the contaminated dust particles has up to three times more exposure to DEHP than if they inhaled just the airborne plasticizer.[902] Yet another study found that there was evidence that dampness could cause DEHP to degrade. This seems to increase both the secretion rate of a particular enzyme in the nasal membrane, and eye and nasal symptoms.[903] Of course, vinyl flooring is often used in damp locations or on top of damp concrete slabs.

In general, harder vinyl flooring has less plasticizer, and is less offensive, than softer vinyl flooring. Some sensitive people have had good luck in airing new vinyl in a little-used room or garage for a few weeks prior to installation to allow the outgassing to

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[899] Lars Rittfeldt, Maria Sandberg, and Mats S. Ahlberg, "Indoor Air Pollutants Due to Vinyl Floor Tiles" (Stockholm, Sweden: *Proceedings of the 3rd International Conference on Indoor Air Quality & Climate, Vol. 3, Sensory and Hypersensitivity Reactions to Sick Buildings*, 1984) 297-302.

[900] Lars Rosell, "High levels of a semi-VOC in indoor air due to emission from vinyl flooring" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 3, Characteristics of Indoor Air*, 1990): 707-712.

[901] J.J Jaakkola and others, "Interior surface materials in the home and the development of bronchial obstruction in young children in Oslo Norway," *American Journal of Public Health* (February 1999): 188-192.

[902] "Researchers look at plasticizers as one possible cause of asthma, *IEQ Strategies* (April 1988): 7-9.

[903] G. Wieslander and others, "Nasal and ocular symptoms, tear film stability and biomarkers in nasal lavage, in relation to building-dampness and building design in hospitals," *International Archives of Occupational and Environmental Health* (October 1999): 451-461.

take place outside the occupied part of the house. You can avoid potentially bothersome coatings by choosing a no-wax flooring—but some of these products eventually need to be coated with a finish anyway.

Installation

Individual tiles of resilient flooring must be glued down, so a low-tox adhesive is important. Self-stick tiles are sometimes recommended as being less objectionable.[904] If a room is less than 12' wide, 12' rolls can often be laid without using an adhesive. First, the baseboard molding should be temporarily removed from the room, then the vinyl can be cut to fit the exact shape of a room. Once the resilient flooring has been trimmed and is in place, the baseboard molding is reinstalled around the perimeter, thus holding the flooring in place. An aluminum threshold can be installed over the edge of the flooring at doorways.

Wood Floors

Wood flooring is available in two basic types: strips and parquet. When strip flooring is wider than $3^1/_4$" it is normally referred to as plank flooring. Parquet flooring is available in a wide variety of patterns. All wood-flooring types can be installed over either a wood subfloor or a concrete slab, although installations over concrete require special precautions. Health considerations can be related to the wood itself, to the finishing materials, and to any adhesives that are used. From a practical standpoint, wood floors are not recommended in kitchens or bathrooms because they are susceptible to water damage.

Strip and Plank Flooring

Oak is the most widely used wood for residential strip and plank flooring, but other species are available. Of the hardwoods, maple, beech, walnut, ash and pecan are also manufactured, and there are local or regional flooring producers in many parts of the country who can custom make flooring out of virtually any species of wood,[905] but this can result in a higher cost. Southern pine is the most common softwood flooring, but Douglas fir, West-Coast hemlock, spruce, and Western red cedar are also seen.

Some wood flooring has square edges, but most is made in a tongue-and-groove style. This results in a tighter floor, with shallower cracks that will collect dirt and dust. All wood expands and contracts with the seasons—depending on the temperature and humidity—so the cracks in a wood floor also expand and contract. Debris can collect in these cracks, but it can be minimized by regular vacuuming, so it’s usually not a major consideration.

On some flooring styles, the upper corners are beveled at a 45° angle. This enhances the appearance, but it can provide a place for debris to accumulate, and it makes the floor difficult to sand and refinish in the future. Such flooring must either be sanded extremely lightly to preserve the angle, or sanded heavily to remove it completely. A

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904 Oetzel, “Build For Health.”

905 Clem Labine, “The Rise of the Wood Floor, Special Report,” *Traditional Building* (October 1991): 34-40.

moderate sanding often removes more of the angle in some places than others—resulting in an uneven and unattractive refinishing job.

Strip and plank flooring is usually $^3/_4$"-thick, although it is occasionally thicker. To save cost, some manufacturers produce $^1/_2$"-thick material. The thicker flooring can often be sanded and refinished several times, so it can last for decades, but the thinner materials can often only be sanded once, and sometimes one heavy sanding is too much. Oversanding will cut through at the tongue and groove at the edges, ruining the appearance of the floor.

In recent years, a manufactured flooring has been developed that is made of a sandwich—just like plywood. These materials are tongue-and-grooved, but they are generally not nailed down—instead the individual flooring pieces are glued to each other, and the finish floor *floats* over the subfloor.[906] This type of flooring can be installed quickly, is more springy (so it is more comfortable to walk on), but it cannot be refinished. The glues used to assemble it are often problematic for sensitive people. See also *Composite wood floors* below.

Parquet

There are a wide variety of patterns of parquet flooring in several different wood species such as oak, maple, walnut, cherry, mahogany and teak. Small individual pieces of wood are held together by either glue or wire to make tiles which are 4 to 12" square. Different thicknesses are available. Sometimes parquet flooring is assembled as a glued-plywood sandwich, or the pieces are attached to some type of backing material. Tongue-and-groove edges are common.

Much of the parquet flooring being made today cannot be sanded and refinished because the upper layer of wood is too thin. Only the thicker, solid-wood floors can stand sanding.

Installation

When wood flooring is to be nailed down, most installers put down a layer of asphalt-impregnated felt paper between the subfloor and the finish floor. This minimizes infiltration through any cracks in a solid-wood subfloor, and it makes squeaking a little less likely. In many cases, builders foil can be substituted to avoid any outgassing from the asphalt. Foil-faced cardboard sheathing, which is considerably sturdier, can also be used.

If you're planning to remove carpeting from an existing house, prior to installing a wood floor, a plywood subfloor may be several years old, so there may be little formaldehyde left to worry about. However, if the plywood (or a particle board underlayment) has been covered with a foam pad (or foam carpet backing), the foam can act as a diffusion retarder, so the plywood (or particle board) will not have outgassed nearly as fast as if it were exposed directly to the air. If particle board has been used as an underlayment on top of the plywood, it may have outgassed downward, to a certain extent, into the subfloor. Thus, removing particle-board underlayment could leave you with a plywood subfloor containing more formaldehyde than when it was new. This can

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[906] Dennis Parks, "Floating Hardwood Floors," *Journal of Light Construction* (September 1990): 27-28.

usually be dealt with by covering the subfloor with builders foil.

Three-quarter-inch-thick strip flooring is easily installed over a wooden subfloor, usually by blind nailing through the tongue. Wider plank flooring is often blind nailed *and* face nailed to minimize warping. Today, plywood is the preferred material for subfloors because of its strength and lower cost, but sensitive people often request a solid-wood subfloor to minimize formaldehyde exposure.

Installing any wood floor over a damp crawl space or basement can result in excessive cupping or expansion of the finish floor,[907] so you should only install a wood floor where there are no moisture problems. It's extremely important to consider moisture migration before installing a wood floor over concrete. That's because moisture can migrate up from the soil through a concrete slab, exposing the wood to dampness. This can result in excessive expansion of the floor and possible buckling—or a mold problem. In new construction, there should be a high quality diffusion retarder, and a capillary break, under the slab (often polyethylene sheeting). In addition, flooring manufacturers generally recommend some type of diffusion retarder between the slab and the wood floor because of the possibility of the under-slab material being damaged.[908] In an existing house, you may not know what is under the slab, so a diffusion retarder above the slab is very important.

There is a simple test that can be performed to determine if moisture is migrating up through a concrete floor slab. You take a piece of polyethylene sheeting about two-feet square and tape it down to the slab with duct tape. After it has been allowed to set for about 24 hours, lift up the poly and see if it is damp beneath it. If the concrete's damp at all—even slightly damp—installing a wood floor over it is risky.[909]

To install a wood strip or plank floor over a concrete slab, you must first install a diffusion retarder on top of the slab. Then, wood *sleepers* are attached to the slab with concrete nails or anchors, and the strip flooring is blind nailed or face nailed to the sleepers. Sleepers are usually placed on 16" centers and are $^{3}/_{4}$" to $1^{1}/_{2}$" thick.

Some manufacturers make their flooring so it can be attached to metal runners rather than wood sleepers. This approach is often used in commercial installations and athletic courts. The strip flooring is attached to the runners with metal clips, which fit into a special groove in the flooring itself. Manufacturers include **Connor Sports Flooring** (Griptite) and **Robbins Sports Surfaces** (Lock-tite). (These companies also make other attachment systems that use plywood.) The metal-runner method of attachment only works with flooring that has a special groove to accept the mounting clips. Manufacturers recommend a plastic diffusion retarder and foam insulation between the slab and the wood floor.

If a concrete slab is uninsulated, the wood floor can be cooler than the rest of the room, resulting in a microclimate of high relative humidity near the floor which is not

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907 Mickey Moore, "Hardwood Floors," *Custom Builder* (July 1988): 14-17.

908 National Oak Flooring Manufacturers Assn. (NOFMA), *Hardwood Flooring Installation Manual* (Memphis, TN: NOFMA, n.d.).

909 Howard Brickman, "Laying wood floors over concrete slabs," *Journal of Light Construction* (October 1994): 49-52.

good for the wood. In an existing house having an uninsulated concrete slab and no under-slab diffusion retarder, another type of finish flooring may be a better choice—perhaps ceramic tile.

It's possible to insulate a concrete floor slab, then install a wood finish floor over the insulation, but it can sometimes add 2-3", or more, in thickness to the floor.[910] One method uses sheets of foam insulation with two layers of $^1/_2$" plywood laminated together on top of the foam. A layer of builders foil can be placed over the plywood, then the wood flooring can be installed over that.

Most parquet installations today require an adhesive or mastic to actually glue the material down to either a concrete or wood subfloor. (The mastic or adhesive often functions as a diffusion retarder.) Water-based adhesives are preferred over solvent-based products, but both can bother sensitive people, as can some self-stick backings. The glue holding the individual pieces of the parquet flooring together has also been found to be troublesome, especially if it emits formaldehyde. When applied over a wood subfloor, blind nailing or face nailing can be used instead of a mastic or adhesive, but some flooring is too thin to accept the nails. The healthiest choice for parquet flooring is a product held together by wire, and thick enough to attach by blind nailing to a wood subfloor. Installations over concrete always require an adhesive.

When installing wood flooring over a radiant floor heating system, special care is necessary to avoid excessive shrinkage of the wood, and unsightly gaps between the individual pieces.[911] For example, you should use a radiant system with a low temperature, use narrower rather than wider boards, use quartersawn wood where possible, *etc*.

If you plan to install wood flooring in an existing house, be sure to consider the fact that you will be adding thickness to the floor, doors may need to be trimmed at the bottom, and baseboard trim will need to be raised.

Finishing

Several major manufacturers produce wood flooring that is pre-finished. This can be advantageous to someone sensitive to the odors generated when finishing a floor in place, however, very sensitive people are sometimes bothered by factory-applied finishes. In the past, a variety of different finishes were in use, but many major manufacturers are now switching to water-based polyurethane finishes, which are often tolerated by sensitive people.

Unfinished flooring is installed, sanded in place, then finished in place. This exposes the occupants to both sawdust and outgassing from the finishing process. Do-it-yourselfers are urged to read up on the process before attempting to sand and finish a

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[910] "Insulated Floors Over Concrete," *Journal of Light Construction* (December 1994): 14.

[911] Doug Mossbrook, "Hardwood flooring over radiant heat," *Journal of Light Construction* (September 1998): 47-53.

floor for the first time.[912] [913] There are a variety of clear finishes that can be used, some of which outgas very quickly, and are very well tolerated. If you don't like the natural appearance of wood, you may consider staining it before applying the clear finish. Stains are usually less of a problem than finishes, simply because they are under the finish, so they are not directly exposed to the living space. Still, low-tox water-based stains are preferred.

Water-based finishes are the least objectionable, while oil-based finishes are more bothersome. *Swedish finishes* are made with a urea-formaldehyde resin and are very potent. In selecting a finish, toxicity is a major consideration, but you should also consider durability. Some wood finishes aren't particularly durable, but if a finish is specifically designed for floors, it should last 15 years or more.

If a sensitive person is bothered by a particular species of wood, a finish can sometimes seal it enough to make it tolerable. However, the edges and the underneath side of the flooring remain unfinished, so the type of wood chosen should be as tolerable as possible. Oak, the most common flooring, is fairly odorous—especially after sanding. It can bother someone sensitive to oak for several weeks (occasionally several months) after being finished—even when a low-tox finish is used that outgases in less than a week. Thus, sensitive people should test a sanded piece of wood and a clear finish in combination to determine how long the combination will take to become tolerable.

When building a new house, a sensitive person can often delay moving in until the finish has outgassed sufficiently. If you already live in a house and are installing a new floor (or refinishing an existing floor) it is helpful to know ahead of time exactly how long it will take for the floor to become tolerable. Testing ahead of time will yield this information.

Sources

Most manufacturers offer wood flooring in different grades, widths, thicknesses, and wood species. Prefinished hardwood flooring manufacturers include **Bruce Hardwood Floors**, **Harris-Tarkett**, **Hartco**, and **Robbins Hardwood Flooring**. All these are currently using water-based polyurethane finishes, but manufacturing processes occasionally change, and some product lines may use a different finish, so if you are interested in a specific finish, check with the manufacturer.

Augusta Lumber Co. Inc. produces unfinished wood flooring in several species. **Sheoga Hardwood Flooring and Paneling** offers unfinished wood flooring in ash, cherry, maple, oak, walnut, pine, and poplar in different styles and grades, including a "Character Grade" that is less expensive and more rustic in appearance. They also have a herringbone pattern and solid-wood vents for in-floor heating/cooling registers. Most flooring manufacturers don't sell direct, rather they have distributors across the country. **Harmony Exchange** is one distributor that handles several flooring-manufacturer's products, in various wood species, in different grades and widths.

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912 Howard Brickman, "Sanding and refinishing wood floors," *Journal of Light Construction* (November 1994): 25-29.

913 Roger Yepsen, "Hardwood Strip Flooring," *Practical Homeowner* (February 1988): 70-76.

Harris-Tarkett has several styles of unfinished parquet flooring in a $^{5}/_{16}$" thickness that are made of solid wood. This product is made to be sanded and finished after installation.

The **National Oak Flooring Manufacturers Assn.** and the **National Wood Flooring Assn.** maintain a list of their members who produce wood flooring. They also have very good literature on the care, installation, and maintenance of wood floors. Some of their literature is particularly useful to do-it-yourselfers.

Composite Wood Floors

There are two basic types of composite wood flooring. One type is made entirely of wood and/or manufactured wood products. This type of composite flooring generally has a thin, attractive, hardwood veneer glued to a less-costly, solid softwood, plywood, or other base material. It is generally both prestained and prefinished, usually with a clear solvent-based or water-based polyurethane.

The second type of composite flooring uses a durable high-pressure plastic laminate surface (such as the material used on countertops, Formica being one brand name) glued to a base of some type of manufactured wood product (usually particle board or medium-density fiberboard).[914] This is usually called laminate flooring.[915] The edges are also susceptible to moisture damage, so it is not suitable for bathrooms or kitchens.[916]

Most composite floors are installed by applying glue to their tongue and groove joints, and they are not nailed down to the actual structure of the house. So, these floors "float" on top of the subfloor. **Junckers Hardwood** has a floating floor that is made in Denmark of solid $^{3}/_{4}$"-thick hardwood with an oil-based polyurethane finish. It is often used over radiantly heated floors, and is held together with metal clips—so no glue is necessary—and it can be removed easily and relaid somewhere else.

There are several drawbacks to composite flooring products. First, "floating floors" can have a hollow sound when they are walked on. And they usually can't be sanded or refinished in the future. Also, the plastic-laminate flooring just doesn't look like real wood.

From a health standpoint, composite flooring has the potential to outgas bothersome compounds. This is particularly true for products made with manufactured wood products because they are usually produced with formaldehyde-based glues. (The glue used during *installation* is often a low-tox white glue or a yellow carpenter's glue.) The stains and clear coatings used on wood-surfaced composite-flooring products can be bothersome unless low-odor, water-based, non-formaldehyde-containing finished are used.

For one of the healthier products, **PermaGrain Products, Inc.** has a flooring made of "engineered wood planks with formaldehyde-free plywood with a top layer of

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914 "Laminate flooring," *Building Products* (July/August 1999): 108.

915 "Laminate flooring sales keep rising every year," *Professional Builder* (November 1996): 122.

916 "Laminate flooring comes on strong," *Journal of Light Construction* (November 1996): 9.

hardwood." They also have a solid-wood plank style. These products are available either prefinished (with a zero-VOC urethane sealer) or unfinished, and you have a choice of a top surface of red oak, white maple, ash, beech, or cherry. This product can be stapled together to avoid installation glues.

Laminate flooring is made by a number of companies, such as **Formica Corp.**, **Bruce Hardwood Floors**, *etc*. One of the first to come on the market was Pergo (**Perstorp Flooring, Inc.**). It has a heat-compressed, softwood base made with urea-formaldehyde glue (which has the potential to outgas a great deal of formaldehyde). Pergo flooring was originally imported from Sweden but is now also made in the U.S.

Ceramic Tile

Ceramic tile is usually well-tolerated and inert. The tile itself is a clay product that is fired in a kiln. There are various types: mosaic, quarry tile, glazed tiles, *etc*. All can be installed in similar ways. Glazed or vitreous tiles have an impervious surface and are often recommended in healthy houses because they do not need to be sealed. Sealers are often necessary with quarry tiles, pavers, and slate. Porous unsealed tiles can harbor bacteria and other micro-organisms, and they are easily stained.

Some tiles are made for specific applications. Never use a wall tile on a floor, because it won't wear well.[917] Foyers that get wet from rain-soaked shoes, can benefit from tiles that don't get slippery. Look for those that have a *high friction coefficient*.[918]

As a rule, sensitive people generally tolerate glazed ceramic tile very well.[919] Occasionally someone will be bothered by a slight earthy odor on the back of a tile but, once installed, the tile is usually tolerable. Some tile glazes contain lead, but this is more of a problem with imported tiles than with those produced in the U.S. Some foreign tiles also contain asbestos fillers which can release fibers when the tiles are being cut during installation. Reputable manufacturers will be able to tell you if a lead glaze or asbestos filler was used, but neither are significant problems with floor tile—once installed. However, a lead-containing glaze can contaminate food prepared on a tiled countertop.

Ceramic tiles are available in a variety of sizes, colors, and surface textures.[920] With larger tiles you will have fewer joints to fill with grout. Color is generally a matter of personal taste, but darker colors absorb more warmth from sunlight in passive-solar applications. If used outdoors in cold climates, the tiles should be able to withstand freezing conditions. Major ceramic-tile manufacturers include **American Olean Tile Co.**, **Daltile Corp.**, and **Florida Tile.**

For ceramic tiles that are more environmentally responsible, the tiles produced in the North Carolina plant of **Summitville Tiles Co.** are made from a recycled waste

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[917] Michael Byrne, "Ceramic Tile Troubleshooting," *Journal of Light Construction* (January 1992): 24-26.

[918] Gordon Tully, "The Right Tile for the Job," *Journal of Light Construction* (August 1991): 11.

[919] John Bower, "Safe Ceramic Tile," *Environ* #5 (Fall/Winter 1986-1987): 21-22.

[920] "Spotlight on Ceramic Tile," *Custom Builder* (September/October 1992): 94-102.

product of feldspar mining, and **Terra Green Ceramics, Inc.** make tiles from recycled glass.

Blazestone tiles from **Bedrock Industries** are made using 100% recycled glass and can be used indoors or outdoors on floors, counters, pools, backsplashes, fountains and hearths. These fall into the "art tile" classification, and can be expensive.[921]

Ceramic-tile installations can be expensive—especially if you are considering tiling all of the floors in a house. While much of the cost involves the labor to install the tile, some ceramic tiles themselves are very high-priced. However, attractive, low-priced tiles can often be found in discount building-supply centers. And some manufacturers offer *seconds*. Seconds usually have a slight color or surface variation, or a small chip or defect on an edge. This isn't much of a disadvantage because every installation requires trimmed tiles along walls, so major defects can be cut off and discarded. Tiles with significant color variation can be used in closets where they won't be readily noticed. With seconds, the cost savings can be up to 50%.

Most ceramic-tile manufacturers have instruction sheets available to guide do-it-yourselfers through the installation process. There are also several books on the subject for both the homeowner and the professional.[922] [923] *Healthy House Building for the New Millennium* by John Bower shows the complete step-by-step process of installing and grouting ceramic tile on a concrete slab in a Model Healthy House.

Installation

The traditional, centuries-old method of attaching ceramic tile is the most inert, but it's also the most expensive, and it requires an experienced tilesetter. This is known as a *thick-bed method* and is often referred to as a *mud-job*. It involves a $1^1/_4$"-thick mortar bed (composed of Portland cement, sand, and water) applied over a wood or concrete subfloor. The tile can be attached to the bed with a paste of Portland cement and water—*if the bed is still plastic, or uncured*. There are no chemicals required with this method, only Portland cement, sand, water, and the ceramic tile itself.[924] While there are some professional tilesetters who use a thick bed, most allow the bed to cure, then attach the tile with *thin-set mortar*. If the bed is cured, a Portland-cement paste will not adhere properly. A thick-bed installation is the most expensive way to install ceramic tile, because it takes more skill and labor than other methods.[925]

There are actually several different materials that can be used to attach ceramic tile to a variety of surfaces. Organic mastics or petroleum-based products are commonly

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921 Michelle Buetow, "Trash to Treasure," *Seattle Times* (April 20, 1997): 11-14.

922 Michael Byrne, *Setting Ceramic Tile* (Newton, CT: Taunton Press, 1987).

923 Tile Council of America, *Ceramic Tile Installation Handbook* (Princeton, NJ: TCA, 1986).

924 G.L Marsh, "Ceramic tile installation for the chemically sensitive," *The Human Ecologist* (Summer 2000): 25-26.

925 Rick Anderson, "Working with Tile Backerboard," *Journal of Light Construction* (October 1994): 53-57.

used by do-it-yourselfers. They aren't often long-lasting, and they are usually poorly tolerated by sensitive people. Other choices include epoxies, furans, thin-set mortars, and modified latex-Portland-cement mortars. The epoxies and furans are the most odorous. Modified latex-Portland-cement products contain either powdered or liquid latex. They, and thin-set mortars (sometimes called *dry-set* mortars), contain a variety of ingredients that can be bothersome to some people if exposed to them directly—however they often aren't significant outgassing sources, and are generally well-tolerated once installed. The actual ingredients in these products are often considered trade secrets by manufacturers.

Modified latex-Portland-cement mortars are designed to be used on a variety of surfaces, such as concrete, exterior plywood, water-resistant drywall, cementitious boards, *etc*. Thin-set mortars have fewer additives but are designed to adhere only to masonry, concrete, or cementitious boards. Both products are mixed with water and applied with a notched trowel to the subfloor. The tile is then set into the mortar and it's allowed to cure, usually overnight. The spaces between the tiles (the joints) are filled with grout later. If the joints are kept fairly narrow, less grout is required. This is advantageous in damp locations because mold growth is more likely in the joints.

Most modified latex-Portland-cement mortars and thin-set mortars are usually well-tolerated once an installation is complete. This is because the mortar is completely covered up by the tile and the grout, so it is well-separated from the living space. However, a few products have a very strong chemical odor—an odor that can be very noticeable and bothersome—even after an installation is complete. The major mortar producers often have several manufacturing facilities around the country. It's possible for the mortar from one plant to be very tolerable, but the same product from another factory to be very odorous. This can happen because they get their raw ingredients from different suppliers. For this reason, it's important to secure a sample of the powdered mortar prior to starting a job. It can be mixed with water and tested ahead of time. If you have a sample with odorous additives, it will have a very noticeable chemical odor to anyone with a sense of smell. Fortunately, most modified latex-Portland-cement mortars and thin-set mortars are fairly inert. Manufacturers include **W.R. Bonsal Co.**, **Bostik**, **C-Cure**, **Custom Building Products**, and **Laticrete International, Inc.**

If you want to install ceramic tile over a concrete floor slab, you can simply use a thin-set mortar. If you want to install it over a wood subfloor, you have several choices. If the sub-floor is plywood and is sturdy enough, you can attach the tile directly to it with a modified latex-Portland-cement mortar. If the floor is too bouncy, the tile will be prone to cracking. A much better method is to use a cementitious board (also called backerboard) as an underlayment between the wood subfloor and the tile. Or, you can install a $1^1/_4$" thick mortar bed over the wood and attach the tile to the top of that.

Most cementitious boards are $^1/_2$" thick. They are made from Portland cement, fiberglass mesh, expanded shale, water, and a few minor additives. They can have a slight odor, but once they are covered with tile, the odor generally isn't noticeable. The Durock brand (**USG Corp.**) has been used by chemically sensitive people. Other manufacturers include **Cemplank, Inc.** (Cemroc), **Custom Building Products** (Wonder-Board), **Eternit** (Cemroc), and **James Hardie Building Products** ($^1/_4$"-thick Hardibacker and $^1/_2$"-thick Hardibacker 500). In addition, **Cemplank, Inc.** has an Ultraboard product that is $^1/_4$"-thick and denser. It is lighter in weight, and also has less odor than some of the other products.

To install a cementitious board over a wood subfloor, you first put down a layer of modified latex-Portland-cement mortar with a notched trowel, then you lay the cementitious board in the mortar and screw it down to the subfloor. The joints between the sheets should be covered with fiberglass-mesh tape and filled with mortar for strength. Once cured, the ceramic tile can be attached to the cementitious board with either a modified latex-Portland-cement mortar or a thin-set mortar.

Grouting

As with mortars, there are several different types of grouts that can be used to fill the joints between tiles. All contain various chemical additives, but epoxies, furans, and silicones are the most offensive—especially for sensitive people. Dry-set grouts, latex-Portland-cement grouts, commercially-prepared Portland-cement grouts, and acid-resistant grouts are less bothersome. Because grout is exposed to the living area, chemical additives (*e.g.* acrylamide or latex) are more bothersome than when similar chemicals are used in mortar, simply because the grout is exposed to the living space.

Many commercially prepared grouts are fairly inert, but there can actually be dozens of different ingredients in them. Grouts that require *damp curing* are the most inert because they typically don't contain latex additives, so they are often tolerated by sensitive people. Most manufacturers who make ceramic-tile mortar (see above) also offer different types of grout.

For a very inert grout, it's possible to make it from scratch—from Portland cement, sand and water—and avoid chemical additives completely. Sometimes lime is added for workability. Marble dust can also be added as a filler, but it's softer than sand, and can result in a less-durable, more-absorbent grout. Pure-white Portland cement can be used with white sand to achieve a white grout. Mineral colorants can be used to make a colored grout. White cement is often recommended for use with colorants because it allows you to obtain a brighter shade. See *Chapter 10, Concrete and Masonry* for a discussion of the ingredients.

With home-made grout, you mix the dry ingredients first. For joints up to $^1/_8$" wide, 1 part Portland cement is used with 1 part of dry, clean, fine, graded sand. The ratio is 1:2 for joints up to $^1/_2$" wide and 1:3 for joints over $^1/_2$" wide. When making grout from scratch, it's a good idea to mix enough dry ingredients together at one time to do the entire job. This will insure a uniform color. Then small batches of the dry material can be mixed with water to grout an area that can be worked without being rushed. Slight color variations are to be expected—even with commercially made grout[926]—but premixing the dry ingredients will minimize them. If the finished joints are flush with the surface of the tile, rather than concave, they will be easier to keep clean and dry, but slightly concave joints are more common.

In order for grout to be hard, durable, and long-lasting, it must cure slowly. Various chemical additives can be used to slow the curing process. But some commercially made grouts—and all grouts made with only Portland cement, sand and water—must be *damp cured*. This means keeping the grout damp for 72 hours. If this is done, the grout will be just as hard, durable, and long-lasting as any other grout. Damp

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926 Lynn Comeskey, "Grout wars," *Journal of Light Construction* (June 1989): 42.

curing involves covering a freshly grouted floor with plastic sheeting for 72 hours, so it will retain moisture. Sometimes Kraft paper is used, but it will need to be misted with water as it dries out. After the curing period, the plastic, or Kraft paper, is removed and the floor is given a final cleaning.

For most people, any ceramic tile installation is quite healthy. But for sensitive people, ceramic tile attached to a concrete slab with a thin-set mortar and an additive-free grout is one of the more inert installations. However, when sensitivities are severe, testing for personal tolerance is recommended.

Cleaning and Sealing

Glazed ceramic tile is relatively easy to keep clean with a damp mop and a mild cleaner. If hard water has left deposits on tile (*e.g.* in a shower) they can usually be removed with vinegar.

Grout can be somewhat absorbent and susceptible to staining. Commercially prepared grouts contain various additives that make them more resistant to stains. Various commercial sealers are available that can be used to seal the grout (or a porous tile such as quarry tile) but these are sometimes poorly tolerated by sensitive people. However, sodium silicate, often called water glass, is often well tolerated—even when wet. It can be applied to grout with an artist's brush. Manufacturers include **AFM** (Penetrating Water Stop, Grout Sealer, and Water Shield) and **Aqua Mix** (Penetrating Sealer). **Concure** has *potassium* silicate sealers. Their Concrete Admixture can be mixed into wet grout before it is placed (10 oz. per 100 pounds of grout), and their Concrete Flooring Sealant can be applied to grout after it has hardened.

Beeswax has sometimes been recommended as a grout sealer, but it can be difficult to apply, and it often has a flowery odor. Fullers earth, a natural clay-like material, can be mixed with water to make a paste for use in absorbing stains from unsealed grout. It can be ordered through most pharmacies and is very good at removing oil stains. The paste is applied to the stain and allowed to remain overnight. In the morning, the dry powder is simply vacuumed up. Stubborn stains can sometimes be removed with a very dilute solution of muriatic acid, but this should not be used as a regular method of cleaning because the acid actually eats away part of the grout's surface.

Because the grout on kitchen countertops is particularly susceptible to staining, it has been recommended that it be colored to match the shade of "dirty dish water" and the stains will be less noticeable.

Grout joints can harbor mold if they are allowed to remain damp. Some grout additives such as methyl cellulose can actually encourage mold growth.[927] Actually, most common allergenic molds live in an acidic environment (low pH) and, because Portland cement has a relatively high pH, it tends to discourage mold growth if kept dry.

Marble and Slate

Although their cost is usually higher than ceramic tile, marble or slate floors can be just as inert. They can also be very attractive. Both come in different grades, so be sure to choose a material that is suitable for floors. The primary drawback to marble is the fact that it is more absorbent and softer than ceramic tile, thus more prone to wear and

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[927] Bower, "Safe Ceramic Tile."

staining. Although considered an expensive floor, marble has come down in price in recent years.[928]

Marble and slate are typically installed in a manner similar to ceramic tile—with a modified latex-Portland-cement mortar or a thin-set mortar, and grout.[929] They can be sealed with a sodium-silicate (water-glass) product, available from **AFM** (Penetrating Water Stop, Grout Sealer, or Water Shield) and **Aqua Mix** (Penetrating Sealer). Suppliers of marble and/or slate flooring include **Buckingham Virginia Slate Corp.**, **Georgia Marble Co.**, **Structural Slate Co.**, and **Westchester Marble & Granite**.

Terrazzo

Terrazzo floors have been around for centuries. They are costly, can be very attractive, but tend to look more commercial than residential. As with ceramic tile, the traditional installation method is the most inert. It consists of a mixture of marble chips, Portland cement, and water. The mixture can be applied over a variety of surfaces such as concrete or wood. When this mixture has hardened, grinding machines are used to smooth and polish the surface. Metal divider strips are used to accent or separate colors, highlight certain areas, or control cracking. This traditional method is becoming a lost art, as newer, faster, cheaper methods have been developed—so a contractor who uses the traditional techniques may be difficult to locate. The traditional method can be up to $2^1/_2$" thick, depending on the surface to which it's applied.

Today, latexes, vinyls, rubbers, epoxies, polyesters or other materials can be used instead of Portland cement, and various other minerals can be substituted for marble. This usually results in a less tolerable floor for a sensitive person. Chemical bonding agents can also be used when installing terrazzo over some surfaces.

Traditional terrazzo requires a sealer of some type. There are a number of different products on the market, but sodium-silicate (water-glass) sealers are the most inert.

Concrete Floors

Bare concrete can be used as a finish floor and it's generally a very inert choice. The surface can, however, be subject to wearing, which results in a very fine dust. A tolerated sealer such as sodium silicate (water glass) will help to harden and seal the surface to minimize wear. While a large expanse of plain, gray concrete can be cold-looking and unattractive, a colored concrete floor will be much warmer looking. Tooled joints can break up a floor into interesting patterns. For example, diagonal joints can add a new dimension to the space. Various surface forms can be used to give a concrete floor the appearance of tile, slate, or stones. Once furniture and throw rugs are in place, a room takes on a personality that makes the appearance of the floor itself less important.

Concrete floors should be adequately reinforced with steel and engineered properly to minimize unsightly cracking that could become a pathway for radon or other soil gases to enter the living space. If a concrete floor is covered with ceramic tile, a crack

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928 Ray Bolger, "Stone Age," *Building Products* (Fall 1991): 95-96.

929 Scott Duncan, "Laying Marble and Granite Tiles," *Journal of Light Construction* (October 1990): 11-14.

in the concrete will result in cracked tile as well. For additional information, see *Chapter 10, Concrete and masonry*.

If you have a concrete floor with carpet or resilient tile that's glued down, and you want to remove it to install a different type of finish flooring, you may need to use a heavy-duty sanding machine, a commercial floor scrubber with an abrasive pad, or a terrazzo grinding machine. Hand scrapers can work in some situations. Solvents or strippers should only be used with extreme care and never in the presence of a sensitive person.

Summary

While there are many different types of flooring in use today, the most popular—carpeting—is the worst from a health standpoint. Resilient floor coverings, while better than carpet in many respects, can still contaminate the indoor air. Ceramic tile and solid wood both make excellent healthy choices—if they are installed correctly. With ceramic tile, it is best to use mortars and grouts with few chemical additives. With a wood floor, stains and finishes should be chosen with care. Terrazzo and marble are also healthy materials—if a healthy sealer is used—but they tend to be the most expensive floors. For a low-cost healthy floor, bare concrete only requires some preplanning and thought to be both healthy and attractive.

19. Walls and Ceilings

There is more surface area devoted to interior walls and ceilings than anything else in a house. Therefore, walls and ceilings have more *potential* to cause indoor pollution than other components.

If a wall or ceiling is tightly constructed, the materials behind them—inside wall or ceiling cavities—(*e.g.* plumbing lines, electrical wires, and insulation) rarely affect the air inside the living space. In general, plaster or drywall yield smoother, better-sealed surfaces than materials like individual boards or acoustical tiles, which have crevices where dust can collect and infiltration can pass through. Sometimes these "leakier" materials can be used for decoration on top of a well-sealed plaster or drywalled surface.

Preliminary Considerations

Concrete and masonry are both fairly inert structural materials that can hold up a house. Some masonry materials can also be very attractive as the interior finished surface.

Steel framing can be inert for both walls and ceilings, but wood is much more widely used for the structure of a house because builders are familiar with it. Once insulated, wood and steel framing must be covered with an interior finishing material. If this finishing material is tightly constructed, the insulation, and the outdoor pollution sources, can be well-separated from the living space. Ideally, an interior finishing material should be inert, and installed in a gap-free (airtight) manner.

Partition walls (those walls between interior rooms) generally don't need to be tightly constructed. This is because the most offensive material inside a wall cavity is insulation, and partition walls usually aren't insulated. While these walls often do contain plastic plumbing lines and plastic-jacketed electrical wires, these materials aren't nearly as offensive as most of the common insulations. Besides, wires and pipes can be dealt with in other ways, such as purchasing them early in the construction process so they can have plenty of time to air out, or wrapping them with aluminum foil prior to closing up the wall.

Plaster

Plaster is a very old building material, and it's well tolerated by most people. However, as with most older materials, there have been *improvements* over the years that can cause difficulties with sensitive people. Plaster is a gypsum product that is sold in powder form. It is mixed with water on the job, and applied to a wall where it hardens, leaving a very durable surface. Years ago, plaster was applied over wood lath but, more recently, other base materials have been developed. Plastering is a labor-intensive process so it can be fairly expensive. Less-expensive drywall is becoming much more common, so it's difficult in some parts of the country to find workers skilled in the art of plastering. Plaster can be finished to a hard, durable, scrubbable surface that doesn't necessarily require painting. This can be an advantage to sensitive people who are bothered by paint odors.

Base Materials

Thin strips of wood lath are no longer used as a base for applying plaster. The most common base today is a gypsum-board product called gypsum lath. Gypsum lath is easily nailed to wood framing or screwed to steel framing. It is a sandwich of gypsum with paper on both sides, and it can be purchased in different thicknesses and sheet sizes. The gypsum core can contain limestone, glass fibers, perlite, starch, or other additives.

There are several types of gypsum lath for use in different situations. A denser fire-rated material is available where required by certain building codes, and a heat resistant paper is used on sheets in contact with electric radiant-heating cables that are sometimes embedded in ceilings. Gypsum lath is also available with a backing of aluminum foil that acts as a diffusion retarder.

The gypsum core of gypsum lath is chemically treated so it won't absorb too much moisture when wet plaster is applied to it. The paper on the front surface is specially treated so the plaster will bond securely. This facing paper is usually blue in color, hence gypsum lath is often called blueboard. Although drywall sheets are also gypsum products, they do not have a treated face paper, so plaster will not adhere to drywall.

Metal lath is occasionally used in commercial construction but, because of the increased cost of labor and materials, it is almost never used in residences. It is made from sheet metal that has been perforated with small slits and expanded. Several types are available, such as diamond mesh and flat ribbed. Metal lath is either painted or galvanized, and some has a backing of asphalt-impregnated paper. Metal lath is easily applied to steel or wood framing members and generally is well tolerated once covered with plaster.

Plaster can be applied directly to masonry materials such as clay tile, brick, or concrete block—but only if the surface is sufficiently porous to allow proper bonding. A concrete surface must usually be treated with a potentially bothersome bonding agent in order to get the plaster to adhere properly.

Gypsum Plaster

The main ingredient in gypsum plaster is gypsum rock. When the rock is taken from the earth, even though it appears dry, it contains about 20% water. During processing, the gypsum is crushed into a powder and heated to drive off most of the water. When plasterers add water back to the powder, the material rehardens into its original rock-like form. Fillers can include natural sand, manufactured sand (crushed rock, blast furnace slag, *etc*.), perlite, vermiculite, or wood fiber. In the past, things like animal hair or asbestos were used as fillers. So, if you plan to demolish an old plaster wall, you should first determine if asbestos is present, and then take appropriate precautions. Pure gypsum plaster sets very fast and is referred to as plaster of Paris, after the huge plaster deposits underlying that city. Various kinds of plaster (*e.g.* neat plaster, bond plaster, gauging plaster, and finish-coat plaster) are specially formulated to control setting time and provide certain other characteristics.

When limestone is crushed and heated in the same manner as gypsum, quicklime—often simply called lime—is the result. Quicklime must be mixed with water (slaked) and stored for as long as two weeks before it can be used. Hydrated lime is quicklime that has been slaked before packaging. It is a powdered product that, when mixed with water on the job, is referred to as lime putty. It cannot be used as a plaster itself because it is subject to excessive shrinkage when drying and it lacks a hard finish. Hydrated lime is, however, added to gypsum plaster to control the setting time, plasticity, early hardness, strength, and to prevent shrinkage cracks.

Keene's cement is a gypsum plaster with the addition of alum that, in powdered form, has practically all of the water driven off. The resulting material is denser than ordinary gypsum plaster and has greater moisture resistance and hardness. It can be used for surface coats, but is more difficult to work with than other plaster products.

Portland cement may be combined with lime to be used as a plastering material, but it is generally only used where very high moisture conditions exist. It cannot be applied to gypsum lath or to smooth, dense surfaces, but is suitable over metal lath. Portland cement plaster must be kept moist by misting water on the surface during the curing period in order to insure proper hardening. Its cost is generally higher than a comparable gypsum-plaster installation.

Some plastering materials contain polyvinyl or other additives to modify the setting time. These can be subject to outgassing. According to **USG Corp.**, its products only contain plaster of Paris (or Portland cement) and lime. If a filler is used, it is clearly stated on the label. Plaster is generally white, but it can be tinted slightly with a mineral pigment (like concrete or grout) to give it some color if it is to be left unpainted.

Application

The traditional method of applying gypsum plaster involves three coats, but today a two-coat method is often employed. The result is a plastered surface that is between $^1/_2$" and $^5/_8$" thick. With metal lath, the three-coat system must be used. Over gypsum lath, brick or masonry, either the two- or three-coat system is acceptable. The first of the three coats is called the scratch coat because it is scratched after application to provide a rough surface. The second coat, the brown coat, is applied after the scratch coat has hardened. It is leveled and left with a slightly rough surface to accept the third, or finish, coat. In two-coat work, the first coat is called the basecoat. It is applied in a manner similar to a brown coat, and left rough to receive the finish coat. Portland-cement plasters are applied in a similar manner: the three coat method over metal lath; the two coat method over masonry.

A finish coat in either the two- or three-coat system can be applied in several textures ranging from a hard, smooth, steel-troweled surface to a more textured finish. Aggregates such as sand can be added to the finish coat to create a rougher finish. Smoother surfaces are harder, denser, and easier to keep clean.

Veneer plastering systems involve very thin layers of plaster over gypsum lath (blueboard) and they are much more common (and less costly) than the traditional thick method—especially in residential construction. A two-coat veneer system adds less than $^1/_8$" thickness of plaster and yields a durable, abrasion-resistant surface. The first coat, or basecoat, is left slightly rough and is allowed to dry before applying the finish coat. At a lower cost, single-coat veneer plaster is also less than $^1/_8$" thick and not quite as durable.

Paints and wall papers are often problematic for sensitive people. While most plaster walls and ceilings are painted, they can be left unpainted when a hard, steel-troweled finish is used. For the hardest, densest surface, a lime-putty finish coat made of gauging plaster and lime putty is recommended. A minimum amount of water should be used because extra water will render the surface more porous. While this type of surface will be quite hard initially, it can take as long as two years before all the lime carbonizes, and finally yields a rocklike finish.

Plaster and Health

As a rule, plaster walls and ceilings are quite inert but there are several components that can negatively affect sensitive people. For example, although not often used in residential construction, an asphalt-impregnated backing on metal lath could outgas asphalt odors, and metal lath can be coated with a residual oil film from the manufacturing process. The paper on gypsum lath can bother some sensitive persons as can some of the minor additives in the gypsum core. Most additives are usually minerals, such as lime, that are bound up in the plaster itself and, because plaster is so hard and dense, it usually prevents any of the slightly bothersome materials from outgassing into the living space. So, in most cases, most sensitive people tolerate plastered walls and ceilings very well—either when finished with the traditional thicker methods or the newer, thinner veneer techniques. However, a few sensitive people have reported that fresh plaster has a natural, but bothersome, odor for as long as 4-6 weeks after application.

Drywall

Drywall was developed after World War II as a less-expensive wall treatment than conventional "wet" plastering. Drywall sheets are gypsum/paper sandwiches that are similar, but different, from gypsum lath. They can be either nailed or screwed to wood or steel framing members. The joints between the sheets, and other imperfections, are filled, smoothed, and finished with a specially formulated joint compound.

With sensitive persons, negative health effects are more likely to occur with drywall than with plaster because of the surface paper used on drywall sheets, the more-odorous joint compound, and the fact that drywall requires painting. However, there are ways to minimize outgassing considerably.

Drywall Sheets

Generally, the gypsum core is similar in both drywall and blueboard. The chief difference has to do with the surface paper. In drywall it's a lower-quality paper made from recycled newspapers, old telephone books, *etc*. Because sensitive people often react to newspaper and printing ink,[930] they can react to the paper on drywall if they are exposed to it directly. One source, in 1976, found PCBs present in the paper and assumed they were either added as fire retardants or were contaminants in the recycled

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[930] Natalie Golos, Frances Golos Golbitz and Frances Spatz Leighton, *Coping With Your Allergies* (New York: Simon and Schuster, 1979): 47.

newspaper.[931] It's doubtful if there are any PCBs in drywall produced today. Actually, outgassing from the paper facing is a minor source of emissions. Still, with several thousand square feet in a house, it can be a problem for some people.

Drywall is sold in four-foot widths and in various lengths and thicknesses. Like gypsum lath, it can be purchased (usually by special order) with an aluminum-foil backing that acts as a diffusion retarder. There is a moisture-resistant drywall product—often used in bathrooms—that contains a certain amount of asphalt to enhance its moisture resistance. The standard, general purpose drywall is better tolerated because it contains no asphalt. Denser, fire-rated drywall sheets are also available.

Moisture-resistant drywall not only contains a modified core, but the paper is chemically treated to combat water penetration. It is easily recognized because the paper facing is green in color instead of the usual light gray. Ceramic tile can be attached to moisture-resistant drywall—but not to standard drywall, which will tend to fall apart. However, ceramic tile will be longer lasting and more durable if installed on surfaces other than drywall.

Being relatively soft and absorbent, all gypsum-board products are scavengers, that is they act like sponges, absorbing odors. These odors can then be released back into the air later. This can sometimes be a source of outgassing for sensitive people. For example, sheets of drywall stored near a propane-powered fork lift or a gasoline pump can absorb those smells. Similarly, a stack of drywall sheets on a delivery truck can absorb exhaust gases while being transported. Sensitive people can also be bothered by drywall that has been stored where people smoke.[932] When the sheets are attached to the walls of a house, the various odors will then be released slowly into the indoor air. Usually, this type of contamination only seriously affects the uppermost sheet in a stack. The solution is simple—discard the top sheet after the material is delivered to your job site, or use it outside the living space, perhaps in the garage.

Even once installed and painted, if there are a lot of odors in a room (say, from new synthetic wall-to-wall carpet), drywall can absorb them and then release the odors slowly, when the concentration in the air is lower.

There do not appear to be any significant differences between the products made by the major national drywall manufacturers: **USG Corp.**, **Gold Bond Building Products**, and **Georgia-Pacific Corp.**

Joint Compound

The joint compounds used to finish the seams and nail holes in drywall are more bothersome to sensitive people than the sheets of drywall themselves.[933] While composed mostly of gypsum, joint compound can also contain other minerals such as mica, talc, limestone, and clay. Adhesives are added so the material will stick to the drywall, and

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931 F. Silver, "The Wallboard, Flexible Plastic, and Polyester Problem," (Dallas, TX: *Presentation to the 10th Advanced Seminar in Clinical Ecology*, December 7, 1976).

932 "Clean Gypsum Board," *Solplan Review* (June-July 1991): 9.

933 Mary Oetzel, "New Wall Treatment," *The Human Ecologist* #29 (Summer 1985): 20.

preservatives are used to prevent mold or bacterial growth while wet. Some compounds also contain a small amount of antifreeze. Joint compound is sold ready-mixed in buckets, or in powder form to be mixed with water on the job. A variety of similar products are sold for texturing ceilings. These sometimes contain an aggregate such as perlite or polystyrene to enhance the texture.

Today, the adhesives in joint compounds are usually vinyl products, such as polyvinyl alcohol and polyvinyl acetate. Polyvinyl acetate is usually well tolerated by sensitive people, because it is the same basic material used in Elmer's glue, which is also well tolerated. The preservatives and antifreeze compounds can, however, outgas into the air. A variety of chemicals have been used over the years as preservatives—such as mercury compounds which can outgas toxic mercury vapor. Years ago, casein, which is derived from milk, was commonly used as an adhesive in joint compound, but its use has been discontinued by the major manufacturers because of a limited shelf life once mixed with water. Casein was highly susceptible to mold growth until thoroughly dry, so very toxic preservatives were often added to extend the shelf life. Today, vinyl adhesives are widely used but, because of the other additives, none of the nationally distributed joint compounds is particularly tolerable for sensitive persons.

Asbestos, once a common ingredient in joint compound, was banned in 1977 by the **CPSC**.[934] Many drywall products made prior to this ban did contain asbestos—some contained as much as 15%.[935] So, there is a good chance that drywall joint compounds used in houses built prior to 1977 contain asbestos. If such materials are loose and flaking, or if they are sanded by the homeowner, they can release asbestos fibers into the air. While a solid, intact surface will not release any fibers— you should take appropriate precautions if walls are deteriorating, or if you are planning to do any remodeling or demolition. See *Chapter 25, An in-depth evaluation of six common pollutants* for additional information about asbestos.

Even though drywall compounds no longer contain asbestos, many contain silica and/or kaolin, both of which can cause permanent lung damage if enough is inhaled over time.[936] This is primarily a concern to drywall finishers who are exposed to a great deal of airborne dust during the sanding and finishing process. If a house is occupied while drywall is being sanded, care should be taken to prevent the dust from traveling throughout the house, and workers should always wear proper respiratory protection. Once the drywall is painted, dust is no longer a concern. To avoid sanding, some drywall finishers use a damp sponge to smooth out any irregularities.

There is a joint compound available from a Texas company that is very well tolerated by sensitive people.[937] The M-100 Hi-PO Compound is a powdered material that is mixed with water on the job. When first mixed with water, this product can be

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[934] CPSC, *Asbestos in the Home*.

[935] Alf Fischbein and others, "Drywall Construction and Asbestos Exposure," *American Industrial Hygiene Association Journal* 40 (May 1979): 402-407.

[936] "Drywall dust may be hazardous—still," *Journal of Light Construction* (October 1998): 20.

[937] "A Healthier Joint Compound," *Safe Home Digest* (January 1991): 6.

lumpy, but if it's allowed to set for a while, then is remixed, the lumps will dissolve. Because it contains no biocides or antifreeze, it should not be stored for an extended length of time after water has been added. According to the manufacturer, **Murco Wall Products, Inc.**, it contains "no mildewcides, preservatives, asbestos, formaldehyde or hydrocarbon solvents." Small samples for testing are available at a nominal cost. Because of the weight, quantities are usually shipped by truck. While shipping charges can be seem high (typically $100-200 for enough material to do an entire house) this does not increase the total cost of a house appreciably. This product can be used for both finishing drywall joints and for texturing ceilings. Although not a significant disadvantage, it does have one drawback—it cannot be coated with an alcohol-based primer, because the alcohol and the joint compound will react together and the compound will deteriorate.

Painting

Unlike hard, steel-troweled plaster, drywall must be painted to protect it from daily wear and tear. Because the facing paper, which is made from recycled newsprint, is a potential problem for sensitive people, a paint should be chosen that will seal the paper well. Fortunately, because the paper facing does not outgas significantly, most paints do a reasonably good job of sealing the surface.

As mentioned earlier, if you are chemically sensitive, you should test a paint, the joint compound, and the drywall in combination—because that is how you will be exposed to walls once they are ready for occupancy. One of the best ways to do this is to start with a good-sized piece of drywall—about 2' x 4'. Cover about one-third of the sheet with a thin layer of joint compound, let it dry, then apply two coats of paint to each side of the sheet. Once dry, write the date on the panel, along with the specific materials used, then set it aside until it seems to have lost its odor. When the panel seems odor-free, set it next to your bed and see if it has a negative effect on your sleep. If it's bothersome, set it aside for another week or two, then bring it back into your bedroom and test again. Once it's tolerable, make a note of the date, so you know how much time it took for the combination to become safe. It's important to know how long the process takes if you are going to need to stay away from your home until everything has cured.

For very sensitive people, testing should always be done under the supervision of a physician. Keep in mind that testing paints takes time, so it should be done early in the planning process. If a tolerable paint/drywall/joint compound cannot be found, then you will still have time to schedule a plastering job.

Wall Paneling

Today, when most people think of wall paneling, thin 4' x 8' sheets usually come to mind. These sheets are made with particle board, plywood, or hardboard and they have a decorative face of wood veneer, vinyl, paper, or a printed surface. Most of these materials are formaldehyde emitters and they are not recommended in healthy houses. The products made of hardboard contain the least formaldehyde, but all are usually bothersome to sensitive people. Outgassing can also be coming from the decorative surface, or from adhesives used to attach the sheets to the wall.

There are predecorated gypsum panels made with attractive facings that can also be used on walls. These do not require any joint compound because the joints are neatly beveled and can be left exposed. The facing material on the exposed surface is typically a vinyl film of some type. These panels are often embossed and scuff resistant, but the vinyl is subject to outgassing, so they are not recommended for sensitive people. However, because outgassing decreases with time, older panels may be tolerable.

In order to avoid the outgassing of manufactured paneling products, solid-wood paneling can be used. However, solid-wood tongue-and-groove wall paneling can be quite expensive. Actually, in some cases, a lesser grade of solid-wood paneling—perhaps poplar, or a #2 grade of oak—can be less costly than top-of-the-line walnut-veneered paneling. In order to have the beauty of solid wood, at a more affordable cost, you might consider using solid wood as an accent material, perhaps only on one wall—or on a ceiling. Wall accents include wainscoting or a simple horizontal chair rail. Solid-wood paneling can usually be prefinished outdoors (on both sides, if necessary) and allowed to air out before it's brought indoors and installed, thus avoiding occupant exposure to the finishing materials.

If paneling is to be used on an exterior, insulated wall or ceiling, it is difficult to make the joints airtight. The best solution is to make the structure airtight with another material first—usually well-sealed drywall—then attach the paneling to the airtight surface.

Ceramic Tile

Ceramic tile, slate, and marble can be attached to walls by methods similar to those discussed in the last chapter for floors. Concrete or masonry walls can be easily covered with tile by using a thin-set mortar, a modified latex-Portland-cement mortar, or the thick-bed method. In damp areas such as showers, manufacturers usually recommend a cementitious board for a base if a traditional thick bed is not used. Water-resistant drywall can also be used for a base, but it isn't as long-lasting. While water-resistant drywall might be suitable for a dry area, it should never be used as a backing for ceramic tile in a bathtub or shower—it simply won't hold up as long as a cementitious board.[938]

In most cases, a ceramic-tile surface is dense and tight enough that outgassing from the base materials isn't a problem. However, sensitive people are urged to test materials ahead of time—preferably in a combination similar to the proposed installation.

Coarse sanded grouts are usually not used on wall installations. Unsanded commercially prepared wall grouts that require damp curing are usually quite inert, or you can use a home-made Portland-cement-and-water mixture. After filling the joints, these grouts will need to be kept damp to allow it to cure slowly. This can be done by covering the wall with Kraft paper and misting or sponging periodically. Grout on walls is more difficult to keep damp for curing than floors,[939] but it typically doesn't need to be as hard or durable because it isn't subject to foot traffic.

When using ceramic tile in a shower or bathtub, the corner joints, and the joint at

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[938] Michael Byrne, "Durable Substrates for Thinset Tile," *Journal of Light Construction* (August 1996): 40-45.

[939] E.W. Carles and L.G. Wines, *The Art of Tilesetting* (Peoria, IL: Charles Bennett Co., 1954): 114-117.

the bottom of the tile (where it meets the tub), are usually not grouted because they're prone to cracking. They are best sealed with a more flexible caulking. If grout is used in these locations, it *will* eventually crack and quickly become a breeding place for mold.

Wall Coverings

At one time, all wall coverings were made of paper but, today, fabric and plastic coverings are also available. All these materials can be bothersome to a sensitive person, as can binders, inks, paints, dyes, fungicides, pesticides, or the adhesive used to attach them to the wall. If very much wall covering is used, the home becomes "an insecticide-and-fungicide-lined box." [940] Not a very healthful thought. Vinyl wall coverings contain plasticizers to make them flexible. The plasticizers are similar to those used in vinyl flooring, and they can outgas resulting in health problems. In fact, a Finnish study found that there was more persistent wheezing, asthma, and pneumonia in young children when there was vinyl wall covering in the home.[941] For additional discussion, see vinyl flooring in *Chapter 18 Flooring*.

When coverings are attached to new walls, manufacturers often recommended that the walls be painted with an odorous and bothersome alkyd paint to facilitate removal of the covering if remodeling is done in the future. Fabric coverings are often treated with flame retardants.

Many wall coverings are prepasted, either with a glue, that must be moistened, or an adhesive with a peel-off backing. Other coverings require a paste that is either ready-mixed or mixed on the job with water. All water-based pastes and glues are subject to mold growth or insect attack, so they usually have potentially unhealthy mold retarders or insecticides added. In the past, arsenic compounds were used but, today, most are synthetic concoctions. Without the additives, there is the potential for mold growth behind the covering, and it can eventually attack the covering itself. Mold or mildew are often found when removing old wallpaper. The self-stick adhesives with peel-off backings, are usually not subject to fungus attack, but they may not be tolerated by sensitive people. Synthetic adhesives can outgas through porous coverings such as paper or fabric.

A wheat-flour-and-water mixture that is made from scratch can be made mold resistant by adding a about tablespoon of boric acid (from the drug store) to a quart of paste. **Roman Adhesives** makes several types of wallpaper paste, including a simple Wheat Wallpaper Paste that doesn't contain a mildewcide. It can only be used with wall coverings that are porous and will allow the paste to dry quickly.

To remove old wall paper, there is a product called DIF (**Wm. Zinsser & Co.**) that is a unique enzyme-based stripper. It can be applied with a garden sprayer or a sponge and is formulated to break down the wallpaper glue to make scraping easier. It is relatively non-toxic and low-odor and cleans up with water.

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940 Zamm, *Why Your House*, 58.

941 J.J. Jaakkola, P.K. Verkasalo, and N. Jaakkola, "Plastic wall materials in the home and respiratory health in young children," *American Journal of Public Health* (May 2000): 797-799.

In general, because of their outgassing potential, wall coverings are not recommended in healthy houses. However, some sensitive persons have had good luck rolling out a covering in a little-used room or garage and allowing it to outgas there for a few weeks before bringing it indoors. Another way of reducing your exposure is to use less material. For example, instead of covering all the walls in a room, just use the wall covering on the lower third of the wall, and cap it with a chair rail. Or, just use a narrow border around the top of a room, or a border around doors and windows.

Metal Panels

Reproductions of embossed metal ceilings are being manufactured to resemble those used in the 1900s. These can be used on both walls and ceilings for a striking accent effect, and they are available in a very wide range of styles. They are attached by tacking the individual tiles of embossed metal to wood furring strips. Manufacturers include **Chicago Metallic Corp.**, **Pinecrest**, **Shanker Industries, Inc.**, and **W.F. Norman Corp**. A drawback to these products is the fact that many of them must be either painted or coated with a clear finish. Water-based finishes are not suitable because they can cause rusting of the metal. More odorous oil-based paints or lacquers are recommended by the manufacturers. If they are prefinished before installation, they can be placed in a garage, or somewhere else outside the living space, until the outgassing is complete, then installed. The brass and copper-plated panels made by **Shanker Industries, Inc.** have a baked-on epoxy coating that should have minimal outgassing. **Pinecrest** offers ceiling tiles that are either unfinished steel, chrome plated steel, tin-plated steel, or copper- or brass-plated with a baked-epoxy finish. They also have a few stainless-steel patterns. **Chicago Metallic Corp.** has Traditions all-metal ceilings in either a nail-up style, or a style that sets in a suspended ceiling. Some of the styles from **W.F. Norman Corp**. and **Shanker Industries, Inc.** are also designed to fit into a suspended ceiling.

Contemporary pre-finished metal-strip ceilings are also available, but their use is generally confined to commercial buildings because of cost. They can, however, be used in homes on walls or ceilings, and they are available in a variety of colors on an aluminum base. Installed by attaching the strips to special metal tracks, they can be used over most types of surfaces. Manufacturers include **ATAS International, Inc.** and **Chicago Metallic Corp.** In addition, **Chicago Metallic Corp.** has a Planostile suspended ceiling system that uses all-metal tiles.

These materials cannot be installed in an airtight manner. So, if they are to be used over an insulated exterior wall or ceiling, the wall or ceiling should be made airtight first (usually with well-sealed drywall) then the metal tiles or panels can be installed.

Porcelain Panels

Porcelainized panels are very inert as a wall and ceiling covering material, but they are also quite expensive. However, for small areas—such as a shower or tub surround in a bathroom—they can be a good alternative to ceramic tile. Porcelain panels are made of either steel or aluminum and they have a glass-like porcelain coating fused to the surface.

Many sinks, ovens, and bathtubs have porcelain coatings, and some outdoor barbecue grilles are made of porcelainized steel. There are several different methods of attaching flat porcelain panels to the structure of a building, and the details and panel sizes need to be worked out well in advance, because once the panels are fabricated, they cannot be trimmed to fit.

Because of the cost and advanced planning required, porcelain panels are seldom used in residential construction. They are, however, used in commercial installations. Someone interested in this material should remember that, for residential applications, the panels will probably need to be custom made. This is not only costly, but it takes extra time that effects construction scheduling. For information about having porcelain panels made, contact the **Porcelain Enamel Institute** for a list of manufacturers. For the designer, standard construction details can be found in a book titled *Basic Building Data*.[942]

Acoustical Tiles

Acoustical-tile ceilings are popular with do-it-yourselfers because they can be installed easily and inexpensively. Suspended ceilings consist of individual panels up to two feet by four feet, laid into a metal track system that is suspended from the structure. They are often called drop-in panels. The panels themselves can be a source of symptoms in some people. They are made of mineral fiber, wood fiber, fiberglass, metal, or other materials. Some older products should be handled with care because they might contain asbestos.

Ceiling panels made of fiberglass tend to release some formaldehyde into the air. Plastic, latex, fabric, or vinyl surface finishes also have their own outgassing characteristics. Many acoustical tiles are very absorbent, so they can absorb outgassing from other sources, then release it later. The small individual acoustical tiles, generally one-foot square, are made of similar materials to the larger drop-in panels. They are attached to wood or metal furring strips with staples, clips, or an odorous glue.

The basic manufacturing process used in producing mineral and wood-fiber tiles is similar to paper making and can be contaminated with a variety of materials. It's been reported that 1-2% of the tiles produced by Armstrong World Industries between 1969 and 1970 contained PCBs.[943] At that time, the dangers of PCBs were not fully known. These particular tiles were used primarily in commercial buildings and it's unlikely they would be found in homes.

One of the problems with acoustical tiles has to do with how they are installed. They almost always have an airspace above them that isn't airtight. The airspace may be less than an inch thick or, in the case of a dropped ceiling, several feet thick. In commercial buildings and offices, ventilation air may run through this space, along with plumbing lines, electrical conduit, telephone lines, *etc*. Because the airspace isn't airtight, it often becomes contaminated. If the space is used to transport ventilation air, the air you

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942 Graf, *Basic Building Data*, 565-580.

943 J. Fagliano and others, "PCB Contamination of Ceiling Tiles in Public Buildings—New Jersey," *JAMA* 257 (March 13, 1987): 1297.

are breathing can also become contaminated. One report found that sick building syndrome was more likely when the air contained man-made mineral fibers from ceiling tiles, insulation, and ventilation systems.[944]

A series of studies at Cornell University found that there was a significant link between complaints of sick-building syndrome (*e.g*. sneezing, congestion, throat irritation) and the presence of dust from man-made mineral fibers shed by acoustical ceiling tiles.[945] These tiles are prone to shedding small amounts of dust, especially when they are taken in and out to maintain hidden pipes and wiring.[946]

If the relative humidity is high enough (usually above 85%), most acoustical tiles, even new ones, can support fungal growth.[947] This is especially a problem if the tiles get wet because of a roof or plumbing leak. When most acoustical ceiling tiles are manufactured, a certain amount of butyric acid is bound up in the tiles. Butyric acid has a distinctive vomit-like odor and some people can detect it on some new tiles. While the amount of butyric acid varies considerably between batches of tiles, the odor can be dormant—as long as the tiles are dry. But if they get wet, the vomit-like odor can be quite strong. **Chicago Metallic Corp.** has a Eurostone acoustical tile line in several patterns that is made from perlite, ceramic clay and inorganic binders. It is unaffected by moisture and is impervious to microorganisms, so it will not support bacterial or fungal growth.

Soundproofing

Acoustical tiles are often used to deaden noise and sounds *within* a room. However, the characteristics that make them good for soundproofing (*e.g*. porosity, light weight) also make them prone to shedding fibers and dust into the air (see above). The "egg carton" foam soundproofing materials used in recording studios (one manufacturer is **Illbruck, Inc.**) are not prone to shedding, but they can look out-of-place in residential applications, and they can bother some sensitive people. Carpets, drapes, and soft furnishings can also absorb sounds within a room.[948]

Preventing sound transmission *between* rooms can be quite involved. In recording

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944 *Sick Building Syndrome Linked to Mineral Fibers and Job Stress, Not Smoking or Air Quality, Cornell Studies Suggest* (Press Release, Cornell University, November 10, 1993).

945 Alan Hedge, William Erickson, and Gail Rubin, "Effects of man-made mineral fibers in settled dust on sick building syndrome in air-conditioned offices" (Helsinki: *Proceedings of the 6th International Conference on Indoor Air Quality & Climate, Vol. 1, Health Effects*, 1993): 291-296.

946 Jim Beck, "Man-Made Minerals Could be Key to SBS," *Indoor Air Review* (January 1994): 4.

947 John Chang and others, "Growth of Fungi *(Penicillium* and *Aspergillus ssp.)* on Ceiling Tiles," *Atmospheric Environment* 29 (1995): 2331-2337.

948 A.C.C. Warnock, *The soundproof basement*, (Ottawa, ON, Canada: National Research Council of Canada, December 1981). Building Practice Note #25.

studios, walls, floors, and ceilings might be filled with sand, or constructed so they float and are not connected to adjoining rooms. This is only feasible in residential construction in special situations. Sometimes sound is transmitted between rooms through ductwork.[949] This is particularly important when there is a relatively short duct run between a quiet room and a noisy room, and it can be minimized by separating the points where the individual ducts depart from the main trunk line.

In houses, there are three approaches to reducing sound transmission between rooms. While each recommendation will help, the best results involve all three.[950] First of all, you can fill a wall or ceiling cavity with insulation to absorb sound that passes through the cavity. Secondly, you can add an extra layer of drywall. This adds mass to the structure that permits less sound to pass through. Thirdly, you can mount *resilient channels* between the drywall and the framing, to minimize the amount of solid contact between the materials. Resilient channels are made of galvanized sheet metal folded into a Z shape. They are available from most drywall suppliers or from steel-framing manufacturers. Concrete or masonry walls often transmit less sound than framed walls because of their mass.[951]

If insulation is used inside a partition wall between rooms, or in a floor system between rooms, it's generally good idea to make the assembly airtight to prevent fibers or outgassing from entering the living space.

Solid doors block sound better than hollow doors, and both are more effective if weather-stripped. In either case, a double door will block even more sound transmission.[952]

There are a number of things you can do when designing a house to minimize sound transmission. For example, keep the quiet areas (bedrooms) separate from the noisy living areas. While open floor plans have advantages, they can result in competing noisy areas in the same room—a piano, stereo, and TV in the same room will conflict with each other. Acoustically, it's better to have them in separate rooms if they will be used simultaneously.[953] If you are bothered by the hum of the refrigerator, consider placing it in a pantry.[954]

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[949] Jerry Germer, "Details for damping household noise," *Journal of Light Construction* (October 1999): 27-28.

[950] *Sound Advice For Improving Your Home Sales*, (Valley Forge, PA: Certainteed Corp., 1992). Publication #30-21-1035.

[951] A.C.C. Warnock, *How to reduce noise transmission between homes (apartments)*, (Ottawa, ON, Canada: National Research Council of Canada, July 1983). Building Practice Note #44.

[952] Jerry Germer, "Retrofit sound Control, "*Journal of Light Construction* (July 1991): 24-28.

[953] Gordon Tully, "Sound planning for a quiet house," *Journal of Light Construction* (May 1991): 6-7.

[954] Paula Jhung, "Cutting down on kitchen clamor," *Home* (September 1991): 30-32.

Sprayed-on Ceilings

Plaster and drywall ceilings are sometimes coated with a textured product.[955] These coatings are often sprayed-in-place and they consist of a material similar in composition to joint compound and/or paint. Sometimes latex paint is added for color. The actual texturing material might consist of perlite or vermiculite, but older ceilings can contain asbestos. These ceilings can deteriorate and introduce fibers or dust into the air if they are abraded but, being ceilings, they are generally undisturbed. Asbestos would be the biggest concern. If an asbestos-containing ceiling isn't deteriorating, it probably won't be shedding any fibers, so you may decide to do nothing about it. If it's deteriorating, and shedding fibers, you can remove it (expensive), cover it with a well-sealed layer of drywall, or coat it with a sealant (encapsulatant) to stabilize it and prevent further deterioration. See *Chapter 25, An in-depth evaluation of six common pollutants* for more information about asbestos.

Summary

Plaster walls and ceilings are usually quite inert. However, in most cases, painted drywall can also be healthy—if a low-tox joint finishing compound and paint are used. Solid-wood or metal wall-covering materials can also be healthy choices, but they must be installed over an airtight surface to prevent insulation from entering the living space, and to keep moisture from migrating into the building cavities. Ceramic tile and porcelain panels make for healthy walls, but their high cost generally limits them to specialized areas like kitchens or baths. Most fabric, paper, and vinyl wall coverings, and acoustical ceiling materials, make relatively poor choices by comparison.

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[955] Duffy Gallagher, "Shooting Textured Ceilings," *Journal of Light Construction* (October 1989): 39-40.

20. Coatings, Caulking, Adhesives, and Strippers

This chapter covers a variety of products that all have one thing in common—they are applied wet, when the outgassing rate will be high then, as they dry, the outgassing rate diminishes. Because some of these materials take a considerable amount of time to outgas completely, sensitive people should test them for tolerability early in the construction process—preferably during the planning stages, before any work is begun.

Painting your house can improve its appearance. Paint can also make you sick. So can clear finishes, caulking, adhesives, and paint removers. Symptoms such as dizziness may appear immediately—during the actual application of these products—then subside as the odor diminishes. On the other hand, some symptoms, such as mental retardation, may not manifest themselves until after older products, such as those containing lead, have begun to deteriorate. Outgassing from all these materials has been shown to cause a wide variety of symptoms in susceptible individuals. The effects cover the entire range of physical and mental diseases.[956]

In all, there are about 15,000 chemicals that can be used to manufacture paints.[957] The amount of time it takes these ingredients to outgas varies considerable, as do their health effects. The initial outgassing might take place in a few hours or a few days, but some compounds can be absorbed into the material being painted, and be slowly released over a much longer period. In fact, long-term emissions often depend on the absorbency of the base material or substrate.

There are actually quite a few less-hazardous products on the market today. However, because none of them can actually be ingested, they can't be considered truly non-toxic. Therefore, they are often referred to as being less-toxic or low-tox rather than non-toxic. They are clearly better environmental choices, but they still aren't perfect, so some precautions are generally in order.

It isn't unusual for someone to ask "What's the healthiest paint for my painter to use? He's coming this afternoon." If you wait until the last minute to select a healthy product, your choices will be severely limited. Some of the healthy materials mentioned in this chapter must be ordered through the mail, and sensitive people should always test them for personal tolerance, so preplanning is vital.

General Suggestions

There are some basic rules that should be followed when using any of the products discussed in this chapter. First of all, select the right material for the job. For example, don't use an exterior paint indoors, or an interior caulking outdoors. Follow label directions carefully, apply the correct amount of material, and do not apply a second coat until the first has cured.

Surface preparation is always of prime importance, especially with water-based products. If a surface is deteriorating, remove the old loose material before recaulking or

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956 Randolph, *An Alternative Approach*, 89.

957 Michael Bender, "Paint," *Green Alternatives* (October/November 1993): 36.

repainting. If an old paint contains lead, be extremely careful to not create a more-hazardous situation by stirring up lead dust. If a surface, on a kitchen wall for example, has a thin layer of grease on it, an adhesive, paint, or caulking may not stick well. The grease can be removed by washing with a tri-sodium phosphate (TSP) solution, then rinsing. TSP is often tolerated by chemically sensitive people but, being a skin irritant, rubber gloves are recommended. It is typically sold in hardware stores.

Basic Health and Safety

There are a variety of steps that can be taken to protect your health, and that of your family. First of all, if finishes, caulking, adhesives, or strippers are to be used indoors, always have plenty of ventilation. Open windows, and use a powerful window fan to exhaust any odor. Painting can also be done on a room-by-room basis with window exhaust fans used to keep odors from traveling throughout the house. The heating or air conditioning seasons—when windows are typically closed for energy conservation—are not good seasons for doing this type of work. Seasons with excessively high humidity can result in water-based finishes drying slowly—and possibly resulting in mold growth.

If you are using a flammable product indoors, ventilation is extremely important,[958] and a window fan might need an explosion-proof motor to prevent a spark from igniting the solvent. Wear a respirator rated for organic solvents when using materials with a high solvent content, or when adequate ventilation is not possible. Spray painting can be more hazardous than brush or roller application because fine paint mists can be inhaled deeply into the lungs. Many health-conscious people wear respiratory protection when using any odorous product—even the healthier alternative ones.

Protect your skin by wearing long-sleeved clothing. A wide-brimmed hat will help protect your face and hair when working overhead—and be sure to put on protective eye wear. Take special care to cover any exposed wounds. Rubber gloves can protect your hands from spills and splatters while working, or from excessive exposure when cleaning up. This is important because many solvents can be absorbed into the body directly through the skin.

Some preservatives are toxic to fish, and they can render conventional sewage treatment processes ineffective. Therefore, waste materials should never be poured down a drain. Even water-based latex paint is considered household hazardous waste, so it needs to be disposed of in accordance with environmental regulations. Check with your municipal sanitation department or sewage-disposal facility for a drop-off site. Better yet, give away any products you don't need to someone who can use them.

Precautions for the Chemically Sensitive

All of the products discussed in this chapter have the potential to bother sensitive people. So, individual testing is highly recommended. Paints and clear finishes are especially problematic because, on a typical project, they cover hundreds or even thousands of square feet. In many cases, it's a good idea for a paint-sensitive individual to leave the house while the painting is actually being done, and perhaps for several days afterward, to allow the outgassing rate to diminish. Painting can often be done while the

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[958] Don Best, "Using Floor Finishes Safely," *Practical Homeowner* (February 1988): 84-86.

occupants are on vacation. Careful testing ahead of time should help you determine the best product, and the amount of time you will need to be absent.

A caulking project uses considerably less material than a typical painting job, so caulking generally isn't as problematic as paint. Adhesives are usually covered up with some other material, so they aren't exposed directly to the air in the living space. But these products can still affect indoor air quality, especially during application, so they should also be chosen with care.

Products to be used outdoors typically do not need to be selected with the same care as those used indoors. This is because, outdoors, most of the outgassed chemicals tend to dissipate into the atmosphere. However, when a lot of material is used—such as when painting the entire exterior of a house—odors can enter the living space through open windows, ventilation systems, or cracks and gaps in the structure.

There are a few extremely sensitive individuals who have tested a variety of alternative products and still can't locate a tolerable one. Some have found it possible to simply wash the walls of their house instead of repainting them. In new construction, you can avoid painting the interior by having plaster walls.

Some sensitive people have tried to get by with *unfinished* wood flooring, cabinetry, or furniture, but there are drawbacks to doing this. A paint or clear finish can often minimize a bothersome woody odor, and it can reduce the chance of cracking or loose joints due to seasonal humidity changes. A finish also protects wood from absorbing excess dirt or moisture from spills or routine cleaning, which can lead to microbial growth.

While many builders routinely use adhesives in a variety of applications, some (*e.g.* construction adhesives) were unheard of just a few decades ago. So, if a tolerable adhesive can't be found, it may be possible to simply not use one. Caulking, on the other hand, is generally necessary—at least in some locations. But, because so little is exposed to the living space, it's usually possible to locate a reasonably healthy product to use.

Ingredients

Over the years, paints have been manufactured with everything from lead to milk, from formaldehyde to clay. Primarily, a paint is made up of three components: a binder, a pigment, and a vehicle. The binder is the glue that holds all the ingredients together. The pigment provides color or hiding ability, and the vehicle (or solvent) is the what makes a paint liquid, what everything else is dissolved in. The vehicle either evaporates or oxidizes into a dried film. Clear finishes have no pigment, only a binder and solvent, while stains are composed mainly of pigments and vehicles. Adhesives and caulking contain a higher percentage of binder than paints.

Binders

In the past, casein—a milk derivative—was widely used as a binder. However, it was very susceptible to mold and bacterial attack, so it was often combined with very toxic fungicides. There is a low-tox milk paint still being made with casein. It is sold in powdered form without fungicides. Another natural binder—egg yolk—is used by some artists in home-made tempera paints. A few specialty manufacturers use a natural-latex resin but, for the vast majority of products today, synthetic resins are used as binders.

They include vinyls, alkyds, epoxies, phenolics, polyamids, silicones, and polyurethanes. All can bother sensitive people to some degree.

Vehicles

Today water is a popular vehicle in residential paints, finishes, caulkings, and adhesives, but linseed oil (derived from flax plants), soy bean oil, tung oil, mineral spirits, lacquer thinner, turpentine, toluene, alcohol, *etc*. are also in use. Health effects vary considerably. In general, water-based products are the least polluting—but they are not totally without risk. One study found high emissions of alkanes from some water-based adhesives.[959]

Solvent-based paints and finishes contain as much as 60% volatile organic compounds (VOCs). Most water-based formulas typically contain less than 10%, so they are considered low-VOC finishes. A few manufacturers are now offering zero-VOC products. California became the first state to regulate the VOC content of coatings in 1987. Other laws were soon passed in New Jersey, Dallas, Phoenix, and New York. Prior to these regulations being promulgated, the major paint manufacturers were opposed to any restrictions on the VOC content of paints and coatings. Now, they are actively lobbying for a federal law because each of the current regulations is slightly different. This means they must have different formulations for different parts of the country. The paint manufacturers now feel that a uniform federal law would simplify their labeling and warehousing requirements.[960]

When paints or finishes are applied inside a house, high levels of VOCs can have a negative effect on both painters and homeowners. Studies have found that painters are more likely to become alcoholics than other tradesmen,[961] presumably because of their regular exposure to solvents. Furthermore, a 1989 study found that painters had a significant increase in overall mortality, mortality from cancer, and incidence of cancer, when compared to electricians.[962]

A 1991 issue of the *American Journal of Industrial Medicine* contained an article that found the risk of accidental slips, trips, and falls was related to the solvents that painters were exposed to. The report noted that some solvents, and their metabolites, can

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959 J.R. Girman, A.T. Hodgson and A.S. Newton, "Emissions of Volatile Organic Compounds From Adhesives with Indoor Applications," *Environment International* 12 (1986): 317-321.

960 John Bower, "Perils of paint," *Custom Builder* (July 1991): 38-40.

961 Ingvar Lundberg and others, "Diagnosis of alcohol abuse and other neuropsychiatric disorders among house painters compared with house carpenters," *British Journal of Industrial Medicine* 45 (1992): 409-415.

962 E. Guberan and others, "Disability, mortality, and incidence of cancer among Geneva painters and electricians: a historical prospective study," *British Journal of Industrial Medicine* 46 (1989): 16-23.

take days or weeks to leave the body.[963] Other medical journals have found that respiratory illness in painters is also related to solvent exposure.[964] [965] In addition, neurological and psychiatric disorders in painters have been related to solvent exposure.[966] [967] A 1990 article warns that "solvents may cause nervous system dysfunction at lower levels than previously suspected." [968]

While painters are exposed to more solvents over the years than homeowners, it's important to remember that painters are generally healthy adult males. But healthy adult males aren't without risk. After painting an unventilated bathroom with a polyurethane gloss paint, one healthy 60-year-old male remained in an acute confusional state for three days, then bone-marrow suppression and liver-cell damage was noted.[969] Infants, children, pregnant women, and the elderly—individuals who are often indoors during the painting process—are at even greater risk. Moreover, a homebound person can be exposed to the smell of a freshly applied finish for 24 hours a day, whereas a painter might only be exposed for 8 hours. An article titled "Who Should Paint the Nursery?" in an issue of *Reproductive Toxicology* concluded that, while the risks weren't crystal clear, "counseling on paint exposure during pregnancy should be designed to minimize exposure to paint." [970]In other words, a pregnant woman shouldn't paint the nursery for the new baby, and the residual paint odor isn't good for the baby after it's born.

Even though some VOCs are much more toxic than others, it's a good idea to reduce your exposure to them whenever possible. With some VOCs being carcinogenic, some mutagenic, and others causing birth defects, they simply aren't good to breathe if it

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[963] Katherine Hunting and others, "Solvent exposure and the risk of slips, trips and falls among painters," *American Journal of Industrial Medicine* 20 (191): 353-370.

[964] Mary White and E.L. Baker, "Measurements of respiratory illness among construction workers," *British Journal of Industrial Medicine* 45 (1988): 523-531.

[965] David Schwartz and Edward Baker, "Respiratory illness in the construction industry," *Chest* 92 (January 1988): 134-137.

[966] Anne Fidler, E.L. Baker, and R.E. Letz, "Neurobehavioral effects of occupational exposure to organic solvents among construction workers," *British Journal of Industrial Medicine* 44 (1987): 292-308.

[967] C. van Vliet and others, "Exposure-outcome relationships between organic solvent exposure and neuropsychiatric disorders: Results from a Dutch case-control study," *American Journal of Industrial Medicine* 16 (1989): 707-718.

[968] Brian Schwartz and others, "Solvent-associated decrements in olfactory function in paint manufacturing workers," *American Journal of Industrial Medicine* 18 (1990): 697-706.

[969] L. Atkinson and others, "Toxic reaction to inhaled paint fumes," *Postgraduate Medical Journal* 65 (1989): 559-562.

[970] Anthony Scialli, "Who should paint the nursery?," *Reproductive Toxicity* 3 (1989): 159-164

can be helped. In general, any conventional water-based product will be healthier than any solvent-based product. That's because they not only contain a lower percentage of solvent, but they contain different solvents. Solvent-based finishes contain mostly aromatic hydrocarbons, many of which are carcinogenic, while water-based products contain aliphatic hydrocarbons, which are believed to be less harmful to humans.[971] An evaluation of four low-VOC paints found that two had significant emissions of aldehydes, especially formaldehyde.[972] This is why zero-VOC products are better than low-VOC products, and they are often well-tolerated by chemically sensitive individuals.

Pigments

Carbon black, which is carcinogenic if inhaled in powder form, and various iron oxides, which aren't particularly hazardous, are often used as pigments in residential paints. Sometimes cadmium compounds are used, but they are only hazardous if ingested or inhaled in powder form. While some pigments can cause skin irritation, those that are problematic are usually only dangerous if inhaled or ingested so, once a paint is dry and the pigment is bound up in the paint film, the pigment is rarely a problem—unless the paint deteriorates—and that's how lead-based paint can be dangerous.

While lead-based paints are very durable and long-lasting, over time they often deteriorate—exposing occupants to lead dust which accumulates in the body until it reaches toxic levels. Lead is no longer used as a pigment, but people can still be exposed. For example, exterior lead paint was designed to chalk off as a self-cleaning process. This results in lead dust accumulating in the soil around a house. Children can get this lead-contaminated dust on their fingers when they play in the yard outside a house. Then, through normal hand-to-mouth contact, they get lead into their system. Flaking or peeling paint can also be inhaled. A few flakes of lead-based paint can contain over 100 mg. of lead.

It's been found that children with elevated lead levels in their blood are most likely to come from deteriorated or dilapidated private housing.[973] However, as more and more middle-class homeowners renovate older homes, they invariably disturb lead paint and inadvertently contaminate their house. See *Chapter 25, An in-depth evaluation of six common pollutants* for more information about lead paint.

Because of the lessons that have been learned about lead, it would be wise to avoid the use of paints containing any toxic heavy metal. When rating paints for toxicity, **Green Seal** will not consider paints containing antimony, cadmium, hexavalent chromium, lead or mercury.

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[971] Dan MacArthur, "Water-based polyurethanes," *Environmental Building News* (March/April 1993): 7.

[972] J.C Chang, R. Fortman, N. Roache, and H.C. Lao, "Evaluation of low-VOC latex paints," *Indoor Air* (December 1999): 253-8.

[973] C.S. Clark and others, "Condition and Type of Housing as an Indicator of Potential Lead Exposure and Pediatric Blood Lead Levels," *Environmental Research* 38 (1985): 46-53.

Additives

Besides the primary components, there can be dozens of other ingredients in finishes including: anti-skinning agents, anti-settling agents, fillers, catalysts, curing agents, defoamers, dispersing agents, emulsifying agents, driers, fatty acids, fillers, extenders, fire retardants, flatting agents, plasticizers, preservatives, fungicides, surfactants, thickeners, thixotropic agents, *etc*.[974] These ingredients can be composed of heavy-metal compounds containing lead or arsenic, or pine oil, coal tar, kerosene, xylene, alcohols, synthetic oils and resins, mineral spirits, *etc*.[975] Of all the various additives, biocides are often problematic—especially for sensitive people.

The prefix "bio" comes from a Greek word meaning "life" and the suffix "cide" is from a Latin word meaning "killer." Therefore, a biocide is something that kills life. In coatings, caulkings, and adhesives biocides are often used to prevent or retard mold, mildew, or bacterial growth or insect attack—either to extend shelf life, while the coating is still in its container, or after it's been applied. This is a concern because microbes can consume oils, latex, and other common ingredients. Biocides can affect many forms of life—even human life.

Exterior products are routinely exposed to rain and moisture, so they usually require biocides in the form of mildewcides and fungicides. This is especially true in hot, humid climates. But products used indoors, in high-humidity areas like bathrooms, can also be susceptible to mold and mildew growth.

In August 1989, an event occurred involving a biocide in paint that affected a large segment of the industry almost overnight.[976] It involved a 4-year-old boy in Michigan. After his family painted the interior of their house, the child began suffering from acrodynia, a rare form of mercury poisoning. It was determined that the latex paint they had used contained a biocide formulated with mercury—a highly toxic metal. Based primarily on this single incident, the **EPA** decided to ban mercury from all interior finishes. At that time, up to one-third of the paint manufacturers used mercury in their products. They had to rapidly come up with new biocides. When mercury-containing paints deteriorate, they can contaminate the soil outdoors, and carpeting indoors, just like lead-containing paints.[977]

Exterior coatings are still allowed to contain mercury, and there are thousands of gallons of older interior finishes on shelves in houses, basements, and garages that also contain mercury. To find out if an old can of paint is safe to use, call the **National Pesticide Telecommunication Network** at 800-858-7378. They maintain a listing of

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974 Ernest W. Flick, *Handbook of Paint Raw Materials*, (Park Ridge, NJ: Noyes Publishing, 1982): 1-2.

975 Robert E. Gosselin, Roger P. Smith and Harold C. Hodge, *Clinical Toxicology of Commercial Products* (Baltimore, MD: Williams and Watkins, 1984): V1.82-V1.84.

976 "Mercury exposure from interior latex paint—Michigan," *Morbidity and Mortality Weekly Report* 39 (March 2, 1990): 125-126.

977 Mary Agocs and others, "Mercury exposure from interior latex paint," *New England Journal of Medicine* 323 (October 18, 1990): 1096-1101.

paints that have contained mercury in the past. In order to make a determination, they may need to know the approximate age of the paint. This is because an older formula may contain mercury but a newer one may not. If your paint does contain mercury, you may decide to dispose of it rather than use it. Be sure to do so through a local household-hazardous-waste program. Never discard paints in the trash or pour them down the drain.

In May 1991, another case of a paint biocide causing illness was described.[978] Symptoms included a burning sensation in the nose and forehead, headache, nose bleed, cough, loss of appetite, nausea, and vomiting. It turned out that a mildew-control additive —bis(tributyltin) oxide, sometimes called TBTO—had been added to the paint by a landlord. Because of a number of other reported cases of people getting sick from exposure to TBTO in paint, the state of Washington now requires such products to be labeled for exterior use only.

Interior Finishes

Interior finishes must be selected with more care than exterior finishes—simply because they are directly exposed to the indoor air. In general, water-based finishes are healthier than oil-based finishes, because they have fewer VOCs. Paints with no VOCs whatsoever are even better. While there are a number of finishes being advertised as "zero-VOC" they can still emit small amounts of VOCs. This is because the common indoor-air definition of VOC does not include *all* VOCs, and some VOCs can actually be formed as by-products of chemical reactions that take place after a paint has been applied.[979] Still, the "zero-VOC" paints currently on the market, though not perfect, are typically very-low VOC emitters.

A number of suppliers now offer alternative paints that are healthier than the widely available, nationally distributed brands. Originally, many of these products were developed specifically for chemically sensitive individuals, but they are now being marketed to environmentally conscious individuals who are in good health and want to remain that way.

All paints and finishes outgas completely sooner or later. But to reduce your exposure, sooner is better than later. In other words, a paint that outgases quickly will expose you to less outgassing than one that takes longer to outgas—especially if you can provide extra ventilation during the initial outgassing period. But outgassing may not be the only problem to consider—a dried finish can occasionally cause a reaction in someone sensitive to the synthetic resin itself.[980]

Off-the-Shelf Products

Most off-the-shelf water-based paints and finishes tend to outgas relatively

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978 "Acute effect of indoor exposure to paint containing bis(tributyltin) oxide—Wisconsin 1991," *Morbidity and Mortality Weekly Report* 40 (May 3, 1991): 280-281.

979 "Evaluation of low-VOC paints," *Inside IAQ* (Fall/Winter 1998): 1-2.

980 A.F., "The Chemistry of Wood Finish" (letter), *Nontoxic and Natural News* (March/April 1986): 8-9.

quickly. But they are not totally without risk. A 1991 article found the following health-related factors to be occasionally associated with water-based finishes: irritation of the skin, irritation of the mucous membranes (which can cause headache), eczema, and skin sensitization.[981] The article also pointed out that ingredients like acrylonitrile and formaldehyde are suspected carcinogens, and that ethylene glycol and ethylene glycol ethylether are possible causes of birth defects. A 1991 issue of the *American Journal of Industrial Medicine* found that painters exposed to ethylene glycol ethers in water-based paint had lower sperm counts than unexposed workers.[982] Low-level emissions from glycol ethers can last for several months.[983]

Latex, which is derived from rubber trees, has also come under fire. According to one source, "rashes and other less severe reactions have been reported as a result of walking into rooms being painted with latex paint."[984] While reactions to latex are not common, they are increasing, and there are a number of articles in medical journals describing everything from dermatitis to anaphylactic shock.[985] Many paint manufacturers define the word *latex* as simply meaning water-based, so some "latex" paints do not actually contain real latex.

Paints

Alkyd-based paints can take three months or more to outgas, yet they have sometimes been recommended for sensitive individuals because, once cured, they leave a hard film that acts as a diffusion retarder to seal such materials as drywall.[986] Another source states that alkyd paint can still have an odor after three years.[987] Obviously, individual testing is necessary, because people's sensitivities vary as well as the products of different manufacturers.

Some sensitive people have reported being bothered by odors from water-based paint for several months after application—when the outgassing rate is extremely low.

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981 Arendina van Faassen and Paul Borm, "Composition and health hazards of waterbased construction paints: Results from a survey in the Netherlands," *Environmental Health Perspectives* 92 (1991): 147-154.

982 Laura Welch, Elizabeth Plotkin, and Steven Schrader, "Indirect fertility analysis in painters exposed to ethylene glycol ethers: sensitivity and specificity, *American Journal of Industrial Medicine* 20 (1991): 229-240.

983 "Short and long-term VOC emissions from latex paint," *Inside IAQ* (Fall/Winter 1995): 15.

984 Dolores Kong, "Link of latex to allergy, deaths spurs a I.S. inquiry," *Boston Globe* (May 27, 1991): 1.

985 "Latex allergies from condoms & surgical gloves," *AGES Magazine* (Spring 194): 19-20.

986 "Product Information," *The Human Ecologist* #31 (Winter 1985-86): 11.

987 Ruth Dabes, "Particle Board" (letter), *The Human Ecologist* #4 (August 1979), 14.

Still, water-based paints are the types that are most often recommended for sensitive people.

Several major water-based paint manufacturers now offer "odor-free," zero-VOC paints. These include **Benjamin Moore & Co.** (Pristine EcoSpec), **Coronado Paint Co.** (Aire-Care), **Devoe Paint** (Wonder Pure Flat), **Duron Paints** (Genesis), **EarthTech**, **Frazee Paints** (Envirokote), **ICI Paints** (Glidden ProMaster Series and ICI Lifemaster 2000), **Innovative Formulations** (The Ecological Paint), **Kelly-Moore Paint Co.** (Enviro-Cote), **Kurfees Coatings, Inc.** (Fresh Air Formula), **McCormick Paints** (Natural Odor Free), **Painter's Warehouse** (Republic), **Sherwin Williams Co**. (Healthspec), **Spectra-Tone** (Enviro), and **Truserv Corp.** (True Value EZO line). Most of these zero-VOC paints are available nationally, but some companies only distribute regionally. Most of these companies also offer conventional water-based finishes (having small amounts of solvents), as well as oil-based finishes.

Many sensitive people tolerate these zero-VOC paints fairly well. However, even though they are advertised as containing no VOCs, many do contain a very small level of VOCs, sometimes on the order of 2-3%. This is because of how the term VOC is defined, and the actual percentage of VOCs present. So, the VOC level does not have to be truly zero for a paint manufacturer to use the terms "zero-VOC" or "no-VOC." In addition, these paints can contain a variety of other additives that some sensitive people cannot tolerate. They are actually different in formulation from other water-based paints—they are not made by simply "leaving out" the VOCs. So, while they are also advertised as being "odor-free," they should instead be assumed to be "very-low-odor." Some companies use an alcohol-based tinting system so, even though an untinted paint may have no VOCs, a tinted paint may, because alcohol is a VOC.

It's been recommended that adding baking soda to a conventional water-based paint will absorb the paint odor.[988] Sensitive people have been told to add $^1/_2$ to 1 cup of baking soda to a gallon of paint with a flour sifter, then to mix the paint thoroughly. Unfortunately, this has resulted in a number of problems—and it doesn't seem to substantially reduce the odor. First of all, it will usually invalidate the manufacturer's warranty, and in some cases it affects the surface sheen—especially when used with a semi-gloss paint. In damp areas, or outdoors, the baking soda can bleed to the surface of the dried paint, something particularly noticeable with darker colors. It can also cause paint to adhere poorly and flake off. In general, one of the alternative finishes is a much better solution.

Interior (or exterior) metalwork can be taken to an automobile repair shop and painted with an automotive paint. A wide array of standard colors are available besides automotive colors. You should choose a shop that has the equipment to bake the finish after it has been sprayed on. Not all body shops do this, but baking can radically reduce outgassing—and yield an extremely durable finish. Automotive finishes are formulated to withstand extreme weather conditions, so they are quite well suited for any metal that will be used outdoors.

Clear Finishes

Shellac is one of the oldest clear finishes available. It is a purified resin secreted

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988 Dadd, *Nontoxic and Natural*, 148.

by an insect, and is one of the few natural ingredients that can still be found in regular use today. Because it uses an alcohol solvent, shellac is quite odorous when wet, but it dries and outgases quickly—usually in a matter of days. The Bulls Eye brand is available in many paint and hardware stores and is manufactured by **Wm. Zinsser & Co.** They have an excellent booklet available titled *How and Where to use Bulls Eye Shellac* that lists several application and finishing tips. A shellac finish can be dissolved by an alcoholic beverage, and it will water-spot if allowed to remain wet for a while. However, shellac finishes are very easy to repair by blending, unlike some synthetic finishes that must be completely removed and then refinished. Auro shellac (**Sinan Co.**) is a pure product imported from Germany.

There are several oil finishes made for protecting woodwork, but they tend to remain odorous for longer periods than other clear finishes and they are generally not recommended for sensitive individuals. Oils dry by oxidation and many utilize various additives to speed up the drying process. Tung oil has immunosupressive effects and has been implicated in reactivation of chronic Epstein-Barr virus.[989]

Linseed oil, which is naturally anti-bacterial, is available in two varieties: raw and boiled. While raw linseed oil will not dry properly when applied to wood, "boiled" linseed oil will. (Actually, it's not really boiled, it's just heated.) In the past, many manufacturers simply heated raw linseed oil to give it drying properties but, today, most "boiled" linseed oil has not been heat-processed at all. Instead, manufacturers add toxic heavy-metal additives, such as lead acetate or cobalt manganese, to aid in drying.[990] Fortunately, there are two types of boiled linseed oil still being made without these types of additives. Tried & True Varnish Oil (nontoxic, 100% linseed oil) and Tried & True Original Wood Finish (nontoxic linseed oil and beeswax). Both are manufactured by **Tried & True** and are available by mail order from **Garrett Wade Co.** or through Woodcraft Supply retail stores.

Waxes are also occasionally recommended for people with paint sensitivities, but they generally contain a solvent, such as turpentine, to render them workable. Beeswax is sometimes used, but it can smell strongly of flowers, the smell having been transferred by the bees that produced the wax. Carnuba wax is harder than beeswax but, in general, waxes aren't as durable as the newer synthetic formulations, so they require more-frequent reapplication.

Clear finishes for floors, woodwork, and cabinetry have changed considerably in recent years. A new generation of water-based finishes—mostly acrylics and polyurethanes—are now readily available. When applied correctly, they can be both attractive and durable.[991] Although considerably safer than solvent-based products, they still can contain glycol ethers, biocides, and other unhealthy ingredients, so ventilation

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[989] Dana Miller, "Chronic Epstein Barr Virus - What is it?," *The Human Ecologist* #33 (1986): 7.

[990] "Linseed oil that's safe for you and the environment," *Environmental Building News* (September/October 1994): 6-7.

[991] Michael Purser, "Waterborne finishes for hardwood floors," *Journal of Light Construction* (October 1991): 15-17.

during application is important.

Water-based 100%-acrylic clear finishes used to be widely available, but most manufacturers have switched to water-based polyurethane formulations. Some are 100% polyurethane, but many are a polyurethane/acrylic blend. All, even the blended products, are simply referred to as polyurethane finishes. There are two basic types on the market: catalyzed finishes, and non-catalyzed finishes.[992]

Catalyzed polyurethane finishes are generally only sold to trained professionals because two components (a resin and a catalyst) must be mixed carefully together on the job. Even though the catalyst is quite toxic by itself, the hardened finish is very inert because the two components undergo a chemical reaction as they cure. Non-catalyzed polyurethane finishes can be used by homeowners. Without a catalyst, they cure more slowly (7-10 days), although they can be walked on within a few hours of application.

There are quite a number of manufacturers producing water-based polyurethane finishes. They include **Basic Coatings** (contractor grades only), **BonaKemi USA, Inc.** (both commercial and residential grades), **Carver Tripp** (Super Poly), **James B. Day & Co.**, (Day's Clear Water Borne Acrylic Urethane), **PPG Architectural Finishes, Inc.** (Olympic), and **United Gilsonite Laboratories** (Aqua Zar).

All water-based polyurethane finishes—whether they are blended or not, or catalyzed or not—outgas quickly and are quite well tolerated by most sensitive people. In fact, many sensitive people report that they are able to be around these finishes within 5-7 days of application. They are often better tolerated than some of the alternative finishes specifically formulated for sensitive people.

Stains

Most woods vary in color from tree to tree, so the furniture and cabinet-making industries tend to stain everything to make different pieces of wood all look alike. Low-cost woods are often stained to resemble more expensive ones. However, some custom woodworkers do not use stains at all—to allow the natural beauty and variations inherent in the wood to speak for itself. Dark stains often result in wood that looks gloomy, so unstained wood—with its color variations, imperfections, and character—is becoming more popular.

Stains are usually protected by a clear finish so, once the finish has been applied, the stain is never directly exposed to the occupants. Therefore, the selection of a stain is less critical than the selection of a clear finish. Water-based stains tend to outgas less than oil-based stains, but oil-based stains often have a richer appearance. Most water-based stains don't have much odor, but a few are relatively potent. So, when choosing an off-the-shelf water-based stain, pick one with little odor. Some woodworkers use alcohol-based stains. Because the alcohol outgases very quickly, these often have as little odor as water-based finishes once covered by a low-tox finish. **James B. Day & Co.** manufacturers water-based stains without added biocides, as well as alcohol-based aniline colors. Their aniline colors can be thinned with either water or alcohol, and they can be used to tint clear finishes.

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[992] Michael Purser, "Using Waterborne Floor Finishes," *Fine Homebuilding* (December 1993/January 1994): 61-63.

Alternative Finishes

Over the last several years, a number of alternative paints and finishes have been marketed as being healthier than conventional, off-the-shelf coatings. Many, but not all, are water-based. Some of these products are more costly than off-the-shelf coatings sold locally—but a few are somewhat less costly. These alternative finishes are generally only available by mail and some of the paints are only made in a limited number of neutral colors. Many are well tolerated by sensitive people but, because everyone is biologically unique, no single product is universally tolerated.

Some alternative finishes have little odor, but others are quite strong during application. Coverage isn't always as good as with off-the-shelf paints, and some aren't very scrubbable. However, other alternative products cover extremely well and are very durable, scrubbable, and long-lasting. Sensitive people are urged to test finishes for personal tolerance, but anyone contemplating a large painting project will want to evaluate them for things like appearance and scrubability. Small samples are often sold for just this purpose.

Sometimes, alternative finishes don't have a very long shelf life. This simple fact has caused some serious problems. In one case, a California homeowner gave her painter some natural paint to use, not realizing that it had gone bad in the can. The painter thought the odor was pretty obnoxious, but he had never used a natural paint before and didn't know what it was supposed to smell like—so he used it anyway. When the homeowner returned home, she couldn't tolerate her house. To remedy the problem, the drywall had to be removed and replaced.[993]

Low-Outgassing Paints

AFM manufactures a complete line of "products for the chemically sensitive." In their Safecoat Paint line they offer a primer undercoat, flat finish paint, semi-gloss enamel, and gloss enamel. These are all zero-VOC water-based products. The only colors available are white and off-white, but their products can be tinted at your local paint store with universal tints—although not all paint stores are willing to tint paints purchased elsewhere.

Best Paint Co., Inc. produces a line of low-tox paints that includes a primer, flat finishes, and enamels. They are specially formulated to be as healthy as possible; they contain no ammonia, ethylene glycol, or formaldehyde; and they are very well-tolerated by chemically sensitive individuals. Plus, they are quite reasonably priced. They also cover very well, and are scrubbable.

Chem-Safe Products Co. has a low-outgassing Enviro-Safe paint and primer that are being marketed specifically to chemically sensitive people. The paint is an interior, acrylic, low-biocide, zero-VOC formulation without any fungicides. The satin and the primer can be used indoors or outdoors. This paint is also well tolerated by many sensitive people, it covers well, and it is scrubbable.

Miller Paint Co. offers a zero-VOC, *low-biocide* paint on special request. When raw ingredients, which are susceptible to spoilage, are purchased in bulk by paint producers, they contain small amounts of biocides. During processing, most

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[993] "Natural paints: Know the shelf life," *Safe Home Digest* (March/April 1992): 5.

manufacturers add considerably more biocides—primarily to extend the shelf life. Miller does not add any additional biocides to its low-biocide paint. This results in 90-95% less biocide than in conventional paints, and a shelf life of about six months. Low-biocide paints are generally not recommended for use in bathrooms where high humidities are common. As a rule of thumb, if steam tends to accumulate on a bathroom mirror, there is potential for mildew growing, so a low-biocide paint would not be suitable.[994]

Murco Wall Products, Inc. makes a low odor Hi-Po flat interior vinyl wall paint and a Hi-Po gloss latex enamel, as well as a semi-gloss latex enamel and an alkyd gloss enamel. These products are advertised as not containing "such volatile compounds as ammonia, formaldehyde, ethylene-glycol, or ethylene glycol butyl ether." The paint does contain a fungicide and a preservative, but they are said to become "permanently entombed" in the dried paint film, so they won't outgas into the air.

Pace Chem Industries has a Crystal Shield water-based paint that is designed to also function as a sealant. It is available in seven colors. This product tends to have a strong odor that some sensitive people claim takes as long as a several weeks to completely dissipate, but once cured, it is often well tolerated.

Natural Paints

As the environmental movement has grown in recent years, *natural* has become synonymous with *healthy*. But that isn't always the case. After all, lead, asbestos, and radon are natural materials. The companies listed below offer paints made from natural materials. Some of the natural ingredients (oil of turpentine, citrus oil, citrus thinner, pine resin, tung oil, *etc*.) can bother sensitive people. With some of the natural finishes, mold or bacteria can attack a partially filled can after a few weeks, but once a paint has dried on a wall, mold is unlikely except in very wet locations.

In Germany, about a dozen manufacturers produce paints and finishes made of natural ingredients such as vegetable oils, plant resins, finely ground minerals, and earth pigments. Overall, they have been well received, but the formulas for some of these finishes have been revised over the years because natural ingredients like balsamic turpentine (from pine trees) and citrus oil (derived from lemons, oranges, or grapefruits) have resulted in painter's rash. So, some of the manufacturers have switched to petroleum-based aliphatic hydrocarbons or isoaliphatic hydrocarbons because they're better tolerated.

Whitewashes have been around for some time, and they continue to be used as a low-cost coating for brick and concrete surfaces.[995] The National Lime Association published a booklet in 1955 containing several formulas for making whitewash.[996] One of the simplest formulas consists of 8 gal. of lime paste, 5 gal. of water, and 15 lb. of salt.

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994 Richard C. Barnes, President of Negley Paint Co., Personal correspondence, February 26, 1987.

995 Will Charnow, *Painter's Pal* (Santa Barbara, CA: The Painter's Pal Co., 1987): 188.

996 National Lime association (NLA), *Whitewash and Cold Water Paints* (Washington, DC: NLA, 1955).

(Lime paste can be made by soaking 50 lbs. of hydrated lime in 6 gallons of water.) Other more-durable formulas include ingredients like formaldehyde, tri-sodium phosphate, animal glue, skimmed milk, or casein. To apply whitewash, the surface should first be dampened, then a very thin coat of the whitewash can be brushed on. The coating will be translucent when wet, but opaque when dry. A second coat can be applied once the first coat is thoroughly dry.

Prior to the introduction of latex paints, casein—a milk derivative—was widely used to make paint. In fact, casein has been used as a binder in paints for centuries. Because it is derived from a food product, casein can be highly susceptible to mold and mildew attack. The liquid formulations, that were in use prior to the development of latex paints, contained very potent biocides. Today, a few companies offer casein paint in powdered form. These paints need to be mixed with water on the job and, because they contain no preservatives or fungicides, they must be used quickly. Casein paint is durable once dry, but it probably shouldn't be used in bathrooms. Casein paints can have a slight milky odor for an extended period of time. Though not necessarily harmful, it may be bothersome to an individual with milk allergies.

Eco Design Co. manufactures natural finishes such as paints, oils, waxes, stains under the Bio Shield brand, including a casein-based milk paint. Their Solvent-Free Wall Paint #18 is a zero-VOC formulation, but it has a linseed-oil aroma that sensitive people may find bothersome. These formulas are based somewhat on the German finishes.

Livos Phytochemistry, Inc. sells the Livos brand of wood finishes from Germany. They have a wide variety of products including a flat, water-based, interior wall paint, and an oil-based enamel paint. They also have a wall primer, a metal primer, and a white-wash. Plus, they have water-based and oil-based earthen and mineral stain pastes which can be used to color their paints. Their Albion Flat White Wall Paint #407 is a zero-VOC formulation, but it contains hemp oil and orange-peel oil that some sensitive individuals may find bothersome.

Sinan Co. imports the complete Auro line of wood finishes from Germany. They handle a variety of products, including a water-based, flat, natural-resin wall paint. They also have some oil-based finishes: an enamel, an enamel primer, and a metal primer. Their earth and mineral tinting pigments can be used for coloring the paints. A complete list of ingredients is available for individuals interested in specifics.

The **Old-Fashioned Milk Paint Co.** manufactures a powdered, casein-based paint that is easily mixed with water and applied with a brush or roller. It contains milk protein, lime, clay, whiting, and earth pigments, and it has very little odor. This particular product was originally developed to look like the milk-paint finishes on antique furniture and it comes in eight colors. It is a very thin paint and does not cover well in some applications,

Homemade Paints

Some people have tried to make their own low-tox paint. This is certainly possible, but paint chemistry can be quite complicated, so it can take a great deal of research and experimentation—and a lot of work. The basic components (binder, vehicle, and pigment) can be derived from a variety of sources. Water is the easiest vehicle to work with. Binders include milk protein, flour, gum arabic, glycerin, sodium silicate, glue, egg yolk, *etc*. There are many things that can be used as pigments, but ground minerals or clay are usually the least problematic. Local ceramic shops can often supply powdered potter's clay in various shades to use as pigments.

An excellent starting place for ideas on making your own paint from scratch is the *Artist's Handbook*.[997] It provides detailed information on advantages and disadvantages of various materials. Some recipes for whitewash and milk paint are listed in *Better Basics for the Home*. [998]

Other sources for ideas include old formula books, several of which have been reprinted in recent years. Keep in mind that less was known about toxicity a hundred years ago—when white lead and gasoline were used to make paints. These old books often give very imprecise measurements that lead to inconsistent results. One old paint recipe says to add as much potash to water as can be dissolved, add a quantity of flour paste the consistency of painter's size, then add pure clay until the mixture is the consistency of cream, then apply with a brush.[999]

Clear Finishes

The new off-the-shelf water-based polyurethane finishes mentioned above are some of the best-tolerated finishes in use by chemically sensitive people. Still, they are not universally tolerable. Following are some other specialty products that are available by mail.

AFM manufacturers several Safecoat clear finishes and sealers including, Polyureseal, Acrylacq, and Hard Seal. They are water-based, synthetic, low-odor finishes that can be applied over a variety of surfaces.

Pace Chem Industries produces Right-On Crystal Aire which is advertised as being an environmental sealant, as well as a clear finish. It is an acrylic, low-odor, water-based product available in matte, satin, or gloss sheens. Crystal Aire can be used as a coating for all wood surfaces, such as cabinetry and furniture. They also sell a more-durable Crystal Shield for use on floors.

Several water-based clear finishes, including those produced by **Pace Chem Industries** and **Basic Coatings**, are made without added biocides, for individuals interested in avoiding those chemicals.

Stains

For do-it-yourselfers, walnut husks can be boiled in water to produce an attractive stain. The following products are perhaps slightly healthier than off-the-shelf products.

AFM produces Duro water-based stains in a number of colors that have a better appearance than many other water-based stains. **Eco-Design Co.**, **Livos Phytochemistry, Inc.**, and **Sinan Co.** offer oil-based and water-based stain pastes made from mineral pigments. Several colors are available.

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997 Ralph Mayer, *The Artist's Handbook of Materials and Techniques* 3rd ed. (New York: Viking Press, 1970).

998 Annie Berthold-Bond, *Better Basics for the Home*, (New York: Three Rivers Press, 1999)286-290.

999 *2000 Down Home Skills & Secret Formulas for Practically Anything* (Laguna Beach, CA: Gala Books, 1971 reprint): 223.

Sealants

Until recently, there was little research into the comparative sealing ability of various finishes. However, in 1995 the Saskatchewan Research Council conducted tests on particle board to determine how various coatings affected the formaldehyde emissions. The reduction of formaldehyde ranged from well-below 50% to 100%.[1000] Unfortunately, the best sealers are often serious outgassing sources themselves.

Benjamin Moore & Co. has a paint product called Impervo that blocked 100% of the formaldehyde emissions. Impervo is a solvent-based alkyd enamel. It is very odorous, and could easily be as bothersome to sensitive people as the formaldehyde it is meant to block.

ICI Paints offers an Insul-Aid paint/sealer that can be used as a moisture diffusion retarder on a wall, if one wasn't installed when the house was originally built. Insul-Aid is not a zero-VOC product like Glidden ProMaster Series wall paint. In the Saskatchewan Research Council test, it blocked formaldehyde emissions by only 38%.

Pace Chem Industries produced one of the first coatings marketed specifically for chemically sensitive individuals. Pace has sponsored research showing that four coats of their Crystal Aire product will reduce the formaldehyde emissions from manufactured-wood products by 94%. Unfortunately, some sensitive people have dutifully applied the four coats to all surfaces of kitchen cabinets or furniture, only to find that the remaining 6% emissions were too much to tolerate. This product is fairly odorous during application, and for as long as several weeks until it is completely cured—then it is quite inert.

Wm. Zinsser & Co. manufactures a B-I-N Primer Sealer that is alcohol-based and has a very strong odor when first applied. However, it tends to outgas relatively quickly as the alcohol evaporates. For some sensitive people this may take several hours, for others, a few days—but some people report a slight long-term odor. B-I-N is an excellent primer for plaster or drywall. It is particularly good at priming over water stains that bleed through other finishes. In fact, it is sold primarily because of its stain-covering ability. B-I-N contains only denatured ethyl alcohol, regular bleached shellac, titanium dioxide, and silicates, and can be purchased in many paint and hardware stores. This particular finish wasn't evaluated in the Canadian testing, however it is similar to SEAL-LOCK (see below), which was tested.

Insul-X Products Corp. had an alcohol-based primer sealer called INSUL-LAC that was tested by the Saskatchewan Research Council and found to block 90% of the formaldehyde emissions. (The INSUL-LAC product has since been renamed SEAL-LOCK.) As with B-I-N, the alcohol is odorous when wet, and it is very good at covering water stains.

There are several oil-based stain-covering products on the market, but they are often bothersome to paint-sensitive people. Because they do not use a rapidly evaporating alcohol solvent, they take longer to outgas. KILZ (**Masterchem Industries, Inc.**) is one such product that blocked 91% of the formaldehyde emissions in the tests performed at the Saskatchewan Research Council. It contains petroleum distillates, mineral spirits, and naphtha.

[1000] "Reducing formaldehyde emissions," *Solplan Review* (January 1996): 13.

Experience among sensitive people is revealing that paints and clear finishes tend to be imperfect sealers. Such people have used a variety of products over the years to seal in odors, only to find that, while the sealing helped, it didn't help enough. Part of this is due to the fact that most coatings don't block diffusion completely—they may be good diffusion *retarders*, but they are not perfect diffusion *barriers*. Also, many people have an imperfect understanding of tight construction. For example, they may coat a wall with a paint that is a reasonably good diffusion retarder, but ignore the fact than far more pollution is entering the living space through cracks because of air-pressure differences. Plus, when sealing a material, it's important to coat all edges. For example, if you are sealing a countertop, and there is a cut-out for the sink, the edge of the cut-out must be coated. Sensitive individuals should always test sealers for personal tolerability.

Exterior Finishes

In general, exterior stains don't last nearly as long as exterior paints—they often need to be reapplied every few years—and clear finishes used outdoors often only last a year or two, depending on the climate. This is because ultraviolet light from the sun damages wood fibers, causing them to break down. When the fibers break down, the finish no longer adheres as well. Pigmented surface coatings—like paints—block most of the ultraviolet, preventing it from reaching the wood, but the ultraviolet light goes right through a clear finish and attacks the wood. Some exterior clear finishes contain ultraviolet blockers that act somewhat like skin sunscreens.[1001] Stains having a great deal of pigment tend to protect wood more than those with little pigment. Still, the best outdoor finish for protecting wood is an exterior-grade paint.[1002]

Actually, exterior finishes are subjected to a considerable amount of abuse from wind, precipitation, temperature fluctuations, as well as ultraviolet light. All this abuse can shorten the life of many exterior finishes. Besides general-purpose biocides, exterior finishes also typically contain fungicides specifically designed to combat mold and mildew growth. Conventional paints and stains generally hold up better outdoors than alternative finishes. For example, off-the-shelf one-hundred-percent acrylics and acrylic latexes are quite durable. While a sensitive occupant might react to these finishes indoors, they are often perfectly tolerable outdoors, where their odor is diluted into the atmosphere.

There are several outdoor finishes that seem to be healthier-than-average. Some of them are alternative finishes, while others are more conventional off-the-shelf products.

Best Paint Co. Inc. offers products that are often tolerated well by chemically sensitive people, and they have three exterior-rated products: a flat latex, a semi-gloss acrylic, and a primer.

Chem-Safe Products Co. has an interior/exterior satin paint and an interior/exterior primer that are often tolerated well by chemically sensitive people.

[1001] Al Rubin, "Keeping the 'natural look' on wood siding," *Journal of Light Construction* (April 1992): 24-26.

[1002] Charles Wardell, "To paint or stain?," *Journal of Light Construction* (June 1992): 15-18.

Gloucester Co., Inc. makes a Phenoseal Liquid Waterproofing that is well tolerated by chemically sensitive people. It can be used on outdoor wood decks or on masonry.

ICI Paints manufacturers a zero-VOC Decra-Shield exterior paint that is available in either a flat or a satin finish.

Kaupert Chemical & Consulting, Inc. has a low-tox Seal-n-Oil finish that can be used as a weather and moisture barrier for outdoor decks. It dries quickly and has little odor after a few days.

Miller Paint Co. offers a low-biocide, no-fungicide, paint for exterior use, but it should only be used in a very dry climate.

Pittsburgh Paint Co. manufacturers an Exterior Semi-Gloss Latex paint that is often tolerated by sensitive people. It is primarily a trim paint, and it works well on doors and windows, but it can also be used for siding.

Valhalla Wood Preservatives, Ltd. has a product called LifeTime Wood Treatment. It is supposed to be non-toxic and is sold in powder form, to be mixed with water. Developed over 50 years ago, it has been used for a variety of applications in Canadian national parks, as well as in Sweden and the US. It is distributed in the US by **Schroeder Log Home Supply**, and is used regularly on log homes. This product is described as being a wood "preservative" but there are apparently no independent tests showing it to be effective against rot or decay when compared to conventionally treated wood, so it would seem to be risky to rely on it to actually preserve wood for in-ground use in a critical application or severe climate. However, it may be suitable for above-ground exterior use. It will impart a silver patina to the wood.

Weather-Bos makes low-tox vegetable-based stains and clear finishes for use on wood decks, siding, and roofing. Their products, which are formulated for water clean-up, include Masonry Boss, Deck Boss, Log Boss, Roof Boss, Marine Boss, and The Boss.

Although it's not really a finish, **Verdant Brands** has an alcohol-based herbicidal soap that can be used to clean outdoor wood decks. It's called Safer Home, Deck & Patio Moss & Algae Killer and is specially formulated to kill mosses, algae, lichens, and liverworts (but not mold and mildew). It has an alcohol odor when applied, but it airs out quickly and isn't as toxic as bleach.

As mentioned above, metalwork can be painted with an automotive paint. A body shop should be chosen that has the capacity to bake a finish after it's been applied. This will make the finish more inert, and quite durable—after all, these finishes are formulated to hold up outdoors on an automobile under very adverse weather conditions.

Paint Removers

Although they work quickly and aren't flammable, paint removers containing methylene chloride are very toxic. When used indoors, even with the windows open, concentrations can be a whopping 86,000 times higher than the State of California says is without risk.[1003] The **Consumer Product Safety Commission** requires these products to have cancer labeling as well as a notice that they should only be used outdoors or with

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[1003] "Paint strippers removed from California market," *Indoor Air Review* (December 1992): 3.

adequate ventilation. In the May 1991 issue of *Consumer Reports*, it was pointed out that methylene chloride has been linked to kidney disease, irregular heartbeat, and heart attack—as well as cancer.[1004] Neoprene gloves, goggles, and respiratory protection is mandatory. *Home Mechanix* went a step further in February 1992 and recommended a respiration system that actually supplies you with air (like a deep sea diver), rather than a simple filter mask.[1005]

There are some solvent-based strippers available that don't contain methylene chloride, but their ingredients (toluene, methanol, acetone) are still toxic, and very flammable. Switching from methylene-chloride strippers to solvent-based ones has been described as "getting away from cancer and going to the bomb." [1006]

Caustic, non-solvent strippers containing organic esters are much safer, although they are considerably slower acting. There are several brands on the market including Safest Stripper (**3M**), Peel Away 6 (**Dumond Chemicals**), EasyOff (**Klean Strip**) which is a dried latex remover, and Biodegradable Strypeeze (**Savogran Co.**). Peel Away 6 is often used by lead abatement contractors. It can remove many coats of paint at a time. Do-it-yourself recipes for making your own caustic stripper are available.[1007] While paint removers containing organic esters are healthier choices, they contain very caustic chemicals that can burn the skin, so basic safety precautions are still in order. Also, these caustic strippers leave a very alkaline surface that must be neutralized with a vinegar/water solution before being repainted, or the paint won't adhere properly.[1008] This is usually covered in the manufacturer's directions.

If you've tested the paint you want to remove (as well as the layers underneath the topcoat) and it doesn't contain any lead, then a heat gun can be effective. They blow out hot air (640°-875°F) like a hand-held hair dryer. The heated air softens the paint which you then scrape away. Heat guns work better on several layers of paint than on a single thin layer, but they don't work well on painted metal. If used on lead-based paint, and the temperature of the heat gun is over 500°F, lead-oxide fumes will be released into the air,[1009] so this is not a recommended method of dealing with lead paint. Because any heated paint can have a noxious odor, proper respiratory protection and plenty of

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[1004] "Paint removers: New products eliminate old hazards," *Consumer Reports* (May 1991): 340-343.

[1005] Matt Phair, "Stripping interior woodwork," *Home Mechanix* (February 1992): 50.

[1006] Thomas Sweeney, "Safe strippers get tough," *Practical Homeowner* (July/August 1991): 21.

[1007] Debra Lynn Dadd, *Nontoxic and Natural* (Los Angeles: Jeremy P. Tarcher, 1984): 150-151.

[1008] John Leeke, "Stripping exterior paint," *Journal of Light Construction* (June 1990): 29-33.

[1009] Alf Fischbein and others, "Lead poisoning from 'do-it-yourself' heat guns for removing lead-based paint: Report of two cases," *Environmental Research* 24 (1981): 425-431.

ventilation are mandatory, and heat guns do pose a danger of burns.

Shellac finishes can be removed with alcohol. It generally works quickly, but is very odorous. It is also flammable.

One of the healthiest ways to have a piece of furniture, door, cabinet, or wood molding, stripped is to take it to a commercial stripper and let them do it. They typically use more powerful products that act quickly, and they have the proper facilities, the correct safety equipment, and an environmentally approved means of disposing of the old finish and spent stripping chemicals. Because some of the healthier strippers are expensive, it may not cost much more to leave the job to a professional.

Caulking

There are a wide variety of caulking products available today that are formulated to seal gaps between a variety of different materials. If the wrong caulking is used in the wrong application,[1010] [1011] or if it is applied incorrectly,[1012] it may not last, or perform its intended function, so it's important to choose a product that is compatible with its intended use. Many caulks require long outgassing periods and are intolerable to sensitive people.

In one study, a clear acrylic latex caulk with silicone outgassed the following products: acetone, methyl ethyl ketone, methyl propionate, ethyl propionate, dimethyl pentane, C-6 ester, butanone, toluene, C-8 alkene, dimethyl cyclohexane, butyl propionate, N-octane, dimethyl benzene, and C-8 alcohol.[1013] Not a very healthy sounding list.

In another study, researchers measured the weight loss of 19 different caulking materials after 48 hours, then calculated how long it would take them to lose 100% of their volatile components. A silicone caulking lost 2.06% of it's weight after 48 hours, and was projected to lose a total of 4.49% of its weight when fully dry after 487.2 hours (about 20 days). A polyurethane caulking only lost 1.2% of its weight in the first 48 hours, but was projected to lose a total of 14.86% of its weight when fully dry after 8,269.4 hours (nearly a year). While most caulkings will dry enough to perform their intended function fairly quickly, this research shows that it can take some time before a material is considered 100% cured, and the VOC-outgassing rate is zero. Still, a low outgassing rate for VOCs that is close to zero is often obtained within several days. For example, an acrylic emulsion latex caulking lost 5.48% of it's weight after 48 hours, and was projected to lose a total of 11.80% of its weight when fully dry. While it wasn't fully

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[1010] Karl Stum, "Caulks and Sealants," *Custom Builder* (August 1988): 29-31.

[1011] Bruce Sullivan, "Choosing a High-Performance Sealant," *Journal of Light Construction* (October 1993): 44-45.

[1012] Bruce Sullivan, "The Perfect Caulk Bead," *Journal of Light Construction* (April 1993): 43-44.

[1013] Bruce A. Tichenor, "Measurement of Organic Emissions from Indoor Materials - Small Chamber Studies" (Raleigh, NC: *Paper presented at EPA/APCA Symposium on Measurement of Toxic Air Pollutants*, April 28, 1986).

dry after 48 hours, there were no VOC emissions at that time—so the rest of the drying was most likely due to the release of a small amount of water.[1014] No brand names were revealed in this study and, most likely, different brands of the same type of caulking would have different outgassing characteristics.

Based on the fact that they are often reasonably well tolerated by chemically sensitive people, the following caulkings seem to be healthier-than-average. Keep in mind the fact that different caulkings are formulated for different purposes, and a caulking must be compatible with its intended use. In other words, if you use the wrong caulking for a particular purpose, it may not adhere properly or last very long.

Dap, Inc. produces DAP Kwik-Seal Tub and Tile Caulk. It is sold in many paint and hardware stores, and it is often well tolerated by sensitive people after a few days of outgassing. This is a vinyl preparation containing several ingredients, including ethylene glycol and n-butyl acetate. It contains a mild fungicide and is a very good product to use in damp areas, such as in bathrooms and kitchens. It is available in two colors: almond and white.

Gloucester Co., Inc. manufactures Phenoseal Adhesive Caulking, a general-purpose caulking that is often tolerated by sensitive people. It is a polyvinyl-acetate emulsion, which is similar to Elmer's glue, but it contains other minor ingredients that could bother some people. It is made in ten different colors and is tougher and more flexible than the DAP product. It is distributed nationally, but can be difficult to find in some areas. Actually, most of the widely available water-based caulks seem to outgas within a few days.

Several manufacturers offer 100%-silicone caulking that can be used in a wide variety of applications. Although highly odorous when wet, it can be tolerable after extended outgassing. One study found emissions near zero after about 4 days.[1015] Silicone caulking is a very-long-lasting product so, once in place, a repeat application may not be necessary for years. A disadvantage to 100%-silicone caulking is that it can't be painted easily. However, if the surface is already painted, a clear silicone often looks just fine over it.

Most silicone caulkings contain acetic acid to aid in curing. Neutral-cure silicone caulking contains no acetic acid, and it is somewhat less odorous. **Dow Corning** offers a #795 Silicone Building Sealant that is a neutral-cure caulking—it is alcohol-based and contains no acetic acid. The RTV5222 white silicone caulking by **GE Silicones** is also a neutral-cure product (It also comes in other colors). Aquariums are generally held together with silicone caulking that is FDA approved, but those products are generally acetic-acid cured. One manufacturer of aquarium-grade caulking is **Perfecto Mfg. Co.**

[1014] D. Jennings, D. Eyre, and M. Small, *The Safety Categorization of Sealants According to Their Volatile Emissions* (Ottawa, ON, Canada: Ministry of Energy, Mines and Resources, Canada, 1988).

[1015] Bruce Tichenor and Mark Mason, "Organic emissions from consumer products and building materials to the indoor environment," *Journal of the Air Pollution Control Association* 38 (1988): 264-268.

Aerosol Foam

A number of companies offer foam insulation in small aerosol cans that can be used for filling gaps and crevices. This material is widely available in hardware stores and building-supply centers. As it comes out of the can, it's about the consistency of shaving creme. It expands somewhat, then after it hardens, the excess can be trimmed flush with a knife if necessary. These foam products contain potentially noxious ingredients (See *Chapter 17, Insulation*) and should be used with plenty of ventilation, but most of them seem to outgas fairly quickly, and they are almost never directly exposed to the living space. A typical use would be to fill the gap between a door or window jamb and the house framing. In such an application, the foam would be trimmed flush with the interior wall surface, then covered with wood trim. Chemically sensitive people generally tolerate these products quite well once cured.

There are a number of manufacturers of aerosol urethane-foam products. They include **Convenience Products** (Touch 'n seal, Touch 'n Foam), **Flexible Products Co.** (Insta-Seal), **Fomo Products** (Handi-Foam), and **Macklanburg-Duncan** (Polycel). These materials are generally available in both consumer-sized aerosol cans and also in contractor sized containers with application guns.

Adhesives

Adhesives can be particularly polluting materials. There are reports of at least two individuals who died while laying carpet. Both were using non-carpet adhesives—one being a contact cement containing 1,1,1-trichloroethane—without adequate ventilation.[1016] In another incident in Seattle, ten employees were evacuated from the Children's Hospital when alarms, designed to detect poisonous chemicals, were set off by odors released from adhesives being used by carpet layers.[1017]

Solvent-based adhesives can be very odorous, but in recent years many manufacturers have begun developing water-based products that are much healthier. As with most water-based products, they do require some time to outgas. Adhesives are formulated for specific applications, so a product designed for paper or wood won't necessarily work well with metal or glass. Following are some adhesives that are among the healthier products currently available.

AFM produces a low-tox Safecoat 3-in-1 adhesive suitable for a variety of applications.

Chicago Adhesive Products Co. manufactures several adhesives that have low-VOC emissions, are non-flammable, and have anti-microbial properties. Their product line includes multi-purpose adhesives, carpet adhesives, a cove-base adhesive, pressure-sensitive adhesive, clear-spread adhesive, and a ceramic-tile adhesive. They contain no solvents or carcinogens.

Dap, Inc. has some low-tox adhesives. The have a white glue (Weldwood Hobby 'n Craft Glue) and yellow glue (Weldwood Carpenter's Glue) that can be used for general

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1016 "Progress on Carpets," *Indoor Air Quality Update* (May 1991): 1-5.

1017 Small sidebar, *Seattle Times* (June 16, 1990).

purpose projects or cabinet making. They also have a low-VOC water-based contact cement and a construction adhesive.

Elmer's Products, Inc. makes several low-emission adhesive products that are often well tolerated by sensitive people. Elmer's Glue-All (white glue) and Elmer's Carpenter's Wood Glue (yellow glue) are both widely used in cabinet making, as well as for around-the-home projects. Elmer's Saf-T Contact Cement can be used to adhere plastic laminates in cabinetry and countertops, and can be used with leather, polystyrene, and metal.

Franklin International has a low-odor, water-based Titebond Solvent-Free Construction Adhesive that is actually stronger than many solvent-based products, and is often tolerated by sensitive people after it's cured. They also offer a solvent-free water-based contact adhesive that works well in a variety of applications such as adhering plastic laminate in making countertops. Other solvent-free products include a Cove Base Adhesive, an FRP Adhesive, a Subfloor Adhesive, and a yellow carpenter's glue (Titebond II Wood Glue) that is weatherproof, making it suitable for outdoor use.

OSI Sealants offers a solvent-free PL Premium construction adhesive. It's stronger than conventional construction adhesives, it cures faster and, because there are no solvents, it goes up to twice as far as some other products.

W.F. Taylor Co., Inc. produces a line of Envirotec Healthguard adhesives that contain no solvents, alcohol, glycol, ammonia, or carcinogens. They have a Multi Purpose Adhesive, Bond-N-Peel Pressure Sensitive Adhesive, Bond-N-Peel Top Bond Adhesive, Clear Thin Spread Adhesive, Latex Additive Floor Sealer, Cove Base Adhesive, All Vinyl Adhesive, and a Release-A-Bond Carpet Adhesive.

If you must remove an adhesive, it can be a very difficult process. After ripping up old carpeting, one individual resorted to using a floor sander to remove the glue, but the sanding disk kept clogging. Eventually, he learned that there was less clogging if he first sprinkled silica sand on the floor, but it still took over 120 man-hours to remove all the adhesive from the 1,000 sq. ft. concrete floor slab.[1018] If you try this, you must wear respiratory protection because a great deal of sanding dust, and dust from the silica sand, is kicked up into the air. Both can lead to lung disease.

Lubricants

Lubricants are often very odorous, and they can contaminate the indoor air. E-Z-1 Lubricant (**E-Z-1, Inc.**) is a low-odor alternative. It's available in some hardware stores or it can be mail-ordered from **E.L. Foust Co., Inc.** or **Allergy Relief Shop, Inc.**

Graphite can be used in some applications, but it can be messy, and graphite dust shouldn't be inhaled. Another alternative lubricant is pharmacy-grade mineral oil which can be obtained through drug stores. **Dow Corning** has an FDA-approved food-grade #316 Silicone Release Spray that is not a true lubricant, but it can be used in some lubricating applications.

Summary

[1018] Dave O'Holleran, Personal correspondence, November 21, 1989.

There are certainly a number of paints, finishes, caulkings, adhesives, and paint removers on the market that are healthier than products from the past—after all, we don't use lead paint anymore. In general, the water-based products are more benign than the solvent-based products. For very sensitive individuals, or those wanting products that are healthier-than-average, there are a number of alternative products that are available, usually by mail. The various manufacturers have different ideas as to what makes a product healthy. Some rely on naturally derived raw materials, others opt for low-outgassing, synthetic ingredients. One approach isn't inherently better or worse than the other, they are just different.

Because all paints, finishes, adhesives, and caulking materials require an outgassing period, sensitive people should test materials ahead of time in order to select a product that will be tolerable in the shortest time. For a few individuals, this can be as long as two or three months—even for low-outgassing products. Obviously, this can cause some major inconveniences, but it is far better to know about it *before* beginning a project, so proper precautions can be taken.

In selecting paints and finishes, you must set up your own criteria, and choose accordingly. A healthy person concerned about the ecological devastation being wreaked on planet Earth may choose all-natural products because many of the ingredients are derived from renewable resources. On the other hand, a chemically sensitive person may only be able to tolerate a low-outgassing, synthetic finish. Choose intelligently, and no matter what product you choose, apply it with adequate ventilation.

21. Kitchens and Bathrooms

Kitchens and bathrooms tend to be the most complicated rooms in houses because of the cabinetry, appliance, electrical, plumbing, and ventilating requirements. These things all combine to make kitchens and bathrooms unhealthy, especially for sensitive people.

Cabinetry

Cabinets can be among the most polluting components of a house. This is because practically all commercially manufactured cabinets are partially constructed with plywood, particle board, or medium-density fiberboard—products that outgas formaldehyde for years. Cabinet doors and drawer fronts are often solid wood, but shelves and end panels are almost always manufactured wood products—even in expensive cabinetry. Some components may appear to be made of solid wood but a close examination will usually reveal that they are veneered, having only a thin layer of expensive hardwood over a core of manufactured wood.

Sometimes a manufacturer's literature states that their cabinets are made of solid wood. But if you ask them "Do you use plywood?," they will say "Yes, plywood is solid wood." No matter how you define solid wood, most cabinet-grade plywood contains urea-formaldehyde glue which is a potent formaldehyde emitter.

The majority of wood-cabinet manufacturers also use a urea-formaldehyde clear finish that is significantly more potent than the glue used in manufactured wood products.[1019] In fact, these finishes actually generate formaldehyde as they cure, so much so that there is 2-8 times more formaldehyde emitted than existed in the original liquid finish.[1020] It is usually referred to as an acid-catalyzed finish, and it outgases at such a high rate that it tends to decrease in potency by 82-96% after 4-6 months.[1021] So, it is very potent for several months, then the finish is considerably less volatile.

As with paints and finishes in other segments of industry, kitchen-cabinet finishes are in the process of changing. In a study that looked at the sealing ability of various other clear finishes, it was determined that formaldehyde emissions were significantly lower when non-formaldehyde-based finishes were used on kitchen cabinet materials.[1022] However, other VOCs besides formaldehyde can be emitted from various finishes. In the

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1019 "EPA examines indoor emissions from conversion varnishes," *Inside IAQ* (Fall/Winter 1995): 3. #EPA/600/N-95/007.

1020 "Indoor emissions from conversion varnishes," *Inside IAQ* (Fall/Winter 1998): 14.

1021 Thad Godish and Carlos Guindon, "Formaldehyde from U-F resin finish coatings" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 3, Characteristics of Indoor Air*, 1990): 689-693.

1022 "Reducing emissions from engineered wood products," *Inside IAQ* (Spring/Summer 1998): 8-11.

future, as worker-protection and environmental regulations become stricter, cabinet finishes may no longer be potent formaldehyde sources.

The good news is that, while the choices are limited, healthy cabinets are available. Because cabinets can be a significant outgassing source, they should be selected with care—especially if you are chemically sensitive. Because everyone is biochemically unique, sensitive people should only use materials that have been tested for personal tolerance.[1023]

When you are designing your kitchen layout, you may want to include a cabinet designed for goods to be recycled.[1024] But when you store empty cans and jars indoors in a recycling bin, be sure they are clean, or else they can harbor mold or attract insects.

Cabinetry doesn't need to be confined to bathrooms and kitchens. For example, healthy cabinets can be built into a bedroom closet to eliminate the need for dressers. This can be an important component of a bedroom oasis. For someone sensitive to printing ink, or the moldy smell of old books, bookcases with glass doors will prevent the odors from permeating the house. Similarly, glass doors on display cabinets filled of collectibles will isolate their particular smells from the occupants. A cabinet over the washer and dryer can be a good place to store laundry detergent.

Conventional Cabinets

Outgassing from existing cabinets can be lessened in a couple of ways. However, remedial measures are often not good enough for sensitive people—they may need to have offensive cabinets removed.

With new cabinets, one of the best things to do is uncrate them, open all the doors and drawers, and store them in an uncontaminated garage for the 4-6 months it takes for the potent clear finish to outgas. Of course, this won't have much effect on the outgassing from manufactured wood products because they can release formaldehyde for several years.

Some of the sealants mentioned in the last chapter can substantially reduce formaldehyde emissions—although perhaps not enough for sensitive people. To be most effective, all surfaces must be coated—top, bottom, front, back, and edges. Covering cabinets with aluminum foil can also reduce emissions. While aluminum foil isn't very durable, it can be used on some interior surfaces that don't get a lot of abuse.

Manufactured wood products that are covered with dense plastic laminates—such as European-style cabinets—can have lower emissions than manufactured wood products covered with a wood veneer that is stained and coated with a clear finish. Manufactured wood products covered with a vinyl material have also been shown to have lower emissions than those with a veneer, stain, and clear finish.[1025] To be the most effective,

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[1023] Preston Sturgis, "A healthy perspective on kitchen remodeling," *The Human Ecologist* (Winter 1993): 9.

[1024] Paul Turpin, "Small kitchen recycling center," *Journal of Light Construction* (May 1991): 35-36.

[1025] "Reducing indoor air emissions from engineered wood products," *Inside IAQ* (Spring/Summer 1996): 5.

the laminate or vinyl must cover all surfaces—top, bottom, front, back, and edges. On many commercially made cabinets there are some edges that aren't covered. Also, many of these cabinets have holes drilled in the inside of the end panels for shelf-support clips, and a certain amount of formaldehyde can leak out of the holes.

Cabinets that are 10-20 years old will have lost a significant amount of formaldehyde during that period of time, so they may no longer be a serious problem. If you are planning on replacing them, you might consider a face lift instead—to avoid the formaldehyde in new cabinets. For example, there are companies that specialize in installing new fronts on old cabinets. Because the fronts are often solid wood, redoing just the fronts of the cabinets can be both less expensive and healthier—if you can get a company to use a low-tox clear finish. If you can't find a supplier in the yellow pages, you might ask a custom cabinet maker if they will take on such a job.

If you are considering conventional cabinetry, or are chemically sensitive and are contemplating one of the low-outgassing options below, you won't know for sure if you will tolerate the new cabinets until you actually have them. Here is something you can do to put your mind at ease prior to purchasing an entire kitchen. Simply buy a single cabinet, and test it for personal tolerance. If it is a stock cabinet, ask ahead of time if it will be possible to return it. If it is custom-made cabinet, returns are usually not possible. In any case, you might order a small bath cabinet for a lavatory, or a small kitchen cabinet that will fit into your future kitchen layout. Then place the cabinet next to your bed and see if you notice any difference in how you feel, or how you sleep. Sometimes symptoms will show up quickly, but they can sometimes take a few days. If you can't tolerate the single cabinet, the odds are against tolerating an entire kitchen. Granted, you may have a cabinet on your hands that you can't use, but that is much better than purchasing an entire kitchen you can't spend any time in.

Low-Outgassing Wood Cabinets

There are only a few companies currently manufacturing cabinets that are specifically designed for reduced formaldehyde emissions. These are somewhat healthier than most cabinets, but they could bother sensitive people.

Neff Kitchen Manufacturers Ltd. uses both solid wood and marine-grade plywood (which is made with PF glue) for their cabinets—instead of plywood or particle board held together with a potent UF glue. Plus, the plywood they use is made of a hardwood (poplar) rather than a softwood such as pine. Their drawer sides are anodized aluminum, and drawer bottoms are stainless steel. They also offer stainless-steel drawer organizers and chrome-plated-wire organizer racks. For paints and clear coats, they primarily use an acrylic-polyurethane finish, which has a high-solids (low-solvent) content, but it is not a water-based finish. Neff also offers cabinets with a stainless-steel look, but they contain some marine-grade-plywood components.

The Naturals Collection cabinets from **Neil Kelly Cabinets** are made with sustainable or recycled wood and a choice of environmentally friendly finishes (water-based, natural oils, or low VOC paints). Standard interiors are made of "laminated wheatboard." However, Medite II (a medium-density fiberboard made without formaldehyde glues) is offered as an option. A variety of attractive styles and finishes are available. These cabinets are made on a "per order" basis to insure consistency and quality, and are primarily available in the Pacific Northwest.

Steel cabinets

Steel cabinetry with a baked-on finish can be a low-outgassing choice. While it is still possible to purchase plain white steel cabinets, which are reminiscent of the 1950s, more attractive cabinets in a variety of colors with textured finishes—like refrigerator doors—are also available. Even though steel cabinets often have baked-on finishes, some have a residual paint order that requires a certain amount of time to dissipate.

Some cabinets are being manufactured that, on first glance, look like they are made of steel, but are, in fact, wood/steel hybrids. They use typical construction for ends, shelves, and back panels, such as particle board or plywood (containing UF glue) that has been veneered or laminated. The doors and drawer fronts appear to be stainless steel, but close examination often reveals particle board or plywood with a thin stainless front surface. So, if you are after all-steel cabinets, look carefully.

Ampco has several sizes of base and upper cabinets in two color choices: white or almond. They have adjustable shelves, nylon drawer guides, and concealed hinges. These are low-cost cabinets. They don't contain any asphaltic materials, but do have some cardboard inside the doors for sound deadening. These cabinets can be special ordered through both Ace Hardware stores and Tru-Value Hardware stores.

Arctic Metal Products Corp. has a line of steel cabinets mostly in a white low-tox powder-coated finish, although some styles are available in other colors. They offer individual kitchen cabinets, wardrobe cabinets, broom cabinets, and storage lockers. These are also low-cost cabinets, and some have a sound deadening cardboard inside the doors, but none contain any asphaltic materials.

Dwyer Products Corp. primarily manufactures mini-kitchens that have cabinets, counter, stove, sink, and refrigerator all in one compact unit. But, on special order, they can supply very attractive individual steel cabinets that can be combined into almost any kitchen layout. These cabinets have a baked-enamel finish in several colors, or in stainless steel. The surface can be either smooth or textured. The hollow metal doors have a soundproofing material inside them, but it can be omitted on special request. These cabinets can also be ordered with solid-wood fronts and doors.

Fillip Metal Cabinet Co. has a low-cost, metal, kitchen-cabinet line in one color —white—with a baked-on powder finish. They are not available in an extremely wide variety of sizes, but enough sizes are produced to put together a healthy, low-cost kitchen.

Kitchens and Baths by Don Johnson produces a line of attractive Healthy Green Steel Cabinets. These cabinets are specially designed for chemically sensitive people. They have a low-tox, baked-on, powder finish in a number of standard colors. Power finishes contain no solvents, and they tend to be very inert after they are baked on. These cabinets can also be made completely of stainless steel at only a modest cost increase over painted cabinets. They are also available with solid-wood doors and drawer fronts in a variety of woods, styles, and finishes.

At one time, St. Charles steel cabinets were recommended for chemically sensitive people, but the original parent company no longer exists. During the process of going out of business, St. Charles was split into two parts (residential cabinets and commercial cabinets), and auctioned off. The residential line (which still carries the St. Charles name) no longer consists of all-steel cabinets. The steel residential cabinets are now made with a combination of particle board and steel. However, the all-steel commercial cabinets, which are often used in schools and laboratories, can still be obtained through the **St. Charles Mfg. Co.** commercial division. They are virtually the same as the old all-steel residential cabinets.

Custom-Made Cabinets

One of the healthiest cabinet choices is also one of the more expensive—having cabinets custom made. Most cabinet makers routinely use manufactured wood products, so when you ask them to use anything else, they often refuse. Or they charge a substantial premium. Because cabinetry is potentially so polluting, this is often a place where you should spend some extra money, rather than save a little cash and compromise your health.

For cabinet shops who want to use less-polluting materials, **Cab Parts** offers a wide variety of ready-cut component parts. They can supply (on special order) veneered cabinet sides, end panels, *etc*. made with Medite II (a medium-density fiberboard made without formaldehyde glues).

Charles R. Bailey Cabinetmakers makes custom cabinetry out of solid wood for chemically sensitive people. These are very attractive, well-made cabinets. They will use any type of wood or finish the customer tolerates, and they will ship anywhere in the U.S.

Solid-Wood Cabinets

The most obvious way to avoid manufactured wood products is to have cabinets made of solid wood. However, building cabinets using solid wood requires some extra thought—primarily because wood expands and shrinks with the seasons. A hundred years ago, craftsmen understood how to work with solid wood, but many of today's cabinet makers have grown up with particle board and plywood—and they don't often fully understand the requirements of building lower base cabinets out of 24"-wide solid-wood panels. While it's virtually impossible today to find a single board 24" wide, it's easy to glue up several narrow boards to a 24" width (be sure to specify a low-tox adhesive). But a panel of wood that wide can expand and shrink up to $^{1}/_{2}$" over the course of a year due to seasonal humidity changes. Cabinets must be designed to allow for such expansion and contraction. It can certainly be done, and there are craftsmen still around who work with solid wood every day—It's just that they can be difficult to locate. You might ask the local lumber yard, a hardwood supplier, or a high school Industrial Arts teacher for a reference.

Upper cabinets are usually only 12" deep. Being made with narrower boards, they expand and shrink less, so they are easier to construct with solid wood. Some people have used glass shelves inside upper cabinets.

Most cabinet shops are used to making doors and drawers out of solid wood, but they often use a manufactured wood product for drawer bottoms. A material that is easy to substitute is a thin piece of galvanized steel, something available from most sheet metal shops. You can also use stainless steel, but it's more expensive, and may need to be special ordered. To further avoid manufactured wood products, cabinet backs can be left off. Without a back, some cabinets are not as sturdy, so they must be handled more carefully during transport, but once installed, they can be as sturdy as any other cabinet. When you open such a cabinet, instead of seeing a back panel, you will see a painted wall. If you must have a back, you can use sheets of galvanized steel or stainless steel.

Young Furniture is a regional manufacturer (in the Northeastern U.S.) of attractive solid-wood kitchen and bath cabinetry. These cabinets are made of either pine or red birch. The red birch versions use some pine parts to keep costs down. End panels and shelves are solid wood. Drawer bottoms are typically plywood, but on special request $^1/_2$" solid-wood can be substituted. The backs on their standard upper cabinets are also plywood (the lower cabinets don't have backs.). On special request, upper cabinets can be made either without backs or with $^1/_2$" solid-wood backs. Or you could remove the plywood backs before you install the cabinets. This cabinetry is unfinished, so you can finish it yourself, or have someone locally do so for you, with a low-tox product.

Hybrid Wood/Metal Cabinets

There are a couple of ways to get around working with very wide solid-wood panels, and both involve making cabinets out of a combination of solid wood and sheet metal. First of all, you can buy low-cost steel cabinets and remove the fronts, then replace them with solid-wood fronts. This can often be done by a competent cabinetmaker at a reasonable cost. Once the fronts are removed, you may need to construct a wood frame (generally called a *face frame*) and attach it to the front of the metal cabinet. Then, the hinges of new solid-wood doors can be attached directly to the wood face frame. The frame should be sized carefully, so the existing steel drawers (which have been fitted with new solid-wood fronts) can be reused. Sometimes, it's necessary to make new solid-wood drawers, that are slightly smaller, to fit the new face frame.

Another solution is to combine a solid-wood face frame and solid-wood end panels with metal shelves. Solid-wood end panels are routinely made in many cabinet shops in a frame-and-panel pattern and in several styles. If an end panel is semi-hidden (*e.g*. if it abuts a wall, or another cabinet) it can be made with a wood frame and a galvanized-steel center panel. A metal panel won't be as attractive as a solid-wood panel, but you'll only see it when looking inside the cabinets—it won't be visible when the doors are shut. Once the face frame is attached to the end panels, galvanized-sheet-metal shelves can be fabricated to fit between the end panels and screwed in place.

Countertops

There are a variety of materials that can be used for countertops.[1026] They vary in healthfulness, cost, availability, appearance, and durability. Most can be used in either bathrooms or kitchens. In fact, they can often be used on cabinetry in any room—for example, on a desk or built-in cabinet in a den, recreation room, or bedroom.

Plastic Laminate

High-pressure plastic laminate is one of the most widely used countertop materials because of its durability and low cost. The plastic laminate itself is about $^1/_{16}$" thick and it must be glued to a heavier base material to produce a sturdy countertop. In the vast majority of installations, it's glued to particle board which, of course, releases formaldehyde. If you open a cabinet and look up at the bottom of the countertop, you will

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[1026] David Sellers, "Kitchen Countertop Materials," *Practical Homeowner* (February 1989): 42-47.

generally see exposed particle board. The glue used to attach the laminate to the particle board is most often a solvent-based contact adhesive.

The plastic laminate itself is a very hard and dense material and many sensitive people tolerate it reasonably well. The problem is primarily the particle board underneath the laminate (usually called the *substrate*), and secondarily, sometimes the adhesive. There are a number of ways to reduce emissions, but extremely sensitive people should generally use a different material.

To reduce emissions, you can specify that construction-grade plywood be used for a substrate instead of particle board, because it will have a lower formaldehyde emission rate. Even better—you could use a medium-density fiberboard that contains no formaldehyde-based glue at all. But keep in mind the fact that some low-formaldehyde products are made of pine, a wood that can bother some sensitive people.

You can't adhere high-pressure plastic laminate to a solid-wood substrate because the solid wood expands and contracts too much with the seasons, so there would be too much warpage. But it is possible to use sheet metal as a substrate—but care must be taken because metal expands and contracts as the temperature changes, but laminate expands and contracts as humidity changes.[1027] This can lead to some warping and delamination.

The formaldehyde emissions from a countertop made with particle board can be significantly reduced if laminate is glued to the top, bottom, and all edges. Plastic laminate is actually a very good diffusion retarder, so if the substrate is completely encapsulated with it, emissions will be minimal. Aluminum foil securely taped to the underside of the particle board or several coats of a sealer will also help.

The solvent-based contact adhesive most often used to attach the laminate to the substrate is not a serious emitter once dry, plus it's always underneath the dense laminate. However, there are less-toxic water-based contact adhesives readily available that can be substituted.

Manufacturers of plastic laminate include **Formica Corp.**, **Nevamar**, and **Wilsonart International**. For a different look, laminate is available with a metal facing. Formica Corp. and Nevamar have it in anodized aluminum (colored to look like stainless steel, chrome, copper, or brass) and **Wilsonart International** has aluminum or brass colors. **Outwater LLC** distributes the NuMetal brand of plastic laminate which is available with either an anodized aluminum facing, with a real stainless-steel facing, or a real copper facing. In general, these metal-faced laminates use relatively thin metal foils, so they are designed for vertical surfaces, and are too soft to be used on countertops.

Stone

Solid stone can be used for a countertop. Materials such as marble and granite are very attractive, and they are popular with bakers—but they can be expensive. Granite is virtually indestructible, and you can set hot pots on it. It resists scratches very well, and hot oil is about the only thing that can stain it.

Marble, on the other hand, is more prone to staining than granite, it's softer and

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[1027] Formica Corp., *Fabrication Data Sheet: Formica Brand Laminate Veneered to Metal Surfaces* (Cincinnati, OH: Formica Corp. Technical Services, n.d.)

more easily scratched, plus it can discolor if a hot pot is placed on it.[1028] It also requires a sealer—such as water glass (sodium silicate), which is available from **AFM** (Penetrating Water Stop and Water Shield) and **Aqua Mix** (Penetrating Sealer). A very similar product, available from **Concure**, is made of *potassium* silicate, and is called a Concrete Flooring Sealant.

In general, marble tops are better suited for bathrooms than kitchens because they receive less abuse there. However, a section of marble is sometimes set into a kitchen countertop of another material for someone who prefers a marble surface for preparing pastry or candy. Other natural stones that are less commonly used for countertops include slate and soapstone. Suppliers of slate, marble, and granite countertops include **Georgia Marble Co.**, **Structural Slate Co.** and **Westchester Marble & Granite**. Widely used in harsh laboratory and industrial applications, soapstone sinks and countertops will last a lifetime. They can also be used in residences and are available from **Vermont Soapstone Co.**

Granite deposits often contain radon, so granite countertops can be a source of the gas. Actually, many stones contain radon in small amounts. However, stone materials are usually dense enough that most of the gas remains trapped within the rock, where it goes through its normal radioactive-decay process. Radon is only a problem if you inhale it and it decays in your lungs so, in most cases, stone countertops are not a significant source of radon. But some rocks contain more radioactive material than others, and if they are porous or cracked, there will be more surface area, thus more material is exposed to the air, and there is the possibility of more radon being released. In one unusual instance, high radon levels measured in a bedroom were traced to two large granite headboards. When they were removed (it took six people to lift each one), radon levels went down substantially.[1029]

Artificial Stone

Solid-surfacing materials are artificial-stone products that are generally composed of marble dust and a plastic resin (usually acrylic or polyester). They are homogeneous, meaning they are uniform in composition all the way through. They can have an odor when they are cut or glued together, but once fabrication is complete, they tend to be fairly inert. The various manufacturers use different ingredients[1030] that have different outgassing characteristics, so very sensitive people are urged to test a sample for personal tolerance. Corian (**Du Pont Corian**) is an acrylic product that is often tolerated by sensitive people. Other manufacturers include **Avonite**, **Formica Corp.** (Surell), **Swan Corp.** (Swanstone), and **Wilsonart International** (Gibralter).

Solid-surfacing countertops can be solid all the way through. This makes for the most inert installation, but it can be expensive, so many fabricators adhere a $^1/_4$" or $^1/_2$"

[1028] "Granite and Marble: Which Makes the Better Kitchen Countertop?," *Fine Homebuilding* (November 1996): 132-133.

[1029] John Banta, Personal communication.

[1030] Chuck Green, "Solid Surface Update," *Journal of Light Construction* (November 1996): 46-49.

layer of solid-surfacing material to a substrate of particle board or plywood. This results in formaldehyde outgassing from the bottom. Outgassing can be minimized by specifying a low-formaldehyde product, or a thicker solid-surfacing material with no substrate.

Solid-surfacing countertops can be fairly expensive, compared to using a plastic laminate, but they can also be very attractive. Various styles of pre-molded sinks are available that can be inserted.

While solid-surfacing materials are routinely used in bathrooms, the artificial-stone material most often used for lavatory tops is referred to as cultured marble. Cultured marble is made differently than a solid-surfacing material. It is usually a mixture of marble and limestone dust combined with polyester resin and having a decorative surface.[1031] The color does not extend all the way through the material, and the surface is protected with a plastic resin. These countertops generally have a sink already molded in place. They are reasonably well tolerated by sensitive people, less-expensive than solid-surfacing materials, but more easily damaged.

Ceramic Tile

Ceramic tile is a popular material for use on countertops. Installation methods and materials are similar to those discussed with ceramic-tile floors earlier. The healthiest method of installing tile on a countertop involves a thick mortar bed with a mortar of Portland-cement paste, but this can be expensive. More commonly, a $^1/_2$"-thick cementitious board is attached to a plywood base with thin-set mortar, then the tile is attached to the top of the cementitious board with another coat of thin-set. The plywood, with its formaldehyde emissions, can be avoided by using two layers of cementitious board, laminated together with thin-set. Sometimes cementitious boards have a slight odor—which can outgas downward, into the lower cabinets. If you trowel a coat of thin-set on the bottom surface before the boards are installed, this is often enough of a sealant for sensitive people.

Disadvantages to using ceramic tile on countertops include the fact that foods or beverages can stain the grout joints, and the working surface is not perfectly smooth. Petroleum-based sealers should never be used because they will contaminate food placed on the countertop, but water-glass (sodium silicate) sealers work very well on grout. (The use of larger tiles will minimize grout joints.) Sodium silicate is available from **AFM** (Penetrating Water Stop, Grout Sealer, and Water Shield) and **Aqua Mix** (Penetrating Sealer). A very similar product is available from **Concure** that is made of *potassium* silicate. Their Concrete Admixture can be mixed into wet grout before it is placed (10 oz. per 100 pounds of grout), and their Concrete Flooring Sealant can be applied to grout after it has hardened.

Countertop inserts, such as those made by **Vance Industries**, can provide a flat, smooth, non-porous surface cutting surface. They are made of tempered glass in a variety of patterns with a stainless steel rim. They are scratch-, stain-, and heat-resistant and come in three sizes.

The joint between a ceramic-tile countertop and a ceramic-tile backsplash can be prone to cracking if grouted, thus providing a place for mold to grow. Caulking, which is

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1031 Ray Brewer, Cultured Marble Institute, Personal correspondence.

more flexible than grout, is a much better material to use in such joints.[1032] Chemically sensitive people often use DAP Kwik-Seal Tub and Tile Caulk (**Dap, Inc.**).

Wood

Wood chopping-block countertops can be quite attractive, but they eventually age and split. It's been widely believed that they harbor mold and bacteria[1033] so they are no longer used in commercial kitchens. However, until recently, there was no research that actually evaluated the safety of preparing food on wooden cutting surfaces. Then, in 1993, a team at the University of Wisconsin-Madison's Food Research Institute purposefully contaminated both wood and plastic cutting surfaces and they were surprised at the results. On the wood surfaces, most of the bacteria died, but on the plastic surfaces the bacteria survived.[1034] These findings were soon contradicted by the **National Sanitation Foundation (NSF)**, a non-profit organization that certifies products relating to public health.[1035] **NSF** compared the viability of *E. coli* bacteria on both wood and plastic cutting surfaces and found there was no difference in the bacterial growth on either surface.

Wood isn't necessarily a healthy countertop material—it's just no different than plastic as far as supporting microbial growth. Actually, it's important to keep all countertops clean and free from microorganisms—especially if they are used for cutting meat because meat is frequently contaminated with bacteria.

Some new wood countertops are coated with water-repellent preservatives that can cause problems for sensitive persons. The glues used to laminate wood countertops together can also be bothersome to some people. Manufacturers of wood countertops include **Bally Block Co**., **John Boos & Co**., and **Michigan Maple Block Co**. Unfortunately many of these wood countertops are held together with a urea-formaldehyde glue or are coated with a urea-formaldehyde clear finish. **Block Tops, Inc.** makes tops of maple or oak with a polyvinyl glue (like Elmer's white glue), then coats them with one of two oil finishes. Wood countertops can also usually be custom made by local cabinetmakers out of any wood. In general, in damp locations, like kitchens or bathrooms, a wood countertop is probably not the best choice. But they can work well for cabinets in living rooms, dens, or closets.

Metal

[1032] Paul Turpin, "Substrates for Ceramic Tile," *Journal of Light Construction* (May 1992): 40-41.

[1033] Debra Lynn Dadd and Alan S. Levin, *A Consumer Guide for the Chemically Sensitive* (San Francisco: Nontoxic Lifestyles, Inc., 1982): 133.

[1034] Agricultural and Consumer Press Service, *New Study Shows Wood Cutting Boards, Not Plastic, are Safer for Food Preparation* (Madison WI: College of Agricultural and Life Sciences, 1/21/93).

[1035] George A. Kupfer, *News Release: Tests Conducted by NSF International Indicate No Difference in Safety Between Wood and Plastic Cutting Boards* (Ann Arbor, MI: NSF International, August 18, 1993).

Stainless steel makes an excellent countertop material. It's durable, non-toxic, non-staining and easy-to-clean. Widely used in commercial kitchens, it's also popular with homeowners.[1036] Stainless is generally regarded as the healthiest countertop material available.

Sometimes, thin 18-ga. stainless steel is used, but it needs a backing of plywood to add rigidity. Heavier 14 ga. material is stiff enough that no backing is necessary, but sometimes a few stiffening ribs are added. If a backsplash is desired, it can be extended all the way up to the bottom of the wall cabinets. Countertops and backsplashes are routinely made in one easy-to-maintain piece. Sinks can be welded into the top for a completely seamless installation, however this can add considerably to the cost because welds must be polished until they are invisible.

Stainless-steel countertops must be custom fabricated for each installation. Look in the telephone book under *Restaurant-Equipment Suppliers*, or ask at a sheet-metal shop for a near-by fabricator. Most sheet-metal shops can work with stainless, but they often don't have the facilities to properly weld and polish corners and seams. Occasionally, fabricators apply a soundproofing material to the back side of the stainless steel. This should generally be eliminated because of its outgassing potential. **John Boos & Co.** offers several sizes of freestanding stainless-steel work tables.

Early in the twentieth century, some individual kitchen cabinets, and some tables, had tops made of porcelainized steel. These were quite inert and fairly durable, although they could be chipped by a falling cast-iron frying pan. In fact, most of the porcelain tops seen in antique stores are badly chipped. No one currently makes porcelain countertops, so if you want one, it will need to be custom made. There will be a limit to the size that can be fabricated, because the fabricator will need to run the top through an oven to fuse the glass-like surface.

Storage Concerns

When odorous belongings are stored inside cabinets, odors can build up there, then be released into the room whenever the cabinet doors are opened. However, this isn't always a significant problem. Here's why. When inside a small enclosed space, an item will continue outgassing until it reaches an equilibrium with the concentration of pollutants in the air inside that space. Once equilibrium is reached, the outgassing will slow down and stop. If the door is opened, the contaminated air will flow into the living space and be quickly diluted—it's often diluted enough that it isn't bothersome. Then, when the door is closed, the outgassing again slowly fills the cabinet. If a bothersome item is stored in the room itself (or the cabinet door is left open), it will continue outgassing until it's in equilibrium with the air in the entire room. A room filled with contaminated air can be much more bothersome than the amount of polluted air in a small cabinet after it's released into the room and diluted. The important factor is the concentration of contaminants in the occupied space.

Closets

[1036] Patrick Galvin, "The Choice of a Metal Countertop," *Custom Builder* (November/December 1993): 50-51.

A closet can be thought of as a large cabinet—or a small room. If bothersome belongings are stored in a closet, their outgassing will fill the entire closet until equilibrium is reached. When the door is opened, a larger quantity of contaminated air will spill into the room—much more than when the door of a small cabinet is opened.

Opening contaminated cabinets or closets may only be an occasional, periodic problem—such as with a display cabinet that's only opened once a year. But, some cabinets and closets might be opened several times a day. The more often a cabinet or closet containing contaminating contents is opened, the more likely the concentration of pollutants released into the rest of the living space will be bothersome.

It's not unusual for closets to get moldy. This often occurs because of localized areas of high relative humidity. For example, if one or two walls of a closet are exterior walls, they will be cooler in the winter, thus there will be a high relative humidity near them. Clothes can insulate a wall, making it cooler yet. Corners are particularly susceptible to high relative humidity and mold growth.[1037] Many people leave a light on in their closet to combat mold, but it is not the light itself, it is the heat given off by the bulb that helps—it raises the temperature in the closet, which results in a lower relative humidity.

It's possible to mechanically ventilate both closets and cabinets. In that way, fresh air can continually pass through them and carry pollutants or offensive odors outdoors. If ventilation causes warmer house air to enter a cold closet in the winter, it will warm the closet and help reduce the chance of mold growth. This is generally more important with closets than with cabinets because closets are larger, and they can release a larger volume of air when the door is opened. An even more effective solution is to get rid of as many bothersome belongings as you can. After all, it makes little sense to build a healthy house, then fill it with polluting belongings. On the other hand, we all have things we can't possibly part with, some of which are going to be bothersome. As a compromise, a sensitive person might discard some items, store some in small cabinets, some in sealed cartons, some in ventilated closets, and some outside the house—perhaps in the garage.

The closets in which you store clothing should be as inert, and mold-free, as possible. If not, various odors or contaminants can penetrate the clothing then, when you wear it, you will be surrounded by a cloud of pollutants.

Closet Shelving

Closet shelves can be made of a variety of materials. Solid-wood boards used to be common but, today, medium-density fiberboard and plywood shelves are more widely used. They should be avoided because of formaldehyde emissions, but if such shelving is covered on all surfaces with a hard-plastic laminate, the emissions will be reduced considerably.

Most metal shelving/storage systems are quite inert and well tolerated by sensitive people. Soft, vinyl coatings tend to outgas more than harder baked-on finishes. Clothing stays fresher on "ventilated" wire shelving because air can circulate around it freely. These storage systems can also help you keep your closets much more organized. Manufacturers include **Closetmaid**, **Lee Rowan**, and **Schulte Corp.** Wire storage

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1037 Marc Rosenbaum, "Why does mildew grow in closets?," *Journal of Light Construction* (February 1992): 35.

systems can also be used in pantries, garages, and workshops.

Gregory Wood Products, Inc. makes an attractive, solid-wood, slatted, "ventilated" shelving system out of ash in a choice of pickle white, brown, or clear finishes. The shelving is available with or without a garment rail for coat hangers. They also offer a solid style shelving that is made with plywood.

Shelves can be custom-made of galvanized steel or stainless steel. If they aren't going to be used for storing heavy items, $^{1}/_{4}$"-thick glass shelves can be used.

Cedar is often used to line closets to repel moths, but research has shown that cedar isn't an effective deterrent.[1038] Actually, the main way a cedar chest prevents a moth infestation has little to do with the cedar—if the chest is tightly constructed and it has a tight seal, moths simply can't get inside. So, one of the best moth deterrents is to store woolens in tightly sealed containers such as plastic bags or securely sealed nylon garment bags. Sensitive people are almost always bothered by cedar's natural aroma, so cedar is not recommended in healthy houses.

Sinks and Bathtubs

Kitchen sinks are made from a variety of materials: artificial stone, stainless steel, porcelainized steel, and porcelainized cast iron. In general, all these materials are healthy and well tolerated. Some stainless steel sinks have a soundproofing material added to the back side. Many soundproofing materials don't outgas very much, but occasionally an odorous tar-like soundproofing is used.

Bathroom sinks are only occasionally made of stainless steel. Porcelainized-steel sinks are more widely used, as are those made of solid-surfacing materials, and vitreous china. A number of companies offer vitreous-china pedestal-base sinks. One-piece cultured-marble sink/countertops are also popular.

The choice of a sink material is primarily one of personal taste, rather than healthfulness. Stainless-steel sinks are usually used in stainless-steel countertops and sinks made from solid-surfacing materials are generally combined with countertops made of the same material. However, you can easily mix different materials for a particular look. Porcelainized sinks can add color to a room, with the cast-iron versions being more durable (and more expensive). Drop-in sinks are much easier to replace if they become damaged, than sinks welded or molded in place. But drop-in sinks have a seam around the perimeter that can harbor mold growth if not kept clean.

Bathtubs made of either porcelainized-steel or porcelainized-cast-iron are well tolerated. Porcelainized-cast-iron tubs are heavier, more durable, and more costly. They often have a coating on the back side but it won't be exposed to the living space once installed. Fiberglass and acrylic tubs, and one-piece tub/shower combinations, are also available. Some sensitive people do not tolerate these materials, primarily when new, but after they've aged, they tend to be fairly well tolerated. Fiberglass is generally more inert than acrylic, although the back side of a fiberglass unit can be more bothersome than the finished front surface. Some tubs have foam insulation or particle board stiffeners on the bottom or rear. (Again, the back side won't be exposed to the living space once installed.) Sensitive people often opt for a one-piece fiberglass tub/shower combination because,

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[1038] Olkowski, *Common-Sense*, 198.

having no seams to harbor mold, it's easy to keep clean. One-piece fiberglass shower stalls are also available. Outgassing can be minimized by purchasing the unit early in the construction process and allowing it to air out outdoors. Fiberglass can generally tolerate the ultraviolet from sunlight, while some other plastics might discolor if left in the sun.

Besides the one-piece fiberglass units, there are several choices for shower walls. Ceramic tile is widely used. The healthiest ceramic-tile installation is generally over a thick mortar bed or, more commonly, over a cementitious board using thin-set mortar to attach the tile. Corner seams, which are prone to cracking, should be caulked, not grouted, to minimize mold growth. If allowed to remain damp, the grout joints between the tiles can get moldy, so be sure the bathroom has plenty of mechanical ventilation to dry everything out quickly. Ceramic-tile floors in showers are not considered waterproof unless they have a seamless plastic or metal (*e.g*. lead, copper, galvanized steel) liner under them. Such liners must be installed with care.[1039] Although they can be made leak proof, liners of hot-mopped asphalt are quite odorous and should generally be avoided in healthy houses.

Acorn Engineering Co. has a very contemporary Neo-Metro collection that includes bathtubs (one style), wall-mount sinks (two styles), and pedestal sinks (two styles) that are made entirely of heavy, industrial-gauge stainless steel. They are all available with either a satin or a high polish finish.

Diamond Spas, Inc. also has a number of stainless-steel bathtubs and sinks. They also offer stainless-steel spas, and they do custom work.

Prefabricated wall surrounds for showers or tubs are widely available that are made of various plastics. They have some outgassing characteristics, but can be tolerable after aging. Unlike fiberglass, they shouldn't be left outdoors to air the sun to age because they can discolor and degrade somewhat. Some of the more inert plastic surrounds are made of sheets of the solid-surfacing materials used for kitchen countertops, such as that made by **Du Pont Corian** (Corian) and **Swan Corp.** (Swanstone).

Porcelain panels can also be custom-made to fit a shower or tub surround. They can be fabricated in a color to match a tub, but can be costly. The **Porcelain Enamel Institute** can give you the name of a nearby fabricator. Stainless-steel panels can also be an option. If they are installed over a solid surface, such as drywall, they can be made of a lower-cost, thin-gauge material. Stainless is very inert, and high-tech looking, but can tend to water-spot. Some less-expensive pre-fabricated shower stalls use steel walls with a baked-enamel finish that is low-outgassing.

Bathtub and shower doors often have mold growing in the lower guide track and in the trim around the glass doors. A solution is to select a model with a free-draining lower track, and doors that have no trim. Instead of metal trim around them, these doors have polished glass edges. They are usually called *frameless* doors, and there are a number of manufacturers, including **Alumax Bath Enclosures**, **Basco Co.**, **Duschqueen, Inc.**, **Sterling Plumbing Group**, and **Work Right.**

Toilets

[1039] Scott Duncan, "Leakproof Shower Pans," *Journal of Light Construction* (November 1989): 17-19.

Vitreous-china toilets can be found in several different styles and colors, and they are quite inert from an outgassing standpoint. However, toilet tanks are notorious for sweating in some humid climates. This occurs because the tank is filled with cool water, which causes the surface of the tank to also be cool. Moisture in the bathroom's air then condenses on the cool surface, where it can eventually lead to a mold problem. **American Standard Inc.** has a Cadet Series that can be ordered with an optional insulated tank to minimize the sweating problem. **Kohler Co.** and **Universal-Rundle Corp.** have several models available with insulated tanks to minimize sweating, as do other manufacturers. The insulation—usually a foam product—lines the inside of the tank and prevents the outer surface of the tank from becoming cool enough for room air to condense on it. Because the foam is inside the tank (and under water most of the time) it's not an outgassing problem.

It's easier to keep the outside of a one-piece toilet clean and mold-free, than a two-piece toilet. This is because it can be difficult to clean between the separate tank and bowl. Most major toilet manufactures make one-piece models.

Acorn Engineering Co. has a very contemporary Neo-Metro collection that includes three toilet styles (One commercial and two residential styles) that are made entirely of heavy, industrial-gauge stainless steel. A urinal is also available and they are all made with either a satin or a high polish finish.

Ventex Systems Corp. markets a toilet with a built in ventilating fan to clear a bathroom of odors quickly, and a retrofit kit for adapting their exhaust system to existing toilets. **Fan America, Inc.** offers a Fantom kit to add ventilation to an existing toilet. These products are designed to minimize odor migration from the toilet into the rest of the room or the rest of the house.

Toilet seats are commonly made of either hard or soft plastic or painted particleboard. Hard plastic seats generally outgas the quickest. Solid-oak seats are also available that are well tolerated after the finish outgases.

Accessories

Metal or wood can be used for towel racks, toilet-paper holders, toothbrush holders, medicine cabinets, and other fixtures in kitchens and bathrooms to minimize outgassing, but plastic fixtures usually aren't significant outgassing sources, especially if they have had some time to age. Towel racks should be wide enough to hold bath towels without folding them, so they can dry quickly after being used.

Mirrors are often attached to walls with a mastic or an adhesive. This should be avoided in favor of screws and clips. Horizontal aluminum tracks are also available that attach to the wall at the top and bottom of a mirror.

Appliances

Appliances can sometimes be significant contributors to indoor air pollution. For example, electric motors can give off ozone or outgas from paint, lacquer, or synthetic components as they warm up. Most appliances are made, to some extent, with plastic components that have the capacity to outgas. Some contain pumps or rubber hoses which sensitive people find problematic when they get warm. Appliances are discussed more completely in other sources.[1040] [1041] Because of their complexity, there are no truly non-toxic appliances. But, there are some healthier features.

Refrigerators

Sensitive people are often concerned about the fact that refrigerators are lined with plastic, which has the potential to outgas. However, plastics tend to outgas more when warm, and less when cold, so a plastic liner inside a cold refrigerator is rarely a significant outgassing source. With a new refrigerator, the paint on the coils can get hot and can be bothersome, but this generally dissipates with time.

A more common health-related problem with refrigerators has to do with mold growth—in the drip pan. Unknown to many homeowners, self-defrosting refrigerators have a drip pan under them, near the floor. After each defrost cycle, the melted frost runs down through a plastic tube into the pan, where it eventually evaporates. There is often a small fan that blows air across the coils to cool them, and across the drip pan to help evaporate the defrost water. However, sometimes enough water remains in the pan for a long enough period of time that it becomes a haven for mold. It's important to get down on your hands and knees, remove the piece of trim at the bottom of the refrigerator, and clean the drip pan regularly to minimize mold growth. Periodically cleaning the coils will allow the unit to operate more efficiently, so it won't need to run as long.

Cooking

Many cooks prefer cooking over an open gas flame because it can be regulated quickly. However, gas stoves release combustion by-products, many of which can be measured in the air of the kitchen. Studies have found that children are more likely to have respiratory symptoms if gas is used for cooking, rather than electricity.[1042] [1043] Researchers have also found that women who use gas for cooking have a significant increase in symptoms such as wheezing, waking with shortness of breath, and asthma attacks, and they are twice as likely to have impaired lung function than women who cook with electric stoves.[1044]

It's been estimated that, when a typical gas oven and three burners are turned on, the same amount of combustion by-products are released as from a typical gas water

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1040 Dadd, *Nontoxic and Natural*.

1041 Bower, *Creating a Healthy Household*.

1042 R.J.W. Melia, C. duFlorey, and S. Chinn, "The relation between respiratory illness in primary schoolchildren and the use of gas for cooking: I—Results of a national survey," *International Journal of Epidemiology* 8 (1979) 333-353.

1043 Frank Speizer and others, "Respiratory disease rates and pulmonary function in children associated with NO2 exposure," *American Review of Respiratory Disease* 121 (1980): 3-10.

1044 D. Jarvis and others, "Association of Respiratory Symptoms and Lung Function in Young Adults with Use of Domestic Gas Appliances," *The Lancet* 347 (1996): 426-431.

heater. All gas water heaters must be connected to a chimney. Gas stoves are never connected to a chimney, but they often do have an exhaust hood. While gas stoves are not recommended in healthy houses, if you insist on using one, you should have an overhead range hood that is exhausted to the outdoors, and you should use it every time the stove is operating.

Electric stoves are much healthier by comparison, but they aren't perfect. For example, spiral or solid-disc heating elements sometimes bother sensitive people, despite the fact that they are made of a ceramic-like material. Some people have gone to a second-hand store and traded bothersome burners from their new stove for used burners that have already had time to outgas. The glass-topped stoves are better tolerated, and easier to keep clean.

Continuous-cleaning ovens outgas whenever they are turned on. Self-cleaning ovens only outgas significantly when the high-temperature cleaning cycle is activated, but they can be bothersome to sensitive people even during normal operation. To minimize this, a stove can be placed in a garage (if there is a 220-volt outlet there) and run through several cleaning cycles to burn off any bothersome odors. Some sensitive people have found that it takes 20-30 cleaning cycles before a new oven is tolerable.

Microwave ovens are extremely popular, but some experts don't like them. In his book, *The Smart Kitchen*, healthy-food guru David Goldbeck lists 38 warnings that, he feels, federal law should require on all microwave ovens. He is concerned about the interaction between food and the packaging used in cooking, food-related injuries, microwave-related injuries, microwave-emission standards, and food safety. If you insist on using one, Goldbeck suggests you stand 4' from an operating microwave, particularly if you are pregnant.

Dishwashers

Dishwashers are very complicated pieces of machinery, with pumps, motors, hoses, and vinyl or plastic parts—all of which can outgas when warm. There are models that are lined with stainless steel, and models that are very energy efficient, but none that are particularly tolerable for sensitive people. Odors from synthetic dishwashing detergents can also be bothersome. The best way for a sensitive person to use a dishwasher is to activate it, turn on the range hood for extra ventilation, and leave the room. If the kitchen can be isolated from the rest of the house by closing a door, so much the better. Eventually, as the synthetic components age, a dishwasher can become more tolerable than it was when new.

If you are leery of installing a built-in dishwasher because of potential outgassing, it's still a good idea to design the cabinetry so there is a 24"-wide cabinet next to the sink. That way, at a future date, you have the option of removing the cabinet and installing a 24"-wide dishwasher in its place.

Two companies (**Asko, Inc.** and **Bosch Appliances**) offer dishwashers that are very quiet when compared to other models. Plus, they have stainless-steel interiors and both typically use only half the water and about two-thirds the energy of conventional dishwashers. While they have clear environmental advantages, they are probably no more or less healthy than other dishwashers. **KitchenAid** also manufactures dishwashers with stainless-steel interiors.

Disposing of Trash

Garbage disposers are a good way to get rid of food scraps quickly, rather than allowing them to stand in a trash container and get moldy. While they have an electric motor that has the potential to be bothersome when running, they generally aren't operated for extended periods of time, so they aren't significant polluters. A trash compactor, on the other hand, can have bits of food in it for several days, so it can easily become a home to mold.

Recycling bins in a kitchen can be a good idea. But the cans, bottles, and other recycled items, must be thoroughly cleaned and dried—or else they can get moldy.

Many health-conscious people put their garbage in compost piles for their organic gardens. Compost piles should be located downwind of the house because they are sources of mold.

Washing Machines and Dryers

Washing machines, like dishwashers, contain motors, pumps, and hoses, that can be problematic for sensitive people. In addition, various chemicals can be released from cleaning products, or volatilized from the water, when washing clothes.[1045] Whenever a dryer is operating—and blowing air outdoors—the area is actually being ventilated. So, odors given off by the washer are often not a problem, because they are exhausted by the dryer.

Gas-fired clothes dryers have been found to contaminate clothing with by-products of combustion, so electric dryers are preferred. Some energy-conscious people vent their clothes dryer into the living space. This is not a healthy thing to do—clothes dryers should always be exhausted outdoors to expel the large amounts of moisture present in dryer exhaust. Dryer exhaust also contains allergenic lint and various odors from cleaning products, clothing, dyes, and fabric finishes. Where a clothes dryer is a considerable distance from an exterior wall, the exhaust duct can be quite long. This can result in a great deal of resistance to the airflow, and insufficient dryer exhaust. **Fantech, Inc.** has an automatic dryer exhaust fan that can be used in such situations to boost the airflow out of the building.

It's not a good idea to dry clothes on racks indoors because that can also introduce a great deal of moisture into the indoor air, and too much moisture indoors often leads to mold growth.

The lint in the exhaust from a clothes dryer can, over the years, build up in the exhaust duct. In 1987, the **CPSC** reported that there were 13,900 clothes-dryer fires in the U.S. that resulted in 20 deaths and 180 injuries.[1046] Lint build-up is more of a problem in flexible plastic duct than in rigid metal duct because there are more ridges for it to catch on. Still, it is a good idea to inspect and clean all dryer-exhaust ducts periodically. This

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1045 C. Howard and R.L Corst, "Volatilization of chemicals from drinking water to indoor air: the role of residential washing machines," *Journal of the Air Waste Management Association* (October 1998): 907-14.

1046 Jeff Gaydos, "When lint clogs a dryer duct: Fire!," *The Detroit News* (April 17, 1990): C1.

can often be done at the same time heating/cooling ducts are cleaned. The **Home Trends** mail-order catalog sells a 10'-long flexible brush designed for cleaning 4"-dryer exhausts.

Where outdoor venting isn't possible (as in some apartment buildings) **Asko, Inc.** offers a special condensing clothes dryer. The condenser pulls humidity out of the exhaust air in the same way a dehumidifier or air conditioner does, and deposits it in a pan that can be pulled out and emptied. (It can also be hooked up to a drain.) This is the only type of clothes dryer that does not need an outdoor vent. **Asko, Inc.** also has a water-conserving clothes washer.

Ventilation

Kitchens require local ventilation, usually in the form of an overhead range hood, to exhaust cooking odors and moisture before they can travel into the rest of the living space. Cooking odors often contain grease and should not be ducted through a heat-recovery ventilator, because the grease can build up in the core and cause a fire. Devices designed to be kitchen exhausts are designed to handle grease.

Kitchen exhausts can also be useful to expel odors from dishwashers and self-cleaning ovens. If a kitchen has an operable window, it can be opened to help clear the room quickly when the fan is operated at high speed.

Sometimes an individual appliance can be provided with its own ventilation system. For example, some sensitive people have installed a small, low-powered exhaust fan behind the refrigerator to expel odors from the hot coil outdoors, and to add to the general ventilation requirements of the rest of the room.

Local ventilation is important in bathrooms to rid the room of both excess moisture and unpleasant odors.

Summary

Kitchens and bathrooms are complicated rooms, and they require considerable thought and planning. Because there are so many possible unhealthy materials, health must be an integral part of such planning right from the beginning. Because the available options for healthy cabinetry are somewhat limited, it's important that the cabinets be addressed early. Too often, people wait until construction on their new house is almost complete then, when they start thinking about cabinetry, they realize it's too late to have healthy cabinets or stainless-steel countertops custom built. If you wait until the last minute, you're often stuck with unhealthy materials.

22. Plumbing Systems

There are several mechanical systems in houses. We've already discussed heating, cooling, filtration, and ventilation systems and how they interact. This chapter will cover plumbing and water filters—and how they impact the health of the occupants.

Plumbing

A plumbing *supply* system carries water into a house, where we drink it, use it for laundering clothes, preparing food, flushing toilets, bathing, *etc*. Once we are done with the water, a plumbing *drain* system carries it away from the house to a sewer or septic system.

All water supplies contain some contaminants, and water can pick up additional contaminates as it passes through municipal water-treatment plants, water mains, supply piping, and fixtures. Water is said to be a universal solvent. This means that virtually anything can be dissolved in it—the good, the bad, and the ugly. Water is absolutely vital to life, so it should be as healthy as possible.

Piping is often run through holes cut in studs, floor joists, and drywall, resulting in gaps where air can leak into building cavities and the living space. *Chapter 9, Tight construction* discusses how to seal many of these locations using caulking, gaskets, aerosol foam insulation, *etc*. For drain piping, **Ryeco Products** (R & S Enviro brand) offers a Plumb Seal gasketed device to seal around $1^1/_2$" or 3" pipes.

Water Supply

The water we use in our houses generally comes from a surface supply (rivers or lakes) or an underground source (a well). Lakes and rivers can be polluted because of agricultural runoff, direct dumping of pollutants by industry, seepage from septic tanks, and spills from sewage-treatment plants. The pollution in the St. Lawrence Seaway is bad enough that beluga whales living there are so loaded with PCBs their bodies are considered hazardous waste.[1047] Wells that pull water up from underground reservoirs—known as aquifers—are also often contaminated with toxic chemicals. This is especially common near landfills, or in agricultural areas where herbicides, pesticides, fertilizers, and other chemicals seep down through the soil into the aquifer.

You don't have to drink water to be affected by it. A major route of exposure to many water-borne chemicals is through the skin while bathing. One study found that up to 70% of the exposure in adults is through the skin.[1048] Another study found that an

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[1047] Glen Martin, "Deep Trouble," *Discover* (January 1993): 39-40.

[1048] Halina Szejnwald Brown, Donna R. Bishop and Carol A. Rowan, "The Role of Skin Absorption as a Route of Exposure for Volatile Organic Compounds (VOCs) in Drinking Water," *American Journal of Public Health* 74 (May 1984), 479-484.

equal amount of contaminants are inhaled when showering.[1049] There are fewer chemicals volatilized into the air from bath water than during showering,[1050] but an individual may have more prolonged skin contact with the water when bathing. Water supplies that come from wells can also contain radon, which is released into the air as water pours from the tap.

Public water supplies are disinfected to kill harmful microorganisms—usually with chlorine, but sometimes ozone, ultraviolet light, silver, iodine, or bromine are used. Many water utilities also add other chemicals, such as fluoride.

Regulations usually require public water supplies to be disinfected routinely, whether the water needs it or not. Chlorine is a very good disinfectant, but it's definitely not without risk. When it reacts with dissolved organic material in water, it produces, among other things, chloroform—a known carcinogen. Chloroform is in a chemical family known as trihalomethanes (THMs) which are very commonly found in water supplies. Chlorine can be so bothersome to some people that they cannot even bathe or wash their faces in water containing it—much less drink it.[1051] A number of studies have found a link between chlorinated surface water and increased cancer mortality.[1052] It's been estimated that there are 6,500 cases of rectal cancer and 4,200 cases of bladder cancer each year in the U.S. due to chlorinated water.[1053] Chlorine can also corrode the inside of galvanized-steel pipes.

Private water supplies, most of which are wells, are often not disinfected at all. So, it's not surprising that a study done by Cornell University found 63% of rural household water supplies were considered unsafe.[1054] A 1988 **EPA** study found dozens of different pesticides in ground water, 46 of which were attributed to normal agricultural use, and 32 were related to pesticide misuse.[1055]

Piping

1049 Clifford Weisel, Paul Lioy, and Wan K. Jo, "Exposure to Volatile Organic Compounds Resulting From Showering in Chlorinated Water" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 2, Characteristics of Indoor Air*, 1990): 495-500.

1050 Julian Andelman, Lynn Wilder, and Steven Myers, "Indoor Air Pollution From Volatile Chemicals in Water" (Berlin: *Proceedings of the 4th International Conference on Indoor Air Quality & Climate, Vol. 1, Volatile Organic Compounds, Combustion Gases, Particles and Fibers, Microbiological Agents*, 1987): 37-41.

1051 Randolph, *An Alternative Approach*, 226.

1052 "Water Filters," *Consumer Reports* (February 1983): 68.

1053 "How safe is chlorinated water?," *Safe Home Digest* (July/August 1992): 9.

1054 Roul Tunley, "Time Bomb in Our Tap Water," *Reader's Digest* (January 1985): 90-96.

1055 "EPA publishes pesticides in water database report," *Residential and Institutional Hygiene* (April 1989): 1.

There are three different piping systems in houses—supply lines, drain (waste) lines, and vents. Water enters through the supply lines. After we are done using it, the water passes into the drain lines. These systems must be kept separate to prevent the waste water from contaminating the supply water. The vent lines are actually a part of the drain system. The plumbing pipe sticking out of your roof is a vent pipe. Vents are necessary to allow the wastewater is to flow freely, without gurgling.

Some supply lines can contaminate the water inside them. Above-ground plastic supply lines can also outgas into the air. If drain lines contaminate wastewater, it won't affect your health—at least immediately. But it could contribute to planetary water pollution because many contaminates are not removed by sewage-treatment plants. Above-ground plastic drain and vent lines can also outgas into the air.

Supply Lines

The water mains that carry water to your house can contaminate the water within them. Underground water mains can be made of cast iron, ductile iron, galvanized steel, copper, asbestos cement, or plastic. If a water main is deteriorating—even slightly—contaminants can be transferred to the water supply. Ingesting water containing asbestos fibers released from asbestos-cement water pipes can result in an increased risk of gastrointestinal cancer. Plastic water mains, especially those glued together, can add VOCs to the water. Many people notice a funny plasticky taste when drinking water from a plastic container, evidence that the plastic is contaminating the water.

Sometimes, organic chemicals in the soil can permeate through underground plastic watermains and contaminate the water inside them. This is more of a problem where the ground is seriously contaminated, such as in the vicinity of a gasoline spill.

Private wells often use a pressurized tank to maintain water pressure in the house. Sensitive people tend to be bothered by tanks lined with plastic, or those containing a rubber bladder, more than plain galvanized-steel tanks. In the past, well-casing pipes and the water lines coming into the house were routinely made of metal, but today they are increasingly made of plastic.

There is little you can do about changing underground water mains. And, in most municipalities, some of the mains are so old, nobody even knows what they are made of. But you *can* filter the water as soon as it enters your house to remove any contaminates that were there originally, were added at the treatment plant, or were released by the mains.

You have more control of the piping that's actually inside your house—to a degree. For example, if an existing house has unhealthy piping, it can certainly be removed and replaced. But that can be expensive, time consuming, and disruptive. Pipes are often hidden inside walls, so replacing them means tearing into the walls, then repairing the damage.

While lead pipes are no longer used in new construction, they can still be found in some older houses. The lead can leach out into the water causing ill health.[1056] Galvanized steel pipes are much more inert, but they are rarely used today in residential construction because of increased costs. It's been suggested that some galvanizing

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[1056] Environmental Protection Agency (EPA), *Lead in Drinking Water* (Washington, DC: EPA, April 1987). #OPA-87-006.

processes can impart small amounts of cadmium into the water.[1057] In most cases, galvanized pipes are quite inert, but there are rare instances where problems have developed. One woman, after 17 years of investigating, got to the bottom of a health problem related to galvanized piping. She found a dead-end section of galvanized piping in which the galvanized coating had eroded away due to soft-water corrosion. This became a prime place for the growth of filamentous rods, bacterial and fungal spores, decomposing algae, and iron bacteria—all capable of producing toxins which could be aerosolized when water flowed from the tap.[1058]

Copper pipes are believed to be quite safe, but one writer has suggested that people can absorb enough copper from drinking water to result in a zinc deficiency.[1059] A more-significant problem with copper piping is the fact that the joints and fittings are usually soldered together. Prior to 1986, most solder contained a considerable amount of lead, and that lead could leach into the water. The amount of lead leaching into the water from solder (or lead pipes) depends on several different factors (*e.g.* the acidity or alkalinity of the water), and there are certainly installations where the lead remains in the solder and does not contaminate the water. Lead leaches into water slowly, so if you run the water for about 15 seconds, you will flush out most of the lead-contaminated water. Then the water drawn off after flushing will contain little lead. In a high-rise building with large-diameter pipes joined with lead-based solder, you may have to run the water for several minutes to flush out the lines. This can waste a great deal water and can be costly.

Another drawback to soldering copper pipe is the fact that the pipe must be coated with flux before soldering. A certain amount of flux can be transferred to the water and it can bother some sensitive people but, in most cases, the flux is eventually flushed out of the lines. In the actual soldering process, plumbers typically heat the pipes with a small gas-fired torch. The burning gas, and the hot solder and flux, release combustion by-products into the air that should be removed from the house quickly with extra ventilation.

In order to eliminate soldering completely in a new installation, flared brass fittings, or brass compression fittings can be used to assemble copper pipe. This tends to be more expensive and more prone to leaks, and it usually isn't necessary because, today, federal law prohibits the use of lead-based solder in houses. Just to be extra safe, one sensitive individual went so far as to use stainless steel for some plumbing lines—an expensive and extreme measure.[1060]

Various kinds of plastic piping are being used more and more to reduce costs. However, sensitive people sometimes complain about water from plastic pipes tasting like plastic. The piping can also outgas slightly into the living space and contaminate the air—especially when used for hot-water lines. PVC plastic has been shown to outgas

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1057 Zamm, *Why Your House*, 131.

1058 Shari Van Enkevort, "Toxic Galvanized Steel Plumbing," unpublished manuscript.

1059 Golos, *Coping*, 196.

1060 Tom Kinder, "Safe Water Pipes," *Greenkeeping* (March/April 1992): 23.

diethyl phthalate, trimethylhexane, aliphatic hydrocarbons, and aromatic hydrocarbons.[1061] However, outgassing from hard plastic water lines is usually not significant. (Softer, flexible plastics tend to outgas more than hard plastics because of plasticizer additives.)

The cleaners and glues used with plastic piping are actually much more polluting than the pipe itself—contaminating both water and air. Plumbers who work with glues and solvents regularly are urged to do so with plenty of ventilation. When used indoors, the area should be aired out until the odors dissipate completely. These materials are quite volatile, so they outgas fairly quickly—usually in a matter of hours. However, they can contaminate the water inside the piping for an extended period of time. The water can be turned on and allowed to run for a while to flush out the pipes, but the chemicals will volatilize into the air, so ventilation is again necessary. Another solution is to install an activated-carbon filter to capture any volatilized chemicals in the water. **Oatey Co.** manufactures cleaners and glues for various types of plastic pipe, most of which are high-VOC products. They also offer a line of LO-VOC versions, but they are still quite odorous, and they are comprised of at least $^{1}/_{3}$ VOCs. These lower-VOC cleaners and glues aren't readily available in all parts of the country (they are primarily marketed in California).

The Gorilla Group has a Gorilla PVC glue that is different in formulation from all the other PVC glues in use. It can be used directly on PVC pipe without a cleaner. It is advertised as being non-toxic and odorless, yet it does have a minor odor. However, the odor is much less than most other PVC glues.

If the temperature and humidity conditions are right, moisture from the air can condense on cold-water supply lines. This sweating can drip onto surrounding building materials and result in a mold problem. This type of condensation can be prevented by using pipe insulation. If the insulation is bothersome to a sensitive person, it can be wrapped with aluminum foil to minimize outgassing.

Drain Lines

The material used for drain lines and vents isn't nearly as important as that used for supply lines, simply because they do not carry water that will be consumed. Most drains and vents are constructed of cast iron, galvanized steel, copper, or plastic. Plastic lines are considerably less expensive that the alternatives, but they can outgas into the air —primarily from the glues and solvents used to assemble them. However, once the outgassing from the glue dissipates (usually within a few hours), the plastic itself isn't a significant outgassing source. But it can be bothersome to some sensitive people—especially if they are exposed directly.

There are actually several things that can be done to minimize outgassing from plastic drains and vents. Plastic drain lines that are underground, or cast inside a concrete slab, are well-separated from the living space, so plastic used in those locations is generally not a problem. Plastic drain lines within the house itself, or inside building cavities can be wrapped with aluminum foil to prevent outgassing into the living space.

[1061] Linda S. Sheldon and Kent W. Thomas, "Volatile Organic Emissions From Building Materials," (Minneapolis, MN: *Paper #86-52.3 presented to the 79th Annual Meeting of the Air Pollution Control Association*, June 22-27, 1986).

In addition, the plastic pipe can be purchased early in the construction process and allowed to outgas before being installed. If these precautions are taken, plastic piping is often acceptable in a healthy house—particularly for drains and vents.

Backflow

It's important that supply lines and drain lines be separated and not interconnected. It they are connected together, the wastewater could easily pollute the supply water. While this doesn't seem like a strong possibility, there are some situations where it does occur. For example, there is an overflow pipe attached to a temperature-and-pressure relief valve on a water heater that is sometimes connected directly to a drain. While the valve rarely opens, if it does, there can be a direct pathway from the drain into the hot water tank. This is called *backflow contamination*.

In the case of a water heater, backflow contamination can be prevented by having an air gap between the end of the overflow pipe and the drain itself—something that is required by building codes. Backflow contamination can also occur when lawn chemicals flow backwards into a lawn-sprinkler system, when a hot-water or steam heating system is interconnected with a drinking-water supply, or when someone is unclogging sewer lines with a garden hose.[1062] Prevention can be as simple as installing a backflow-prevention valve, something that is available from local plumbing suppliers. Using a garden hose connected to a sprayer containing chemicals can allow the chemicals to travel backwards into the water supply. This can be prevented by attaching the hose to a sillcock fitted with a backflow-prevention device.

In one unusual case, an exterminator was using a client's garden hose to power his pesticide sprayer. At the same time, the water utility was doing some repair work to a water main. There was a drop in water pressure, and pesticides were pulled backwards into the main. The resulting contamination lead to $60-65 million in lawsuits, and all the plumbing and water-related appliances (refrigerators, washing machines, dishwashers) in 19-20 houses had to be replaced.[1063] On a much smaller scale the same type of thing can happen with a kitchen-sink sprayer. If the sprayer is dropped into a sink of dishwater, and there is a drop in water pressure, it might pull dirty water back into the plumbing, which could be deposited into a cup of drinking water a little later.[1064]

Fixtures

The brass components used in some faucets can be contaminated slightly with lead. Some manufacturers use plastic components instead to avoid even small amounts of lead. Most faucets contain some plastic or rubber components that can leach into the water that's directly in contact with them. This leaching is a very slow process, so there isn't much water that's actually contaminated. When you turn the water on, if you let it

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[1062] Don Best, "Backflow Contamination," *Practical Homeowner* (April 1989): 24-25.

[1063] "Backflow: A Health hazard?," *Journal of Light Construction* (July 1990): 5-6.

[1064] Bob Wilson, "The hazards of water safety," *Home Improvement Center* (August 1992): 99-101.

run for a second or two before filling a drinking glass, the small amount of contaminated water will go down the drain.

When sinks and faucets are installed, they are often set into a bed of *plumber's putty*. This is to prevent water that gets splashed around the edges from running underneath the sink or faucet. Plumber's putty has a slight odor, but once a sink or faucet is installed, there is only a very thin line around the perimeter that is exposed to the living space, so it generally isn't a significant outgassing source. Because more plumber's putty is exposed at the underside of a sink, it has more potential to outgas downward into a cabinet. If this is bothersome, the underneath side can be covered with aluminum-foil tape. It's possible to substitute caulking for the plumber's putty, but this generally isn't recommended, because the caulking acts as an adhesive, making future removal of the sink or faucet difficult. Plumber's putty is formulated to remain flexible—and removable.

It simply isn't possible to eliminate all possible water pollution. Pumps, valves, dielectric fittings, *etc*. all contain various minor parts that could theoretically contaminate the water. The goal is to eliminate as many contaminants as reasonably possible then, if the water is still a problem for a sensitive person, a filter can be used to polish the water. Occasionally, some very sensitive people must resort to bottled water for drinking and cooking.

Water Heaters

Some water heaters can affect water quality, and some can also affect indoor air quality. Installation and operating costs vary, depending on the equipment chosen. In a combo system, a boiler can be used to provide both hot water for domestic use, and hot water for heating the house.

Some water-heater tanks have a plastic lining, but sensitive people generally prefer glass-lined tanks because they tend to be slightly more inert. The insulation, which is between the inner water tank and the outer sheet-metal shell, is either fiberglass or a foam product, both of which can outgas into the room's air when the tank gets hot. One way to minimize outgassing from either kind of insulation is to set the water heater's thermostat on high—while increasing the ventilation to the area—to speed up the outgassing rate. After a few days of outgassing, the thermostat can be turned back down to a normal setting.

Many water heaters contain a magnesium anode rod to inhibit corrosion. With some water supplies, the reaction between the water and the rod can result in the hot water having a "rotten egg" odor.[1065] This problem can be minimized by filtering the water, choosing a water heater with a plastic liner which doesn't require an anode, or by removing the anode—something that can shorten the life of the heater.

Solar

Solar water heaters can be a healthy option. Most are considered pre-heaters to be used in conjunction with a conventional water heater. There are two basic types of solar water heaters, but there are variations of each. *Batch water heaters* consist of a water tank mounted outdoors in an insulated box with a glass top. Sunlight warms the water in the

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[1065] J.D. Ned Nisson, "Water heaters—The quiet revolution," *Journal of Light Construction* (September 1990): 37-38.

tank, then it flows indoors into a conventional water heater to be heated up to a usable temperature. This is the lowest-cost and simplest approach. A *flat-plate collector* consists of a dark-colored outdoor panel that absorbs heat from the sun and transfers it to a fluid (usually antifreeze) which is pumped to a heat exchanger which, in turn, transfers the heat to the water in a conventional water heater. Some flat-plate collectors, if they are located lower than the water heater, don't require pumps.

Solar water heaters can be expensive to install—sometimes as much as $4,000. But they tend to be less costly to operate than other water-heating approaches. If you are considering a solar water heater, reducing your consumption should be a priority. This can be done by installing low-flow toilets, shower heads, *etc*. If you use less water, you lower your energy needs, thus the cost of the system.[1066]

The primary health consideration with solar water heating has to do with the potential for leaking antifreeze, but if a system is installed conscientiously, this shouldn't be a problem.

Electric

There are three types of electric water heaters. *Conventional tank-type water heaters* are the most common. They consist of a storage tank with two electric heating elements inside. Cold water passes through a tube inside the tank to the bottom, the two heating elements warm the water, then the hot water is drawn off at the top of the tank. *Tankless electric water heaters* are sometimes called demand water heaters. When you want hot water, an electric element heats it immediately. Because they don't have a storage tank, they can't provide a great deal of water at a time—they work best at providing small volumes of hot water. For example they might supply plenty of hot water for a low-flow shower head—but not enough to operate a washing machine at the same time. *Heat-pump water heaters* tend to be the most expensive to purchase—$1,000 to $2,000—but their operating cost is often less than half as much as conventional tank-type water heaters. **Crispaire** manufactures two models, one consists of a storage tank with an integral heat pump mounted on top. The other is installed in conjunction with a conventional electric water heater. They both extract heat from the air and transfer heat to the water. They also extract moisture from the air, so when installed in a damp basement or crawl space they act as a dehunidifier. More than 50% of the houses in Sweden use heat-pump water heaters that are combination water heaters and ventilators.[1067]

In one study, 39% of the conventional electric tank-type water heaters were found to be contaminated with *Legionella* bacteria which causes Legionnaire's disease.[1068] However, follow-up studies by the **Electric Power Research Institute** found no

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1066 Marc Rosenbaum, "Solar hot water for the '90s," *Fine Homebuilding* (July 1991): 50-55.

1067 "Half of new Swedish homes have exhaust air heat recovery ventilators," *Energy Design Update* (November 1993): 2.

1068 Michael Alary and Jean R. Joly, "Risk Factors for Contamination of Domestic Hot Water Systems by Legionella," *Applied and Environmental Microbiology* 57 (August 1991), 2360-2367.

significant association between electric water heaters and Legionnaire's disease.[1069] In the original study, none of the combustion-fired water heaters were contaminated. *Legionella* contamination was more common in older housing districts, where there was a lower water temperature (measured at the faucet), and in older water heaters. The reasons for this type of contamination are unclear, but one theory seems to have merit. Electric water heaters have a heating element several inches from the bottom, thus the water at the very bottom (which often contains sediment in older water heaters) may not be hot enough to kill the microorganisms. Most gas- and oil-fired water heaters have a burner underneath them, so the water at the bottom is hotter. *Legionella* will not survive at temperatures over 140˚F[1070], so even if there is a pocket of cooler water at the bottom of an electric water heater, any microorganisms should be killed before they exit the heater with the hot water. While *Legionella* does frequently contaminate domestic water supplies,[1071] no one really knows what the health implications are. However, Legionnaire's disease generally only affects immune-suppressed people—especially those immune-suppressed in their lungs, such as smokers. It also is more likely to affect alcohol abusers, transplant patients, people on high doses of steroids, cancer patients on chemotherapy, and AIDS patients.[1072]

Combustion-Fired

There are several types of combustion-fired water heaters. The *conventional tank-type water heaters* can be fired by either oil or gas. They are similar to conventional tank-type electric water heaters except that they have a burner under them instead of electric heating elements. The combustion by-products generally leave the house through what is called a "B Vent." *Tankless gas water heaters* are also similar to their electric counterparts, except for the fact that they have a burner instead of an electric heating element. Both of these types of water heaters must be connected to a conventional chimney to expel the combustion by-products from the house. *Power-vented tank-type gas water heaters* pull air from the living space, into the combustion chamber, where it mixes with gas and is burned. Then a fan blows the combustion by-products outdoors through an exhaust pipe. These are much less likely to leak combustion by-products into the living space. **Tjernlund Products, Inc.** and **Field Controls** make power-venting fans that can be adapted to existing conventional gas water heaters. The healthiest gas water heaters are *sealed-combustion tank-type gas water heaters*, which do not need a chimney. They pull outdoor air into a sealed combustion chamber and have a fan that blows the combustion by-products outdoors through a sealed plastic exhaust pipe. As was mentioned in *Chapter 7: Heating and Cooling*, these devices may not be *100% totally*

[1069] "No link between electric water heater and Legionnaire's disease," *Electric Consumer* (April 1996): 3.

[1070] "Integrating heating systems and bacterial growth," *Solplan Review* (January 1998): 7.

[1071] J.S. Colbourne, and others, "*Legionella* in public water supplies," *Water Science Technology* 20 (1988): 5-10.

[1072] "Bioaerosols can cause 'very, very, serious building-related illness," *Indoor Pollution News* (June 27, 1991): 4-5.

sealed, but they are so well sealed that they are generally well tolerated by people who are sensitive to combustion by-products. Manufacturers of direct-vent and power-vented gas water heaters include **GlowCore A.C. Inc.**, **Reliance Water Heater Co.**, **A.O. Smith Water Products Co.**(Power Shot), and **State Industries, Inc.** The “Select Power-Vent/ Direct-Vent” by **State Industries, Inc.** is a sealed-combustion unit that has both an inlet pipe and an exhaust pipe.

The most significant health-related problem with combustion-fired water heaters has to do with combustion by-products entering the living space. This occurs regularly in many houses because conventional chimneys are often prone to backdrafting and spillage. This problem can be minimized by choosing a power-vented unit or, even better, a sealed-combustion unit. Combustion by-products can also be avoided by mounting the water heater outside the living space. **Gas-Fired Products, Inc.** sells a Seahorse gas water heater that mounts on the outside of a house and transfers hot water into a storage tank located in the living space. **American Water Heater Co.** has a Weather-Pro gas water heater that is designed to sit outdoors. In general, outdoor water heaters should not be used in very cold climates because of the possibility of freezing. **Spacemaker Co.** has a metal water-heater enclosure that is designed to sit outdoors. It can be used to get a conventional tank-type water heater out of the house, but it is not insulated, so it’s only suitable for mild climates. There are also sealed-combustion, gas-fired, boilers that are used in combo systems that heat water for warming the living space as well as for consumption.

A growing problem with existing water heaters can occur when a new high-efficiency furnace (either power-vented or sealed-combustion) is installed, and the old combustion-fired water heater is left in place. The existing chimney, which used to carry combustion by-products from both the furnace and the water heater, now serves only the water heater, which may now be referred to as an “orphaned water heater.” While the chimney used to function just fine with both the furnace and the water heater, it is now oversized for just the water heater, and an oversized chimney doesn’t always function very well. Warm combustion gases in an oversized chimney begin to cool as they rise up it. If the gases cool too much, they never make it to the top, and they fall back down into the living space. In such a situation, you may notice condensation and corrosion on the vent pipe above where it connects to the water heater.

Water Quality

Pure water, H_2O, is virtually impossible to find outside a laboratory. In fact, thousands of different substances have been found in water. Not all these substances are harmful—in fact, a certain amount of dissolved minerals such as calcium, selenium, *etc*. can be very desirable. Minerals and other contaminates are what give water its taste. Water without minerals is said to be *aggressive*, meaning it can leach tastes, odors, or minerals out of whatever it touches. Drinking pure, aggressive water over a long period of time could leach minerals out of your body, and lead to deficiencies. So, the healthiest water isn’t necessarily the purest.

Some of the beneficial substances found in water are only beneficial in certain concentrations. For example, you may want a little calcium in your water, but too much calcium can build up in pipes and on fixtures, and contribute to hard water. As it turns out, water quality is more complicated than air quality. In fact it's a subject that deserves its own book.

This book's focus is on improving the quality of the indoor environment—primarily the quality of the indoor air. While water is a part of that environment, it's actually more related to food. After all, we *inhale* air but we *ingest* food and water. Of course, water can affect air quality—*e.g.* when VOCs from water are volatilized into the air when we take a shower. While it's impossible to do justice to the complexities of water quality and water filtration, in just a few pages, the following discussion will give you a general understanding of the subject. More complete coverage can be found in *Creating a Healthy Household* by Lynn Marie Bower.

When we ingest water, it acts as a solvent, a coolant, a lubricant, a transportant, and a dispersant.[1073] If it is highly contaminated, it can't perform these functions effectively. The contaminants routinely found in drinking water fall into four basic categories:[1074]

Particulates

Particulates are small bits of material that do not dissolve in water. They include such things as asbestos, heavy metals, rust, sand, sediment, or soil. If there are many particulates in your water, it can appear cloudy. This is called *turbidity*.

Dissolved Solids

Some solid materials *do* dissolve in water. They include fluoride, nitrates, sulfates, and salts. Fluoride is found naturally in some water supplies, but it is also purposefully added to water at some municipal treatment plants to reduce the risk of tooth decay. However, not everyone agrees that fluoridation is a good idea. Fluoride critics point out that fluoride compounds are actually fairly toxic chemicals, the evidence for a reduction cavities is unproved, and there's enough fluoride in a tube of toothpaste to kill a small child who ingests the entire contents.[1075] There is some evidence that fluoride can accumulate in the body and that it can corrode old water pipes and solder. It may also contribute to the slight corrosion of aluminum cookware. Nitrates are often found in water supplies in agricultural areas. They can interfere with the ability of red blood cells to transport oxygen. Lead is one of the most dangerous dissolved solids commonly found in water. If you suspect you have lead pipes, or copper pipes assembled with lead-based solder, you should have your water tested for lead contamination.

Volatile Chemicals

Volatile chemicals are substances that vaporize easily. Over 700 have been

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[1073] "Eat Right, Exercise and Drink Plenty of RO Water," *Water Technology* (August 1985): 46.

[1074] Debra Lynn Dadd, "Special Report: Water Filters," *Nontoxic & Natural Newsletter* (1985): 1.

[1075] Harriett Fels, "Fluoridation: Health Measure or Hoax?," *East West* (October 1989): 62.

identified in drinking water. They include several cancer-causing compounds. Typical examples include chlorine, chloroform, pesticides, and PCBs. When water is exposed to the air, some of these chemicals are quickly released, contaminating the air. This is particularly true if the water is hot. Chlorine is routinely added to many water supplies to kill microorganisms. This has indeed prevented many diseases—in the 1880s typhoid killed about 90 per 100,000 Americans, but today, the rate is only about 1 per 1,000,000.[1076] But chlorine is a fairly nasty chemical. It's been linked to heart disease, altered metabolism of fat and cholesterol, and cancer.[1077]

Biological Contaminants

Biological contaminants include both plant and animal life, such as microscopic bacteria, parasites, viruses, amoebae, molds, *etc*. Some of these microorganisms have been responsible for devastating health problems throughout history—such as typhoid fever—but today most municipal water systems use chlorine, or another disinfectant, to kill them. Unhealthy microorganisms can be found in many private wells, especially if a well too near a septic system.

Water Filters

Before you decide to filter your water, you first need to have some idea what contaminants are in it. Public water systems are required by law to have their water tested regularly so, if you are connected to such a system, you can ask for a water-quality analysis. If you have a private supply, such as a well, you'll need to have your water tested yourself at a private laboratory. Because there are so many possible contaminants in water, it's possible to spend hundreds of dollars on testing that you don't need. So, it helps to know what kinds of contaminants are common in your area. This kind of information might be available from a neighbor, your local board of health, or from a nearby municipal water system. Many local or state boards of health maintain a list of water-testing laboratories. Some local or state boards of health will actually perform testing, either at no charge or at a reasonable cost, if it's apparent that your health is at risk. **Suburban Water Testing Laboratories, Inc.** and **National Testing Laboratories** offer testing through the mail.

If a water filter is located on the incoming supply line, just after it enters the house, then all the water in the house will be filtered. This is considered a whole-house system, and it can be practical with some filtration strategies, but impractical with others. Individual filters, often called point-of-use filters, can be used at specific locations. For example, an under-sink filter in the kitchen is useful for filtering cooking or drinking water. Sometimes, a small filter is attached to a shower head to remove chlorine. Unfortunately, there is no single kind of filter that's suitable for all situations. Some remove certain contaminants very well, but leave other pollutants in the water untouched. In the 1980s, it was discovered that one manufacturer's portable filter cartridge was

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1076 Mark Mead, "Chlorination: Friend or Foe?," *East West* (December 1989): 32-39.

1077 *Ibid*.

actually adding methylene chloride, a possible carcinogen, to the water.[1078]

Because water filtration can be quite a complicated subject, it's often a good idea to consult a specialist for help in designing a system for your particular needs. Most cities have several listed under *Water Treatment* in the telephone book. Keep in mind the fact that many water-quality consultants make their money by selling equipment, so they may try to sell you more than you actually require. If you talk to more than one specialist, and they all know you are shopping around, they'll be more likely to only recommend the equipment you really need.

The **National Sanitation Foundation (NSF)** is an independent, not-for-profit organization dedicated to public safety and protection of the environment by developing standards and certification. All NSF-certified water systems are listed free-of-charge on their website, or in a booklet you can purchase. The **Water Quality Association** is a national organization for water-treatment equipment dealers, and they have some consumer-oriented materials.

There are a number of mail-order companies that handle a variety of water filters from different manufacturers, including **Allergy Relief Shop, Inc.**, **American Environmental Health Foundation**, **Befit Enterprises Ltd.**, **E.L. Foust Co., Inc.**, **N.E.E.D.S.**, **Nigra Enterprises**, **Pure Water Place, Inc.**, and **Ozark Water Services and Environmental Services.**

Sediment Filters

A sediment filter is very limited in what it can remove. They can remove heavy concentrations of suspended soil, but they do nothing to combat biological contaminants, chlorine, or other volatile chemicals. A sediment filter is often combined with another filtration strategy—sometimes in the same unit. Suppliers include: **Aquathin Corp.**, **Culligan International**, **Cuno, Inc.**, **General Ecology Inc.**, **Kinetico Water Systems**, and **Sears Roebuck and Co.**

Distillers

Distillation devices boil water into steam. The steam condenses back into water in another chamber, leaving behind dissolved solids and particulates.[1079] The heating process kills microorganisms in the water. Distillers allow some volatile chemicals to escape into the air, where they can be inhaled, while other volatiles remain in the water. Some distillers use a two-stage process, whereby most of the volatile chemicals are driven off first, then the water is boiled to remove the other contaminates. For a handful of very sensitive people, even triple distillation is not enough to render water tolerable.[1080]

Distillers have the potential to remove most of the contaminates found in water.

[1078] "A Good Reason to Shut Off Norelco's Water Filter," *Consumer Reports* (March 1986): 141.

[1079] "Treat your own water: Part one, the distillers," *Mother Earth News* (January/February 1980): 163-164.

[1080] Pfeiffer, *Household Environment*, 114.

They are fairly expensive to purchase and operate, and they are not practical as a whole-house method of cleaning up a water supply. Even when used just for drinking or cooking water, they can be inconvenient because they only produce a limited amount of pure water at a time, and they need regular cleaning. The distillation process removes oxygen from the water—making it somewhat acidic—and it removes virtually all the minerals. Stainless-steel distillers can produce water with a metallic taste. This is because the aggressive water leaches chromium out of the stainless steel during the distillation process. Aluminum can be leached from aluminum parts.

Because distillers operate slowly and do not provide water at the turn of a tap, a holding tank or storage jar is generally required. Typically, several gallons of water a day can be distilled and stored for use. Because distillers kill bacteria, they can be legally classified as water *purifiers*,[1081] whereas most other devices can only be called *filters*. Manufacturers include **Scientific Glass Co.** (an all-glass model) and **Waterwise Inc.**

Activated-Carbon Filters

Filters containing activated carbon are often referred to as taste-and-odor filters and they are very effective at removing volatile chemicals such as chlorine, chloroform, pesticides, *etc*. They will not remove dissolved solids, particulates, or kill microorganisms. In fact, bacteria can grow and multiply inside a granular-carbon filter. Chlorinated water can contain some bacteria that's not been killed by the chlorine, and this bacteria can actually grow in the carbon itself. This is most problematic if the water sits in the carbon for an extended period of time—especially over several days. The simple act of letting the water run for a while will flush out the filter and the lines, so many people recommend running the water in the morning (after it has been sitting overnight) for a minute before drinking any water from the tap.

Activated-carbon filters that utilize a block of carbon, rather than granular carbon, are much less likely to harbor bacteria. Some manufacturers add silver to granular carbon to kill the bacteria, but there is some concern that the silver can negatively contaminate the water. If chlorinated water is run through an activated-carbon filter regularly, and the filter is changed regularly, there is usually little danger from the small amount of bacteria present. Not all bacteria are harmful. In fact, some are very beneficial to human digestion. If you are on a public water supply that has been chlorinated, harmful bacteria probably aren't present, so activated carbon is usually a safe choice. But if you have a private water supply, harmful bacteria might be present, and the use of an activated-carbon filter can be risky.

Radon can be removed from water with the use of an activated-carbon filter, however many of the small filters on the market don't have enough capacity to result in much reduction. To be effective, a filter should contain 1-3 cubic feet of activated carbon, depending on the radon content of the water.[1082] Radon is not a widespread problem in water, but it can be in some parts of the country. It's been estimated that there about 200

[1081] "Treat your own water: Part two, the filters," *Mother Earth News* (February/March 1980): 160-161.

[1082] Sherman Hasbrouck and Linda Breece, *Removing Radon From Water Using Activated Carbon Adsorption* (Augusta ME: University of Maine, April 1987).

cancer deaths a year (160 from lung cancer and 40 from stomach cancer) due to radon in drinking water.[1083]

Activated-carbon filters are very good at removing chlorine and other volatile chemicals. The quantity of volatile chemicals removed by an activated-carbon filter is directly proportional to the amount of carbon in the filter. So, a very small filter can have the carbon depleted rather quickly, while a larger model might last for a month or more. Sometimes, if an activated-carbon filter is not changed regularly, it can begin unloading pollutants back into the water supply, but this has been noted only with filters containing powdered carbon.[1084] If you have a good sense of smell, you can often tell when it's time to change an activated-carbon filter—when the hot water starts smelling like chlorine. If your sense of taste is better than your sense of smell, you might start tasting chlorine when the filter begins to become depleted.

Activated-carbon filters are fairly inexpensive and they work well as either whole-house filters or point-of-use filters. There are no moving parts and the only maintenance involves periodic cartridge replacement. Housings are made of plastic or stainless steel. Small models are available for use on shower heads, faucets, or under-the-sink. Suppliers include: **Aquathin Corp.**, **Culligan International**, **Cuno, Inc.**, **General Ecology Inc.**, **General Electric**, **Honeywell Inc.**, **Kinetico Water Systems**, **Multi-Pure Corp.**, and **Sears Roebuck and Co.** A stainless-steel point-of-use filter is available from **Environmental Purification Systems** which uses granular activated carbon, rather than a replaceable cartridge, in order to avoid all plastic parts. And there is a unique kitchen faucet made by **Moen, Inc.** that has a built-in, replaceable, activated-carbon filter cartridge.

KDF filters contain a specially formulated material that can remove some of the same contaminants as activated carbon. In fact, it's been estimated that a KDF filter is ten times better at removing chlorine. A KDF filter can also remove lead from water, and it doesn't support bacterial growth, so it can usually be used safely on a private water supply where an activated-carbon filter may not be a good idea. Sometimes, KDF and activated carbon are combined in the same filter. KDF filters can put a tiny amount of zinc and copper into the water—but the levels are within the **EPA**'s drinking-water standards.[1085] They are available from **Global Environmental Technologies**.

Reverse-Osmosis

Reverse-osmosis filters are fairly advanced water-cleaning devices. They operate by forcing a stream of water through a semi-permeable membrane to rid it of dissolved solids, particulates, and bacteria. This membrane must be flushed clean by a second stream of water, which then directs the contaminants down the drain. The membrane can become clogged with bacteria, so some manufacturers recommend that reverse-osmosis

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[1083] "Regulatory limit for radon in drinking water proposed by EPA," *Indoor Pollution News* (June 27, 1991): 3.

[1084] "Water Filters," *Consumer Reports*.

[1085] Larry Stenger, Don Heskett, and Walter Ball, "Using an alloy to remove metals...and more!," *Water Conditioning and Purification* (June 1990).

filters only be used with chlorinated water supplies. A sediment filter is often used to remove most of the dissolved solids so the reverse-osmosis unit is not overwhelmed. Generally, reverse-osmosis filters are very good at removing all contaminates except volatile chemicals. They are not quite as effective as distillers, but they are easier to use.

These units have a significant drawback—they waste 3-10 gallons of water for each gallon that is processed. This is because the membrane needs constant rinsing. Their effectiveness is dependent on temperature, pH, and water pressure. Usually at least 30 pounds of water pressure is required. Like distillers, they only produce a limited amount of water each day, so a holding tank or storage jar is needed. They are not suitable as whole-house filters. Because they can remove minerals, some produce a slightly aggressive water. They can be relatively expensive, take up a lot of space in a cabinet, and periodic maintenance is required. The operating cost is less than when using a distiller, but more than with a carbon filter. Manufacturers include: **Aquathin Corp.**, **Clean Water Products**, **Cuno, Inc.**, **Culligan International**, **General Electric**, **Honeywell Inc.**, and **Kinetico Water Systems**.

Ultraviolet Light

Ultraviolet light can be used to kill microorganisms in a private water supply, such as a well, but it has no effect on other pollutants. Ultraviolet light can be a very efficient way to prevent waterborne diseases. It has been proposed as a reliable, low-cost disinfection process for third-world countries, costing approximately 2¢ per ton of water processed.[1086] **Nigra Enterprises** and **Ozark Water Service and Environmental Services** sell purifiers that utilize this principle. They can be used for drinking water, hot tubs, spas, or swimming pools. **Aquathin Corp.** also offers an ultraviolet-light purifier.

Swimming Pools

Chlorine is widely used to disinfect swimming pools. While it does a good job of killing bacteria, it is not a good chemical to be immersing yourself in. Fortunately, there are some solutions that are healthier. For example, **GFW, Inc.** has an ultraviolet-light unit for swimming pools.

BioLab offers a BioGuard SoftSwim Clarifier system that utilizes a 27.5% solution of hydrogen peroxide to kill bacteria in swimming pools. Its use doesn't result in the formation of chloroform, which is a drawback to using chlorine. Hydrogen peroxide is an odorless, but powerful, oxidant that is effective at killing bacteria. It must be handled carefully.

Another approach is offered by **Wailani**. They have an electronic device that puts copper and silver ions into the water to kill microorganisms. It has been used successfully by chemically sensitive people who are bothered by chlorine. According to one chemically sensitive man, it made swimming in his pool seem like swimming in a mountain stream.[1087]

[1086] "UV waterworks: Reliable, inexpensive water disinfection for the world," *Center for Building Science Newsletter* (Winter 1996): 6-7.

[1087] Lew Bartley, Personal communication.

Water Softeners

Water softeners are usually not considered water-cleaning devices. They improve water's sudsing ability, but not the water's quality. This saves on soap costs and makes cleaning easier. Hard water contains more dissolved minerals than soft water, primarily positively charged calcium and magnesium ions. The most popular residential method of softening water involves the *zeolite process*. Water softeners of this type utilize salt to cause an exchange to take place between the calcium and magnesium ions in the water and the sodium ions in the salt. With this method, hardness can be reduced substantially, and the water takes on a slippery feeling. Unfortunately, water conditioned in this way is high in sodium, which can be hazardous to the health of people on sodium-restricted diets. Manufacturers of water softeners that use salt include **Culligan International**, **Cuno, Inc.**, and **Kinetico Water Systems**.

When a device doesn't add anything to the water (such as salt) it is considered a water conditioner rather than a water softener. *Magnetic* water conditioner suppliers include **GMX Magnetic**. With these units, water passes through a focused magnetic field which breaks up hard-water-mineral molecules. These devices encourage particulate matter to clump together and fall out of suspension. While they don't actually remove anything from the water, they make it act like it has been softened.[1088]

Care Free Water Technologies, Inc. makes a number of water conditioners using a catalytic technology. All should be used with biologically safe water supplies. Care Free says that it's catalyst units have "increased electron output and harmonics" that others don't, and they require no maintenance. **Emissions Panther, Inc.** has a whole-house catalytic water conditioner. You can buy it at local Home Depot Building Centers, or through a company distributor. **Stabilized Water of Canada, Inc.** also handles a catalytic water conditioner.

Field Controls has a ClearWave water conditioner that attaches to the side of any type of water pipe. This device works by generating inaudible, low-power radio waves that affect the molecular attraction of minute calcium crystals in the water supply so they are less able to bond to each other, or to pipe surfaces, to form scale. You can get this product at some local Ace Hardware stores or directly from the manufacturer.

Summary

Plastic piping can outgas into the air, but this can be minimized by purchasing the piping early in the construction process and letting it air out, or by covering the piping with aluminum foil once it's been installed. With plumbing systems, outgassing into the air is less important than water quality. Because water is so vital to our health, it must be healthy to drink. In most healthy houses, copper is the material of choice for water supply lines.

Water filters can be useful to improve water quality, but they must be chosen carefully. This is because there are different kinds of filters and they don't all remove the same types of contaminants. Plus, some aren't recommended with certain water supplies.

[1088] "Treat your own water: Part three, lesser-known methods," *Mother Earth News* (April/May 1980): 72-74.

For example, an activated carbon filter is not a good choice unless your water supply has been disinfected. Distillation and reverse osmosis are best used as point-of-use filters. They are usually located in the kitchen, and they both work well against a variety of water contaminates.

23. Electrical Systems

Prior to designing and building a new house, there are a few things you should discuss with your electric utility. For example, many healthy houses are all-electric, so you should check to see if you will qualify for a lower electric rate. You should also ask if they have an energy-rating program that would allow you to qualify for an energy-efficient mortgage if you incorporate energy-saving features such as tight construction. (**RESNET** is a clearinghouse for information on energy-efficient mortgages.) And, you should see if your utility offers any incentives. Many utilities offer special deals, or rebates, on energy-efficient lighting, electric water heaters—even heating systems.

If an electric-power pole must be located near your house, request one that is pressure treated with CCA (copper-chromium-arsenic) salts rather than creosote. It will be the lesser of the two evils. Better yet, ask about underground electric service to keep any type of treated pole far from the house.

The electrical systems in houses today are considerably more complicated that those in houses just 50 years ago. Today we require wiring for televisions, satellite hookups, stereos, security systems, telephones, and computers—not to mention the 120-volt and 240-volt lines for lighting, appliances, and heating. There are three basic health problems to be concerned about: First and foremost, is the danger of electrical shock and possible electrocution; second, the outgassing from plastic electrical components; and third, health effects related to electromagnetic radiation.

Electrical systems also affect the tightness of a house (and the infiltration rate) because electricians drill holes in various studs, joists, and rafters. Plus, there are gaps around electrical boxes through which air currents can move. These small gaps and holes create pathways between the indoors, hidden building cavities, and the outdoors. There have been a variety of airtight construction techniques developed to minimize infiltration around electrical boxes. For example, **Thomas & Betts** (Nu-Tek brand) and **Ryeco Products** (R & S Enviro brand) offer gasketed electrical boxes that seal against drywall or plastic sheeting.

There is a Lessco plastic box (**Low Energy Systems Supply Co**.) that can be used to make a conventional plastic or metal electrical box airtight. If the airtight electrical boxes mentioned above aren't sealed properly, or if they develop a leak after installation (perhaps from a loose gasket) they can't be easily resealed unless you tear out some of the drywall. However, if a Lessco box develops a leak, it can be made airtight by drilling a small hole next to the electrical box, then injecting urethane foam into the space between the Lessco box and the electrical box. A variety of these types of energy-related products can be mail-ordered from **EFI** and **Shelter Supply**.

For existing houses, you can reduce infiltration by installing thin foam gaskets (available at local hardware and building-supply stores) behind switch and receptacle cover plates. **Ryeco Products** (R & S Enviro brand) has an Enviroseal insert that can be installed inside existing electrical boxes to tighten them up. **K-Products** markets a gasketed Perma-Flex Care Cover that you install instead of a regular receptacle cover. It has small spring-loaded plastic doors over the outlet holes to minimize infiltration and discourage children from inserting metal objects.

Basic Electrical Safety

Building codes cover basic electrical-safety issues quite well. For example, codes deal with how heavy wiring must be to handle certain loads, grounding specifications, special requirements in damp areas such as bathrooms and kitchens, *etc*. In addition, electrical devices (*e.g*. switches, receptacles, light fixtures, *etc*.) must meet certain standards to perform their intended function safely.

From a homeowner's standpoint, there are a number of things that can be done to minimize the risk of electrical shock.[1089] For instance, never allow anything to come in contact with outdoor power lines—television antennae, metal ladders, kite lines, and metal poles touching power lines are a major cause of electrocution. Another significant danger involves combining water and electricity—never use hair dryers, radios, kitchen appliances, TVs, *etc*. if you are in a wet location, such as on a wet bathroom floor. The danger of electrical shock in wet locations can be minimized by installing *Ground Fault Circuit Interrupters (GFCIs)* in kitchens, bathrooms, garages, and outdoors. GFCIs are now required in these locations by building codes, but they don't exist in many older houses.

People are also electrocuted when they attempt to repair electrical appliances while they are still plugged in. The chance of an electrical fire can be minimized by repairing or replacing damaged cords, and not plugging too many appliances into the same circuit.

The hazards of electrocution are very real, but because they are well understood and already regulated by existing codes, there is no need for this book to delve into them further. Instead we will focus on issues that are not being adequately addressed.

Outgassing

Receptacles, switches, cover plates, and circuit breakers are generally made of a hard plastic that is subject to very little outgassing. These materials are often well-tolerated by sensitive people. Some sensitive people prefer ceramic, wood, or brass covers, which are sold in hardware and department stores or bath shops. Cover plates are also available in stainless steel.

Circuit breakers are usually housed in a metal power panel that is painted. While minor outgassing from the paint can cause reactions in a few sensitive people, it is generally not a problem. The power panel can be purchased early in the construction process and allowed to air out before installation.

Some electrical components, such as doorbells, use small transformers to reduce the voltage. These can get warm and can give off odors, so they should be located where the smell won't migrate into the living space (*e.g*. in an attic or crawl space).

Today, most of the electrical boxes used for switches and receptacles are made of plastic. Plastic boxes aren't strong outgassing sources, but more-inert metal boxes are still readily available. In airtight construction, well-sealed electrical boxes are required on exterior walls to minimize infiltration. The companies mentioned above can supply

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[1089] Consumer Product Safety Commission (CPSC), *Electricity, Handle with Care: CPSC Guide to Electrical Safety* (Washington, DC: CPSC, 1984).

special airtight plastic boxes for this purpose.

Light fixtures can be made from a variety of materials such as plastic, ceramic, glass, metal, wood, *etc*. Because they get warm from the heat given off by the light bulb, low outgassing materials should be chosen. Plastic fixtures are generally poor choices, and wood is marginal—depending on the finish and species. Recessed light fixtures do not collect dust, but they must be airtight if installed in an insulated ceiling.[1090] Several manufacturers are listed in *Chapter 9, Airtight construction* that offer airtight recessed light fixtures.

Plastic-jacketed electrical wiring (or telephone, or TV-cable wiring) can outgas, but the strength of the odor varies by product and by manufacturer. Wiring is more odorous than plastic electrical boxes and switches, but it's generally not a significant outgassing source because it's typically inside building cavities. However, it can be a problem for some sensitive people. There are several ways to minimize outgassing into the living space. Some people recommend that plastic-jacketed wiring be run inside metal conduit. This helps minimize outgassing, but it can be expensive. (It will also reduce the electric-field strength, as discussed below.) When electricians pull wire through conduit, they often use an odorous lubricant that can bother some sensitive people. A tolerated liquid soap can be used instead.

There is a type of electric wire on the market that is sheathed in aluminum and is very easy to use. It consists of a plastic jacketed cable that's encased inside a continuous flexible aluminum sheath. The aluminum acts as a protective metal conduit, and it prevents outgassing. This product is available in rolls and can be easily bent by hand to snake its way through a house. Called Corra/Clad, it's manufactured by **Coleman Cable Systems, Inc**. They also make a Metal Clad Squared product that is also totally sealed, and is a little lower in cost.

When upgrading the wiring in an existing house, there are surface-mounted wiring systems that encase the wire in a decorative metal track, thus minimizing any outgassing from the plastic jacketing. One manufacturer is **Wiremold Co**. These systems are typically painted, so sensitive people should test them for outgassing.

Plastic-jacketed electric wires can be wrapped with household aluminum foil, before the framing is covered with drywall, to minimize outgassing. Outgassing can also be minimized by using foil-backed drywall or foil-backed plasterboard. However, the easiest—and cheapest—way to reduce outgassing is to purchase plastic-jacketed wiring early in the construction process and let it air out for several weeks prior to installing it.

Electromagnetic Radiation

There is widespread interest in the health effects of electromagnetic fields. In fact, many people are more concerned about electromagnetic fields than about indoor air quality. Both are important health issues and both have been downplayed far too much. Is one more important than the other? Well, it depends on who you ask. Without a doubt, we are exposed to far more contaminated air *and* electromagnetic pollution than at any other time in human history. Even if the effects aren't immediately obvious, air and electrical

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[1090] *Home Builders' Energy Update: Installing Airtight Recessed Lighting Fixtures* (St. Paul, MN: Energy Information Center, Spring 1994).

pollution must be affecting us all—virtually all the time.

Discussions of electromagnetics in the popular media are often filled with inaccuracies, incorrect terminology, and sensational statements. To clarify matters, we'll begin with a simple discussion of what electromagnetic radiation is.

Electromagnetic radiation is energy that moves (propagates) from one point to another in the form of *electromagnetic waves*. As an example, sunlight (which is a form of electromagnetic radiation), in the form of light waves, moves outward from the sun in all directions. Some of it reaches us on the earth. Radio transmission towers send out radio waves (another form of electromagnetic radiation), that are picked up by antennae. Electromagnetic radiation can also be propagated through wires. Overhead power lines, house wiring, and extension cords all routinely carry electromagnetic radiation in the form of electrical power. All types of electromagnetic radiation have *electromagnetic fields* surrounding them. When electricity is moving through wires, you can measure the electromagnetic fields surrounding the wires. The fields are stronger near current-carrying wires and weaker further away from those same wires.

Electromagnetic radiation, electromagnetic waves, and electromagnetic fields all have two components—an electrical component and a magnetic component. If you want to measure the electromagnetic field around an electric wire, you will either measure the electrical field or the magnetic field. Electrical fields and magnetic fields have different properties and different health effects. Both are invisible.

Electromagnetic waves exist in many different *wavelengths*. Some are microscopic in length, some are inches long, others are many miles long. All travel at the same speed in a vacuum—the speed of light, 186,000 miles per second. A particular electromagnetic wave always has a specific *frequency* associated with it. The frequency is the number of wavelengths that pass by a point in a second. If you know the wavelength, you can easily determine the frequency. For example, if a wavelength is a mile long, and we know it's traveling at 186,000 miles in a second, then it will have a frequency of 186,000 wavelengths per second. (Frequency is usually measured in *Hertz*, which means cycles [or wavelengths] per second.) If a wavelength is 1,000 miles long, it will have a frequency of 186 Hertz (Hz). Because each wavelength has its own unique frequency, you can use either frequency or wavelength to describe any particular wave.

An electromagnetic wave can vary in its *amplitude* (intensity). Think of two ocean waves. If they have the same distance between troughs and crests, they have the same wavelength. But if one wave is taller than the other, it has more amplitude. The more amplitude an electromagnetic wave has, the more power or intensity.

Types of Electromagnetic Radiation

There are billions of different frequencies of electromagnetic radiation: 1 Hz, 2 Hz, 3 Hz, 4 Hz, 5 Hz, 6 Hz, 7 Hz, 8 Hz, 9 Hz, 10, Hz, 11 Hz, through about 100,000,000,000,000,000,000,000 Hz. The whole range of frequencies is called the electromagnetic spectrum. Different frequencies have different properties—and different health effects. Very short wavelengths (those with very high frequencies) are classified as *ionizing* radiation. When ionizing radiation strikes a molecule, it can strip away some electrons from that molecule, creating ions. This can happen to molecules in the air, or to molecules in living tissue. Longer wavelengths can't do this, so they're often referred to as *non-ionizing* radiation.

As living creatures, we've been exposed to various forms of naturally occurring electromagnetic radiation since the dawn of time. As the human species evolved, we adapted to the visible light, and other forms of electromagnetic radiation that come from the sun, as well as to the low-intensity gamma rays and X-rays that come from outer space. Some of this background radiation is good for us. For example, there is a very weak 10 Hz background radiation that's responsible for regulating our natural biological rhythms. This was discovered by a scientist named Rutger Wever who placed individuals inside well-shielded rooms to protect them from all forms of electromagnetic radiation—even the naturally occurring variety. After a while, the test subjects became completely desynchronized and their metabolic processes started to cycle out of harmony. When they were exposed to artificially generated 10 Hz electromagnetic radiation, their biological rhythms were restored.

Because of modern technical developments, we are now exposed to a phenomenal amount of man-made electromagnetic radiation. But, the health effects of most of these frequencies are not well understood. The radio and television signals surrounding us today are estimated to be 100-200 million times more intense than the naturally occurring background level. The average citizen today is exposed to dental and medical X-rays, microwave ovens and radar, and high indoor radon levels that our forebears did not have to contend with. The biggest controversy has to do with the electromagnetic fields surrounding electrical wires and power lives.

Let's take a closer look at some of the different forms of electromagnetic radiation—from the shortest to the longest.

Gamma Rays

Gamma rays are extremely short, so they have very high frequencies. They are released when materials go through a nuclear decay process. This occurs to a large extent in nuclear reactors and bombs, and to a lesser extent when radon decays indoors.[1091] Nuclear power plants are constructed to contain most of the gamma rays within the reactor, but minor releases do occur. Major releases can result from accidents like Chernobyl.[1092] Gamma rays are ionizing forms of radiation and, as a result, they can cause tissue damage and cancer, so exposure to them should minimized.

X-rays

X-rays are somewhat longer than gamma rays, and they are also ionizing, so they can strip electrons off molecules—whether the molecules are living or not. All X-rays should be considered dangerous, so exposures should be minimized. However, contracting breast cancer may be even more dangerous to an individual's health. In other words, having periodic mammograms may be less risky than not having them, because you may discover a tumor before it becomes advanced. Fortunately, frivolous X-rays are

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[1091] Bernard Cohen, *Radon: A Homeowner's Guide to Detection and Control* (Mt. Vernon, NY: Consumer Reports, 1987).

[1092] Friedrich Naumann Foundation, *Industrial Hazards in a Transnational World: Risk, Equity and Empowerment* (New York: Council on International and Public Affairs, 1987): 25-37.

becoming a thing of the past. At one time, shoe stores used X-ray machines to see how well your feet fit in new shoes. Television sets now emit fewer X-rays than previously.

How much exposure constitutes an acceptable risk? That's a question open to debate. An occasional dental X-ray is probably less dangerous than a ride in an automobile. That doesn't mean that some X-rays are without risk—it simply means that, in some cases, they constitute a reasonable risk.

Ultraviolet Light

Ultraviolet light has both positive and negative effects. The shorter wavelengths of ultraviolet-light are invisible to the naked eye and, because they are ionizing, we should minimize our exposure to them. Most of the ionizing ultraviolet light to which we are exposed comes from the sun, and the atmosphere tends to prevent a great deal of it from reaching the earth's surface. You will be exposed to more of it at a high elevation, such as Denver, where the atmosphere is thinner, than at sea level. As the ozone layer in the upper atmosphere gets depleted, more ionizing ultraviolet radiation reaches all of us at all elevations. For people who spend a great deal of time outdoors, this can mean a higher rate of skin cancer. This form of electromagnetic radiation can be created artificially for germicidal purposes to purify air or water.

Longer wavelengths of ultraviolet light are not ionizing, nor are any of the other forms of electromagnetic radiation that have even longer wavelengths. These longer wavelengths of ultraviolet light from the sun do pass through the atmosphere. While too much exposure can result in sunburn, a certain amount is actually beneficial to our health. That's because long-wavelength ultraviolet light is responsible for activating a steroid-like compound that is naturally secreted by our skin, and converting it into vitamin D, which is then reabsorbed by the skin. Vitamin D deficiency in growing children leads to rickets. Simply standing in front of a window doesn't mean your skin is absorbing any long-wavelength ultraviolet light—ordinary window glass blocks its particular wavelengths—so you must go outdoors to get exposure to this form of electromagnetic radiation.

While a certain amount of ultraviolet light may be beneficial to health, it can cause a photochemical reaction to take place with some air pollutants, changing them into different types of pollutants.[1093] There is also some concern that too much exposure to ultraviolet light from some types of halogen light bulbs can be harmful.

Visible Light

Visible light is the form of electromagnetic radiation we are most familiar with. Pure-white light is composed of a variety of wavelengths. When white light is split with a prism, the various wavelengths can be viewed as a range of colors: red, orange, yellow, green, blue, indigo, and violet. However, not all white light is pure-white. When split apart, the range of colors present in sunlight is somewhat different from that of an incandescent light bulb, which is different from a cool-white fluorescent lamp, which is different from a warm-white fluorescent lamp.

Because we have evolved over millennia under natural sunlight, it's been

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[1093] National Indoor Environmental Institute (NIEI), *Indoor Air Pollution: A Serious Health Hazard* (Plymouth Meeting, PA: NIEI, 1983).

suggested that sunlight is healthier than artificial light.[1094] In fact, there has been much written about the effects of light on health.[1095] Some of the writing dates back to the 1960s, and it focused on the health advantages of full-spectrum lighting, which mimics sunlight more than conventional incandescent and fluorescent lamps.[1096] [1097] The early popular literature suggested that one of the problems with most artificial lighting was its lack of low-frequency (longer wavelength) ultraviolet light. Full-spectrum fluorescent lamps are said to mimic sunlight fairly closely. **BioLight Systems** sells a variety of full-spectrum bulbs and tubes and also fixtures. In addition, full-spectrum fluorescent and incandescent bulbs are available from **Lumiram Electric Corp.**

There have been many health claims attributed to full-spectrum lighting, but most of the claims are unsubstantiated. In 1986, the U.S. Food and Drug Administration censured a manufacturer of full-spectrum lights for "gross deceptions" in their advertising.[1098] While most health effects attributed to full-spectrum lighting haven't been proven, some people simply prefer full-spectrum bulbs because of the color rendition, or the mood it imparts. Full-spectrum bulbs certainly aren't universally desirable—occasionally, sensitive people are bothered by full-spectrum lighting.[1099] Many full-spectrum bulbs are fluorescent tubes, so it should be noted that many fluorescent lamp fixtures contain a ballast that can outgas into the living space when it gets warm. Prior to 1978, many of these ballasts contained PCBs.[1100] Fluorescent bulbs also contain some mercury vapor so, if they are broken, occupants can be exposed to toxic mercury.

As far as positive effects are concerned, reports from the 1980s suggested that exposure to bright full-spectrum lighting could be beneficial in alleviating symptoms of Seasonal Affective Disorder (SAD).[1101] [1102] With this condition, people experience symptoms of depression, fatigue, weight gain, *etc*. during winter months because of less exposure to sunlight. Our bodies produce a hormone called melatonin only in darkness, and SAD patients have too much melatonin. More recent studies have found that SAD

[1094] John Banta, "Full spectrum light," *The Reactor* (Winter 1989-90): 10-11.

[1095] Jane Wegscheider Hyman, *The Light Book* (Los Angeles: Jeremy Tarcher, 1990).

[1096] John N. Ott, *Health and Light* (New York: Pocket Books, 1973).

[1097] John Ott, "Effects of Unnatural Light," *New Scientist* 429 (February 4, 1965): 294-296.

[1098] Merle Henkenius, "The right light, more than meets the eye," *Practical Homeowner* (December/January 1990): 28.

[1099] Ann Bauman, Personal communication.

[1100] Ellen Greenfield, *House Dangerous* (New York: Vintage Books, 1987): 65.

[1101] Norman E. Rosenthal and others, "Seasonal Affective Disorder," *Archives of General Psychology* 41 (January 1984): 72-80.

[1102] Thomas A. Wehr, "Phototherapy of Seasonal Affective Disorder," *Archives of General Psychology* 43 (September 1986): 870-875.

patients respond to artificial light as long as it's bright enough, and that full-spectrum lighting isn't necessary.[1103] In fact, some promising results have been obtained with head-mounted devices such as "light visors" [1104] and by having SAD patients take a morning walk in natural sunlight.[1105] Bright-light therapy certainly seems to help some people with SAD, but there are drawbacks. Common side effects include headache, eyestrain, and feeling "wired." [1106]

Not all people are affected by SAD. In fact, some of us might be getting too much light. With artificial lighting systems, we have extended daylight (or near-daylight) conditions by 4-7 hours, depending on the season. It's been hypothesized that this extra light means too little melatonin for some people, something that might lead to tumor production.[1107]

Selecting healthy interior lighting is not an easy task. However, for most healthy people, the type of lighting is far less important than the chemical pollution inside an average home. And, no matter what type of lighting you choose, it's always a good idea to spend a certain amount of time outdoors in natural sunlight for vitamin D production—but not so much that it results in sunburn.

Compact-fluorescent bulbs have been promoted in recent years because they are energy efficient and long lasting. Those with *magnetic ballasts* contain a small amount of radioactive material that can be released if the fixture is crushed.[1108] *Electronically* ballasted models contain no such material, so they are healthier choices. Different models produce slightly different colors of light. Some are very white, which many people find unattractive, while others give off a more pleasing color.[1109]

Many *halogen* bulbs can be 10-40% more energy efficient than conventional incandescent bulbs, but halogen *torchieres*, which are often used for indirect uplighting, can be very energy inefficient.[1110] The filament inside a halogen bulb gets quite hot, and it can give off ultraviolet light. Do not use high-temperature bulbs such as these near

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1103 R.W. Lam and others, "The effects of ultraviolet-A wavelengths in light therapy for seasonal depression," *Journal of Affective Disorders* 4 (April 1992): 237-243.

1104 E.M. Tam, R.W. Lam, and A.J. Levitt, "Treatment of seasonal affective disorder: a review," *Canadian Journal of Psychiatry* 40 (October 1995): 457-466.

1105 A. Wirz-Justice and others, "'Natural' light treatment of seasonal affective disorder, *Journal of Affective Disorders* 37 (April 12, 1996): 109-120.

1106 A.J. Levitt and others, "Side effects of light therapy in seasonal affective disorder," *American Journal of Psychiatry* 150 (April 1993): 650-652.

1107 N.A. Kerenyi, E. Pandula, and G. Fuer, " Why the incidence of cancer is increasing: the role of 'light pollution'," *Medical Hypothesis* 33 (1990): 75-78.

1108 Bruce Feldman, "Spotlight on new bulbs," *East West* (May 1991): 40-51.

1109 "Shedding light on fluorescents," *Safe Home Digest* (May 1991): 8-9.

1110 "Halogen torchieries: Not a bright idea," *Environmental Building News* (January 1997): 5-6.

flammable materials (*e.g.* curtains or draperies).

To withstand the high temperature, halogen-bulb manufacturers generally use either quartz glass or borate-silica glass (Pyrex is one particular brand of borate-silica glass). Ultraviolet light is not blocked by quartz glass, but it is blocked by borate-silica glass.[1111] When researchers exposed hairless mice to halogen bulbs that gave off excess ultraviolet light, most of them developed skin tumors—some of which were cancerous.[1112] So, if you are interested in halogen bulbs, look for ones made with borate-silica (Pyrex) glass, which blocks the ultraviolet-light portion of the spectrum.

Infrared Radiation

Infrared radiation has longer wavelengths than visible light. It cannot be seen—but it can often easily be sensed as heat. The warmth you feel radiating from a wood stove, or the burner of an electric range, is infrared radiation. The warmth you feel standing in the sun is also infrared radiation. While infrared radiation can make us feel toasty when the temperature is low, it's possible to get too much of a good thing. For example, industrial workers who deal with molten iron or glass are exposed to a great deal of infrared radiation. As a result, cataracts were once common in those occupations.[1113] Today, protective eye wear is mandatory if workers are to avoid eye damage.

Microwaves are a form of infrared radiation, and they are routinely used to heat food in microwave ovens. Radar is another form of infrared radiation. For years, researchers believed that the only effect microwaves had on life was warmth or heat. Microwave ovens use this principle to cook a pot roast. Medical diathermy machines once used this principle to therapeutically apply heat to living tissue.

Today, there have been a wide range of negative health effects associated with microwave exposure. Paul Brodeur, in his book *The Zapping of America*, notes that scientists in the former Soviet Union have accumulated a vast amount of information about the health effects of microwaves. They have found that workers with prolonged exposure report symptoms such as "stabbing pains in the heart, dizziness, irritability, emotional instability, depression, diminished intellectual capacity, partial loss of memory, loss of hair, hypochondria, and loss of appetite." Brodeur has also found evidence of eye strain, cataracts, white-blood-cell-count irregularities, inability to sire male children, sterility, gastrointestinal inflammation, heart disease, increased incidence of Down's syndrome, and club foot—all attributed to microwave exposure. Most of these effects can be related to strong military or industrial sources of microwaves or radar, but some highway-patrol police officers in this country have reported cases of testicular cancer

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[1111] Bruce Sullivan, "Halogen lighting," *Journal of Light Construction* (July 1993): 46.

[1112] F. D'Agostini and S. DeFlora, "Potent carcinogenicity of uncovered halogen lamps in hairless mice," *Cancer Research* 54 (October 1994): 5081-5085.

[1113] Eva Lydahl, *Infrared Radiation and Cataract* (Stockholm, Sweden: Department of Opthamology and Medical Physics, 1984).

which they believe is due to resting radar guns on their laps.[1114] **Less EMF, Inc.** offers meters for measuring microwave leakage from microwave ovens.

Radio Waves

Radio waves (this category actually includes both radio and television waves) haven't been the subject of much research, despite the fact that everyone on the planet is bathed in them continuously. But an article in *Psychological Reports* discussed an experiment where researchers exposed rats to low-intensity UHF radio waves. Compared to an unexposed control group, they found that rats were more active in the early days of the experiment and less active as the days of exposure increased. The UHF-exposed group was also more emotional.[1115]

ELF (Extremely Low Frequency) Waves

The last category of electromagnetic radiation is one of the most controversial as far as human health is concerned. ELF (extremely low frequency) waves have extremely long wavelengths, many miles in length. The electricity we use in the U.S. is an alternating current that operates at 60 Hz. In Europe, power is transmitted at 50 Hz. All the wires that carry electricity across the countryside, into, and throughout, American homes are surrounded by 60 Hz ELF electromagnetic fields. High-voltage power-transmission lines are surrounded by much stronger fields than the wires in our houses.

It is these 60 Hz electromagnetic fields that have raised the most public concern, and led to a great deal of scientific research. Various studies have examined their relationship to cancer (especially leukemia) and rates of miscarriage. And laboratory experiments have indicated that ELF fields can affect fetal development in swine, chickens, and rabbits. In his book, *Currents of Death*, Paul Brodeur documents many of these dangers—as well as the negative health effects associated with video display terminals.[1116]

Electrically Induced Disease

Our bodies operate by sending weak electrical signals through the nervous system. Our nerves act like tiny electric wires, continually transmitting electrical signals throughout every part of our bodies. Dr. Robert Becker has documented many of the fascinating ways our bodies use electricity in his book *The Body Electric*. He suggests that the man-made electromagnetic radiation we are routinely exposed to could be negatively affecting the weak naturally occurring signals inside our own bodies. According to Becker "the entire population of the world is willy-nilly the subject of a giant experiment." Becker believes ELF fields may have the greatest effect on health

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[1114] R.L. Davis and F.K. Mostofi, "Cluster of testicular cancer in police officers exposed to hand-held radar," *American Journal of Industrial Medicine* 24 (August 1993): 231-233.

[1115] Susan Korbel Fakin and William Thompson, "Behavioral Effects Stimulation by UHF Radio Fields," *Psychological Reports* 17 (1965): 595-602.

[1116] Paul Brodeur, *Currents of Death: Power Lines, Computer Terminals, and the attempt to Cover Up Their Threat to Your Health* (New York: Simon & Schuster, 1989).

because they fall in the same frequency range as many of the natural signals in our brains. At the same time, Becker notes that there are beneficial uses of electromagnetic fields. For example, some researchers have found that electro-therapy can be used to speed up the healing process.[1117] Electro-therapy can also relieve pain, reduce edema, dissolve hematomas, and it has been found useful in curing drug addiction.[1118]

Paul Brodeur has written extensively on the subject of electromagnetic fields and health. Three in-depth articles have appeared in *The New Yorker*[1119] [1120] [1121] and he has written three popular books. Brodeur's writing contains a great deal of useful information, but some of his conclusions are controversial. One environmentalist calls his *Currents of Death* a "windy, unreadable diatribe, designed only to scare and make money—all heat and no light."[1122] By implying that the government, military, and the entire electrical industry are involved in a massive cover-up and conspiracy, Brodeur does a tremendous disservice to all the legitimate research that is being done.

There is, in fact, a great deal of legitimate research into the biological effects of electromagnetic radiation, and over 10,000 papers have been published on the subject.[1123] Much of the research is done in laboratories to see how electromagnetic radiation affects living cells. For example, scientists have examined how electromagnetic radiation affects a cell's membrane, how it affects calcium flow from cells to the brain, its affect on how cells communicate with each other, *etc*. *Biological Effects of Power Frequency Electric and Magnetic Fields—Background Paper* by the U.S. Congress, Office of Technology Assessment contains a summary of the most significant studies that have been done. *Questions and Answers: EMF in the Workplace* lists over 20 pages of references for research papers and studies on EMFs.[1124] Still, many professionals in the U.S. often dismiss the possibility of negative health effects. Yet in the Soviet Union, the following clinical conditions were accepted as sometimes being the result of "radiofrequency

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[1117] Albert Huebner, "Healing Cancer with Electricity," *East West* (May 1990): 45.

[1118] Richard Leviton, "Current Affairs," *East West* (May 1990): 47.

[1119] Paul Brodeur, "Annals of Radiation, The Hazards of Electromagnetic Fields: Part I—Power Lines," *The New Yorker* (June 12, 1989): 51-88.

[1120] Paul Brodeur, "Annals of Radiation, The Hazards of Electromagnetic Fields: Part II—Something is Happening," *The New Yorker* (June 19, 1989): 47-73.

[1121] Paul Brodeur, "Annals of Radiation, The Hazards of Electromagnetic Fields: Part III—Video-Display Terminals," *The New Yorker* (June 26, 1989): 39-68.

[1122] Ed Randeggar, "Currents of Drivel," *Environ* (#11): 19.

[1123] Louise Kosta, "Biological Interactions and Health Effects," *The Human Ecologist* (Summer 1995).

[1124] National Institute for Occupational Safety and Health, National Institute of Environmental Health Sciences, and U.S. Department of Energy, *Questions and Answers: EMF in the Workplace*, (Washington, DC, September 1996) DOE/GO-10095-218, DE95013123.

radiation sickness syndrome": dermographism, tumors, hematological alterations, reproductive and cardiovascular abnormalities, depression, irritability, and memory impairment (among others).[1125]

Research into the health effects of electromagnetic fields is costly—running into tens of millions of dollars every year[1126]—yet much of the work has yielded inconclusive and contradictory results. Sometimes effects are noted one day, but not the next.[1127] One theory suggests that microscopic iron-oxide particles (called magnetite) in the air could affect the results. While the magnetite particles apparently pose no threat to human health, they could contaminate electromagnetic-field studies and invalidate the findings.[1128]

Other studies use statistics to see if various diseases are more or less likely when people are exposed to electromagnetic radiation. The vast majority of this *epidemiological* research deals with the 60 Hz electromagnetic fields found around electric wiring and appliances. The **Electric Power Research Institute (EPRI)**, which is sponsored by electric utilities, funds a considerable amount of this research.

It's important to remember that an electromagnetic field is composed of both an electric field and a magnetic field. Researchers are in agreement that electric fields do not cause cancer or chromosomal damage. In general, most researchers believe magnetic fields are more dangerous. However, some people feel it's important to minimize our exposure to both electric and magnetic fields—just to be on the safe side.

While more conclusive research is needed, many people are demanding lower fields and less exposure. Others are suing utilities and manufacturers. It's been estimated that $1 billion is spent each year on litigation while "only" $20 million is spent annually on research.[1129] There will no doubt be more money spent on both research and lawsuits but, because of the complexity of the work, it's unlikely there will be a definitive answer soon. In fact, according to one writer, "many researchers believe a truly scientific study… can never be done."[1130]

The earth is surrounded by a magnetic field. This is sometimes called a geo-magnetic field, and it's what causes a compass to point North. This field is not the same thing as the magnetic field surrounding an electrical wire. The earth's magnetic field is

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1125 Ana G. Johnson Liakouris, "EMF Health Problems are a Medical Reality, *Our Toxic Times* (August 1998): 21-23.

1126 Cecily Dourrachad, "EMF Controversy Costly, Science Inadequate, Researcher Claims," *Indoor Air Review* (August 1992): 9.

1127 Carol Ezzell, "Power-Line Static," *Science News* (September 28, 1991): 202-203.

1128 "Are micromagnets polluting EMF studies?," *Science News* (March 18, 1995): 175.

1129 Robert Weinhold, "A Noted Electrical Engineer Examines EMFs," *The Human Ecologist* (Spring 1996): 15-16.

1130 Cathryn Hodson, "The Electromagnetic Field Controversy: What Engineers Should Know," *Consulting-Specifying Engineer* (March 1992): 44-46.

static; like that of an iron magnet, it doesn't change its direction. The magnetic field around an electric wire is constantly changing, or alternating—60 times a second in North America, 50 times a second in Europe. While most of the research on magnetic fields deals with alternating fields, there is some evidence that there are static geomagnetic *hot spots* in different locations on the planet where negative health effects are more likely to show up.[1131] This is a fairly controversial subject—even more so than health effects related to electromagnetic fields in general—but some dowsers (people who can locate underground water supplies) claim they are able to detect such hot spots. Of course, dowsing is another controversial subject.

Electrical Sensitivity (ES)

The concept of multiple chemical sensitivity (MCS) was once scoffed at by researchers and medical professionals alike. While MCS still isn't a universally accepted diagnosis (the American Medical Association has no official opinion on the subject), hundreds of credible doctors and scientists have seen enough cases that they're convinced it exists—in perhaps millions of people. Similarly, when first reported, electromagnetic sensitivity (ES) was thought to be a psychosomatic condition. But, ES is being recognized more and more. Sweden appears to be an early leader in ES research.[1132]

Common ES symptoms vary, but most are skin-related or neurological—headache, nausea, fatigue, dizziness, tingling or prickling sensation on the skin, burning skin or eyes, difficulty concentrating, memory loss, muscle or joint pain, and heart fluctuations. A few people report much more severe reactions like paralysis, seizures, and unconsciousness.[1133] There appear to be three groups of people who are more likely to be affected by electromagnetic fields: individuals with MCS, computer users, and those who work around high-strength electromagnetic fields.

Based on anecdotal reports, ES does not seem to be as common as MCS. In fact, it appears that many (but not all) people with ES got MCS first, then, as their bodies became weaker and more worn down, they developed ES. When such people begin regaining their health, the ES symptoms often diminish first, then the MCS symptoms decrease in intensity. It's been estimated that roughly $2^1/_2$% of chemically sensitive people also have ES[1134]—but there are also people with ES that don't have MCS. There could easily be tens of thousands of people in the U.S. with electrical sensitivities.

One individual with ES has slurred speech and her legs buckle whenever she's around things like video display terminals, negative-ion generators, burglar-alarm systems, and San Francisco's BART train tunnels. Everyday electrical components, such as televisions and dimmer switches, have been implicated in causing negative health

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[1131] Richard Leviton, "Can the Earth's Stress Spots Make You Sick?," *East West* (June 1989): 48.

[1132] "Son of Radon—Electrical Hypersensitivity," *Energy Design Update* (December 1994): 8.

[1133] Kosta, "Biological," 17.

[1134] Lucinda Grant, *The Electrical Sensitivity Handbook* (Prescott, AZ: Weldon Publishing, 1995): 16.

effects in people with ES. In extreme cases, individuals must live in houses containing no electricity whatsoever in order to minimize reactions. For them, even talking on the telephone, with its weak electrical signals, can cause problems. **FEB (The Swedish Association for the ElectroSensitive)** is an international organization offering information on ES.

Computer Users

It's been widely recognized that computer users can develop carpal-tunnel syndrome and vision problems. Other common complaints involve eye strain, burning eyes, and blurred vision, as well as headaches, and neck problems—symptoms that are often reported by people with ES. The National Association of Working Women found significant numbers of workers reporting nausea, dizziness, or constant exhaustion related to computer work.[1135] A 1992 study compared computer-using women in Finnish offices who had miscarriages with those who gave birth. It found that those who worked at computers with higher-strength magnetic fields were 3.4 times more likely to have a miscarriage.[1136] **Less EMF, Inc.** sells screens to reduce electromagnetic emissions from computer monitors.

Ham-Radio Operators

An editorial in *Amateur Radio Today* discussed the health effects of the powerful square-wave electromagnetic field generated when sending Morse-code messages. It pointed out that there seem to be more personality problems with Extra Class operators than with those operators who don't send Morse code. This may be due to the low-frequency fields (about 6 Hz.) generated by the amplifier. The editorial suggests that "it won't kill you in a day or a week, but slowly, over a period of years, it may be changing your personality (not likely for the better) and shortening your life."[1137] A physician, who is also an amateur radio operator, has recognized that there can be a risk, and he has compiled a list of 16 preventative measures that include keeping equipment at a reasonable distance, using minimal power, *etc*.[1138]

The Cancer Connection

Do electromagnetic fields cause cancer? The best evidence comes from studies done on people who work around electrical equipment (*e.g*. radar operators, electricians, linemen, and welders). The Labor Institute has summarized the results of a number of

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1135 National Association of Working Women and The Service Employees International Union, *VDT Syndrome: The Physical and Mental Trauma of Computer Work* (Cleveland, OH: National Association of Working Women, 1987).

1136 Marja-Liisa Lindebloom and others, "Magnetic Fields of Video Display Terminals and Spontaneous Abortion," *American Journal of Epidemiology* (November 1992): 1041-1051.

1137 Wayne Green, "Never Say Die," *Amateur Radio Today* (February 1991): 4.

1138 Ivan Shulman, "Is Amateur radio Hazardous to our health?," *QST* (October 1989): 31.

epidemiological studies and found that electrical workers seem to have a higher risk of contracting leukemia or brain cancer than the general population. In examining 8 studies, they found one study where electrical workers were no more likely than the general population to get leukemia. The other 7 studies found more risk in the electrical workers, ranging from 1.23 times more likely up to 3.8 times more likely. In five separate studies, the increased risk of contracting brain cancer in electricians ranged from 1.42 times more likely than the general population, up to 3.9 times more likely.[1139]

The most controversial facet of this subject has to do with whether or not electrical power lines cause leukemia. The debate began with a 1979 study, then another in 1982, that reported finding increased cancer rates in people living near certain types of power-line configurations.[1140] [1141] Over the intervening years, many additional studies have been done. Some have found increased cancer risks associated with power lines, some have not. After weighing all the evidence, in 1996, the National Research Council of the National Academy of Sciences determined there is no clear evidence of a power-line/cancer risk. They stated that, at best, the evidence is "inconsistent and contradictory." [1142]

Prudent Avoidance

Do electromagnetic fields cause disease? Some of the evidence indicates conclusively that they do, but other evidence is weak. High frequencies (*e.g.* gamma rays and X-rays) should be avoided at all costs. But the seriousness of 60 Hz fields is open to interpretation. While, in some cases, they may pose a serious threat, the low levels most healthy people are exposed to in daily life don't appear to be extremely dangerous. But, we are all bathed in electromagnetic radiation of all kinds, and there are undoubtedly subtle biological effects that can't easily be measured. Just because there isn't widespread, scientifically acceptable proof, doesn't mean we should ignore the issue.

Because of the amount of research funding and press coverage this subject is receiving, the American Physical Society (the largest organization of physicists in the world, with over 43,000 members) has stated that "more serious environmental problems are neglected for lack of funding and public attention." [1143] Without a doubt, there are much more serious health issues to worry about. What needs to be done is to put things in perspective.

Dr. Granger Morgan, Head of the Department of Engineering and Public Policy at

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1139 The Labor Institute, *Electromagnetic Fields (EMFs): A Training Workbook for Working People* (New York: The Labor Institute).

1140 Nancy Wertheimer and Ed Leeper, "Electrical Wiring Configurations and Childhood Cancer," *American Journal of Epidemiology* 109 (1979): 273-284.

1141 Nancy Wertheimer and Ed Leeper, "Adult Cancer Related to Electrical Wires Near the Home," *International Journal of Epidemiology* 11 (1982): 345-355.

1142 "Newsbriefs," *Environmental Building News* (January 1997): 5.

1143 "American Physical Society Weighs in on EMF," *Environmental Building News* (July/August 1995): 8.

Carnegie Mellon University, has written about the subject, and acknowledged that there may be a problem. He suggests adopting a policy of "prudent avoidance." [1144] This means you should avoid prolonged, unnecessary exposures to electromagnetic radiation whenever it's reasonable to do so—but you don't need to get carried away. For example, you probably shouldn't go camping under a high-voltage power line, but don't go so far as to rip all the wiring out of your house. Fortunately, there are a number of things that can be done to reduce your risk—sometimes substantially. We will probably know much more about this subject as time goes on, but in the meantime, prudent avoidance makes a great deal of sense.

Measuring Electromagnetic Fields

It's very difficult to guess at the strength of electromagnetic fields. For example, there can be weak fields where you'd expect high-strength ones, and strong fields in unexpected places.[1145] So, to get a good understanding of the electromagnetic environment, the fields must be measured, and electric fields should be measured separately from magnetic fields. The biggest concern is over the 60 Hz fields surrounding electrical appliances and wiring, but microwaves are also often measured. Several companies sell hand-held meters that can be used to measure these fields. Costs range from less than $100 to over $1000. The low-cost meters can be somewhat inaccurate—one expert has found that in some situations they can be off by 100%[1146]—but they're generally suitable for obtaining readings in residences.

Because electric utilities have gotten so many questions on the subject of electromagnetic fields, they often have meters themselves, and they will sometimes measure the fields around your house for you. However, they often won't measure them indoors, and they almost never feel electromagnetic fields are a health problem. To seriously evaluate the fields in a house, you should hire a person who is familiar with the subject, or purchase a meter and measure the fields yourself.

If you are interested in measuring all forms of electromagnetic radiation (gamma rays, X-rays, ultraviolet light, visible light, infrared radiation [microwaves], radio waves, and ELF waves), you'll find it very difficult to locate someone with the proper equipment, it will be very expensive, and there will be little guidance as to what constitutes safe levels. The vast majority of today's concern and research involves the ELF fields surrounding electrical equipment and wiring, so they're the ones you will probably be most interested in.

Magnetic fields are measured in a unit called a milliGauss (mG.) with an instrument called a Gaussmeter. A milliGauss is $^{1}/_{1000}$th of a Gauss. With ELF fields, most

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[1144] Granger Morgan, *Electric and Magnetic Fields From 60 Hertz Electric Power: What Do We Know About Possible Health Risks?* (Department of Engineering and Public Policy, Carnegie Mellon University, 1989)

[1145] Bill Sanders, "Electromagnetic Fields," *Green Alternatives* (July/August 1993): 17-27.

[1146] Karl Riley, "Selecting an Electromagnetic Field Meter," *Indoor Air Review* (August 1992): 11.

people are in agreement that you should avoid long-term exposure to fields above 3 mG. Others believe 3 mG. is too high, that 1 mG or 2 mG. is a better number.[1147] There isn't a great deal of solid evidence to support either figure, but the length of exposure is believed to be a very important consideration. For example, 8 hours of exposure to a 5 mG. field is thought to pose greater risk than a few minutes of exposure to a 50 mG. field.

Electric fields are measured in units of volts per meter (v/m). Stronger electric fields are measured in kilovolts per meter (kv/m). A kilovolt is 1,000 volts. Because most people don't believe electric fields are as dangerous as magnetic fields, there is little consensus as to what constitutes a safe level.

The **National Electromagnetic Field Testing Association (NEFTA)** maintains a listing of professionals who do electromagnetic field testing. Individuals who have a certificate from the **International Institute for Bau-Biologie and Ecology, Inc.** may also be able to do this type of testing. Electromagnetic field testing devices are available from **Befit Enterprises Ltd**., **F.W. Bell**, **Less EMF, Inc.**, **Magnetic Sciences International**, **N.E.E.D.S.**, and **Tech International Corp.**

Minimizing Exposure

Minimizing one's exposure to all forms of electromagnetic radiation can be difficult because we are surrounded by so many frequencies, and different frequencies require different control methods. For example, several feet of concrete or water are necessary to protect one from the gamma rays of a nuclear reactor, while thin lead sheeting works well against X-rays. Visible light can be blocked by a piece of cardboard. In houses, most of the concern involves 60 Hz ELF fields, so that's what our discussion will center on.

If there's a strong formaldehyde source in your house, it can contaminate the entire living space. But if there is a strong electromagnetic source in your house, it generally only contaminates the area immediately surrounding it. This is because electromagnetic fields lose their intensity as you move away from the source. This is an important difference between chemical pollution and electrical pollution.

You can reduce your exposure to electromagnetic fields, and your health risk, by either lowering the strength of the fields, or spending less time near the fields. If you have a high-strength field somewhere in your house, and you walk by it occasionally, you probably aren't at great risk. But if the high-strength field is near your bed, you will be at greater risk because you will be exposed to it all the time you are in bed.

All houses—even those that are specially constructed to reduce electromagnetic-field strength—will have some isolated areas of strong 60-Hz electromagnetic fields. These are sometimes called electromagnetic hot spots. The only way to eliminate them completely would be to live in a house without electricity—something few of us would be willing to do. But there are many things you can do to minimize your risk.

Magnetic Fields and Wiring

When electricity is flowing through a wire, you can measure both a magnetic field and an electric field around the wire. The strength of the field is highest right next to the

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[1147] Kathy Morris, "Living with MCS: How to purchase and use a gauss meter," *The Human Ecologist* (Summer 2000): 27.

wire, and it diminishes further from the wire. In most residential situations, it's difficult to measure either field one or two feet away from most of the wires in a house. If an appliance is plugged in, but not turned on, there will not be any current flowing in the wire. When no current is flowing, there will be no magnetic field—but there will still be an electric field (unless there is a power failure). So, you don't have to actually be using any electricity for there to be an electrical field present—but an electrical appliance must be in use for there to be a magnetic field present.

Magnetic fields are very difficult to block, but they can often be reduced in strength. Here's how. The electricity in our houses requires two wires. (Actually, electrical codes also require a third wire—a ground—but it should never have any current flowing in it.) Each of the two wires has an electric and a magnetic field. If the two wires are very close together, the magnetic fields tend to cancel each other out. The closer together the wires are, the more the field strength is diminished. If the wires are close together, *and* twisted around each other, the magnetic fields cancel even further—resulting in extremely low magnetic fields.

To actually block magnetic fields requires a special shielding material. While lead will block X-rays, it won't block magnetic fields; you need a special ferrous alloy containing iron, nickel, or cobalt. The success of shielding depends on the field's direction, size, and shape with respect to the shield, and the intensity of the field, so shielding materials are only effective in certain situations.[1148] Magnetic shielding can be quite expensive so it's generally only used in very specialized applications. Plus, it usually requires a knowledgeable consultant, such as **M. Spark Burmaster**, or **Neuert Electric & Electromagnetic Services.** To locate a consultant in your area, the **National Electromagnetic Field Testing Association (NEFTA)** maintains a listing of professionals who do electromagnetic field testing, and who would be knowledgeable in reducing field strengths. People who have a certificate from the **International Institute for Bau-Biologie and Ecology, Inc.** may also be able to do electromagnetic field testing.

Years ago, when houses were first being wired for electricity, knob-and-tube wiring was common. This involved attaching individual wires to ceramic insulators (knobs) or, when passing through combustible materials, threading the wires through ceramic tubes. In knob-and-tube wiring, the two wires were separated by a foot or more, so the magnetic fields didn't cancel each other out. As a result, older houses that still have knob-and-tube wiring also have high-strength magnetic fields. Today, the vast majority of houses are wired with a material called *romex*. Romex is a plastic-jacked product that has the insulated wires packed very closely together in a single bundle. In most applications, the magnetic fields around romex are so low that twisting isn't necessary. So, in most new installations today, the wiring itself isn't a contributor to strong magnetic fields.

Electric Fields and Wiring

While magnetic fields can't be easily blocked, electric fields can. In fact, outdoors they are often blocked by trees and buildings. However, because most of the health concerns are related to magnetic fields—not electric fields—many people don't worry about electric-field reduction. Still, there are some hypersensitive people who are

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1148 John Banta, "Using magnetic shielding alloy," *Electro-Pollution Troubleshooter* (September 1993): 1-7.

bothered by them.

To effectively block the electric fields associated with the electric wiring in a house, you can run all the wires through metallic conduit that has been properly grounded. This is commonly done in commercial buildings, but it's unusual in residences because it costs considerably more than using romex. However, it will block electric fields effectively. Romex is generally not used inside metallic conduit—individual insulated wires are used instead. These can be twisted together before they are pulled through the conduit to minimize magnetic field strength. Twisted wires inside grounded metal conduit will give you very low magnetic *and* electric fields.

Because there will be an electric field present around wiring, even if there is no electricity being used, one way to eliminate the electric field is to turn off the circuit breaker at the power panel when electricity isn't needed. However, this can be inconvenient, and circuit breakers aren't really designed to be turned on and off frequently. Another approach is to install a *demand switch*. This device will automatically disconnect the circuit and cut the flow of electricity when there is no demand for it. Then it will allow the electricity to flow again automatically when power is needed. So, with a demand switch on a particular circuit, there will only be an electric field around the wires in that circuit when something is turned on. Demand switches are available through **International Institute for Bau-Biologie and Ecology, Inc.** and most professionals who specialize in electromagnetic field reduction.

High-Current Wires

The more current a wire is carrying, the stronger the magnetic field. For example, a wire running to an electric stove will conduct more current (when the stove is turned on), and have a higher-strength magnetic field, than a receptacle circuit serving a single light bulb. To minimize your exposure to high-current wires in new construction, you can simply route them in locations where you won't spend a great deal of time. For example, you might route the heavy wire from the meter to the main circuit-breaker panel inside a closet wall rather than behind the wall where your bed's headboard will be. By looking carefully at a floor plan, you can usually find a way to run high-current wires so they avoid bedrooms and other places where you spend the most time. If you run wires through an attic, rather than under the floor, you will be further from them most of the time. This is especially important in rooms where children are likely to be playing on the floor. In most cases, electricians run wires by the shortest path. Wiring for reduced-field exposure takes a little more wire, but the added expense is usually minimal.

In an existing house, it's possible to relocate high-current lines if they run near areas where you will receive a lot of exposure. Or, you might rearrange your furniture so you don't spend as much time near those wires. For example, you might move your bed to a different side of the room, or move the couch to a different wall.

There are a variety of wires in a house that carry very low amounts of current—telephone lines, doorbell wires, wiring for home security systems, television cables, *etc*. They have tiny electro-magnetic fields, and are generally not considered a health problem.

Entrance Wires

The main power line coming into a house carries more current than any of the individual wires in the house. Therefore, it can be surrounded by strong fields. In the past, the overhead wires running from the utility pole to the house were usually separated, thus their fields didn't cancel each other. Today, entrance wires are often twisted together, so they tend to have much lower fields. Still, because of the amount of current in entrance wires, it's best to locate them, and the meter, in a place where they won't have a big impact indoors. For example, a meter can be located on an exterior wall that has a closet on the other side, or it could be mounted on the garage.

Most of the underground entrance wires being used today are twisted together, so they have low-strength fields—plus they are out of sight. Some older buried installations didn't use twisted wires. Though not common, some had wires buried in separate trenches, so they had high-strength fields. Many electric utilities will run underground wires from a utility pole to a residence, but there is a cost involved—underground wires can cost 2-10 times as much as overhead ones.[1149]

If the entrance wires (buried or overhead) are twisted, but still have high-strength fields, it is because something is out of balance. This can occur if the neutral wire's connection is corroded, or if some current is flowing on plumbing lines (see below). Both situations should be corrected.

Neutral Problems

The two current-carrying wires in a wiring system generally have different-colored insulation. The wire with black insulation is called the *hot* wire. The wire with white insulation is called the *neutral* wire. (In some cases, a hot wire will have red insulation.) The ground wire either has green insulation or it is bare, without any insulation.

Neutral wires from different circuits should never be connected together. If they are, it's a violation of the electrical code. While it's not an uncommon practice, it can lead to high magnetic fields. Here's how. In a correctly wired house, the current flows from the power panel, along the black wire, to an appliance (or a light bulb, a heater, or some other electrical device), then the current returns on the white wire. Such a circuit is balanced. As we said earlier, in most wiring today, the white and the black wire are very close together, so their magnetic fields cancel each other out—but only if the fields are balanced. If the white wires from two, or more, circuits are connected together somewhere, the current will flow along the black wire to the appliance, then part of the current will return on one white wire and part of it will return on a different white wire. If all the white wires are bundled very close to all the black wires, the fields will cancel each other out. But multiple circuits rarely have their wires all bundled together. The result is one black wire and one white wire next to each other that are unbalanced, and another white wire somewhere else that is also unbalanced. This can mean strong magnetic fields.

Neutrals are most often incorrectly connected together inside a junction box. This can occur when an electrician is working on an existing house and assumes all the wires in a box are on the same circuit—when they are not—and he connects the neutrals together.

[1149] Karen Fitzgerald. "Electromagnetic fields: the jury's still out," *IEEE Spectrum* (August 1990): 22-35.

Grounding Problems

Some of the highest strength magnetic fields in houses are the result of grounding problems.[1150] As we said earlier, the ground wire should never be carrying any current. It's only there as a safety factor. If a ground wire is carrying any current, there can be strong magnetic fields.

In most correctly wired situations, the neutral wire is connected to the ground wire at the service-entrance panel—where the main shut-off switch and the individual circuit breakers are—and nowhere else. If the ground and neutral wires are connected together somewhere else, the current will flow along the black wire to an appliance then part of the current will return on the white wire, and part of it will return on one or more ground wires. The current in the individual wires won't be balanced, the magnetic fields won't cancel, and strong magnetic fields can be measured.

Connecting grounds and neutrals together in the wrong place is also in violation of the electrical code—but it does occur. For example, many houses have a main service-entrance panel, as well as one or more subpanels. According to the electrical code, the neutrals and the grounds should only be connected together at the service-entrance panel. They should never be connected together at a subpanel. But they sometimes are. This gives the current multiple return paths on which to travel from the subpanel back to the main panel. This means the fields in the individual wires won't be balanced, so they won't cancel each other, and the magnetic fields can be high.

Grounding and Water Lines

The electrical code requires that metallic plumbing systems be grounded. This is a very important requirement and it should not be ignored. However, sometimes there can be current flowing on water pipes. If this is the case, then the water lines themselves will be surrounded by electromagnetic fields—often strong fields. When current is flowing on the pipes, it isn't flowing where it's supposed to (on wires), so the fields aren't balanced, they don't cancel, and magnetic-field strength is high.

Sometimes, a grounding problem exists in a neighbor's house, but it affects the electromagnetic fields in all the houses in the neighborhood. This can occur when houses have metal piping, and the underground piping is also metal. In such cases, all the houses in the neighborhood are electrically interconnected through their plumbing lines.

Strong fields can also be found on metal gas pipes. This is dangerous because energized pipes (water or gas) will slowly deteriorate due to galvanic action. This can eventually lead to a leak and an explosion.

Grounding problems can be corrected, but they must be done carefully, and in full compliance with the electrical code. The techniques are too detailed to go into here, and they are often unfamiliar to many electricians. Theory and remedial techniques are discussed in *Tracing EMFs in Building Wiring and Grounding*, by Karl Riley.[1151]

[1150] Janet Raloff, "EMFs Run Aground," *Science News* (August 21, 1993): 124-126.

[1151] Karl Riley, *Tracing EMFs in Building Wiring and Grounding*, (Tuscon, AZ: Magnetic Sciences International, 1995). (Available from **Magnetic Sciences International**).

Metal Building Components

Sometimes metal components of a building (*e.g.* steel studs, aluminum siding, metal roofing, *etc.*) become energized if a black (hot) wire is shorted against them, or they become an accidental neutral path instead of (or in addition to) a white wire. This can lead to strong fields throughout a house. Just as with current flowing on water pipes, this means the current isn't going where it's supposed to. This can be the result of several problems, such as a short circuit—or a problem in a neighbor's house that is being transmitted through metallic water lines to your house. Such a problem should be corrected. Metal components should never be energized.

It's been suggested that living inside a metal-sided (or metal-roofed) house will shield the occupants from the beneficial natural background radiation that pulses at about 10 Hz, thus affecting a person's biological rhythms. If every piece of metal siding is well-grounded (a difficult thing to accomplish), it can block some wavelengths—but many of those wavelengths will pass through the windows, so the occupants aren't completely shielded. Also, occasionally being outdoors will allow a person to be exposed to the natural background radiation on a periodic basis. In reality, metal-sided houses don't seem to have much of an effect on biological rhythms.

Among sensitive people, there is a small subpopulation that have metal sensitivities. They report various symptoms when around very much metal, but the mechanism involved is not understood. They may be reacting to minute changes in background-radiation levels, or perhaps a slight current flowing on the metal, or perhaps to the metal acting as an antenna. Metal-sensitive individuals are often electrically sensitive, and chemically sensitive as well. For them, extreme care is necessary to design a tolerable house. Fortunately, such sensitivities don't seem to be common.

Power Panels

Within the main service-entrance panel itself, as well as inside subpanels, the black and white wires are run to different places. For example, the black wires are run to circuit breakers (or, in older panels, to fuses) and the white wires are run to a bar called a neutral *bus* or *busbar*. Because the wires are separated inside the panel, the magnetic fields don't cancel each other. As a result, power panels tend to have strong magnetic fields, so they should be located away from places where you spend a lot of time. Keep in mind that the panel is surrounded on all sides by a magnetic field—not just the front. A panel in a basement might seem to be well isolated from the living space, but if it is directly under your bed or easy chair, you could be exposed to its magnetic fields. Or, a panel might face into one room, but only be separated from the adjacent room by a $^{1}/_{2}$" layer of drywall.

Power panels are necessary, but the electromagnetic field risk can certainly be minimized. Simply mount the panel in an out-of the way location, or in a location where you don't linger. In a small house, a central hallway can be a reasonable compromise. You might walk by the panel several times a day, but that's better than having it near your bed where you would have several hours of continuous exposure.

In an existing house, power panels can be expensive to relocate. So, the easiest way to reduce exposure is to rearrange furniture.

Mu Metal

In some instances, particularly in existing houses, it can be very difficult to relocate a power panel, or to relocate furniture to minimize your exposure to EMFs. In such cases a special shielding material known as Mu metal can help. It is designed specifically to block *magnetic* fields, however it is not perfect. This is because, in most cases, magnetic fields cannot be blocked completely, but they can usually be reduced in strength. The amount of reduction will depend on several factors such as the frequency, source, and strength of the magnetic field, the shape of the area to be shielded, any seams in the Mu metal, the distance from the Mu metal to the source, the orientation of the Mu metal, and the thickness and heat-treatment properties of the Mu metal. So, it can be helpful to speak with someone knowledgeable to discuss your specific situation before purchasing Mu metal—because it can be fairly expensive. **Less EMF, Inc.** sells Mu metal in both a foil and a thicker plate material.

There are also electrically conductive fabrics available from **Less EMF, Inc.** that can be used to minimize *electric* (but not magnetic) fields. When this material wrapped around wires or appliances, and is properly grounded, it will reduce your exposure to electric fields (but not magnetic fields). It is sometimes used under mattresses or sheets in a bedroom.

Appliances

Common household appliances are often surrounded by high-strength magnetic fields, especially if they contain transformers or motors. This is because, when a single wire carrying electricity is looped (like a coil of rope), each loop multiplies the magnetic field. Electric motors and transformers have many loops of wire in their windings, so they have more-intense magnetic fields than, say, an extension cord. Coils of wire don't multiply electric fields, so if an electric motor is plugged into an extension cord, the motor and the cord will have similar electric fields.

Many manufacturers are starting to produce products with reduced electromagnetic fields.[1152] However, there are still plenty of appliances being made that have high-strength fields. If you are buying any new electrical device—from a power drill to a washing machine—and you ask the salesperson if it has reduced electromagnetic fields, they will probably have no idea. The best thing to do is to actually measure the field in the store. For example, if you are in the market for a new television, you can easily compare several similar models by walking in front of them with a hand-held Gaussmeter.

If you have existing appliances with high-strength fields, you have several choices. If money is no object, you can replace them with low-field appliances. Or, with something like a television, you can simply move your chair further away from it. After all, electromagnetic fields drop off in intensity as you move away from them. Clock radios can have very strong magnetic fields, and they are often located near your head while you're sleeping, so it isn't unusual them to be responsible for more exposure than everything else in the house. The solution is simple—just move the clock radio a few feet away from the bed. You might also consider a non-electric wind-up clock, or a battery-operated clock with low-strength fields. With other appliances, you can move away from

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[1152] "Private Industry Responds to Perceived EMF Threat," *Indoor Air Review* (June 1991): 9.

them after turning them on. For example, don't stand within 2-3' of an operating microwave oven. This is easier to do if the microwave oven is off to one side of the kitchen—away from the main work area. (Microwave ovens are sources of both microwaves and ELF waves.)

With appliances, distance is very important. Even low-field appliances often have high-strength fields very close to them. Unless you are willing to do without electrical appliances completely, the best way to minimize your risk is to use low-field models, keep your distance from them when they're operating, and reduce your exposure time. The booklet *EMF In Your Environment: Magnetic Field Measurements of Everyday Electrical Devices* by the **EPA** contains a listing of high, average, and low field strengths at different distances for many typical household appliances. Although it doesn't list manufacturers, it is helpful to have a copy along with a Gaussmeter when shopping for appliances. When you measure the actual magnetic field around an appliance, you can look it up in the booklet and determine if it is high or low for that particular type of appliance. For example, let's say you measure a magnetic-field strength of 80 mG. 6" away from a washer in an appliance store. According to the booklet, at a 6" distance some washing machines will be as high as 100 mG. or as low as 4 mG.[1153] With 80 mG. being on the high side, you might want to look at a different brand. But distance is also important. The booklet also lists readings further away—at 4' no magnetic field was measurable from any washing machine.

Heatway and **Bask Technologies LLC** (SunTouch) both have radiant electric heating systems designed to use under ceramic-tile floors that, according to the manufacturer, generate a low 4 mG. magnetic field 1" above the floor. The field strength will be even less at a greater distance above the floor. By comparison, there is an radiant electric system made by **NuHeat Industries Ltd.** with a magnetic field strength that ranges from 25-300 mG. at 1.2" above the floor.

Electrical Fixtures

Dimmer switches, doorbell transformers, and magnetic fluorescent-lamp ballasts have strong magnetic fields around them because they contain small coils of wire. Electronic fluorescent-lamp ballasts have lower-strength fields, so they should be used whenever possible. Other devices should not be mounted near beds or locations where furniture will be placed.

Ceiling-fan motors can have high-strength magnetic fields (when operating), but they are often up high, away from where you typically sit in a room. But in a multiple-story house, a fan on a lower level might be directly under a child's upstairs bed. The solution might be as simple as not operating the fan when the child is sleeping.

Bedroom Considerations

Because we spend so much time in bedrooms—typically 8 hours a night—

[1153] Environmental Protection Agency (EPA), *EMF In Your Environment: Magnetic Field Measurements of Everyday Electrical Devices* (Washington, DC: EPA, December 1992). #402-R-92-008.

bedrooms should be the healthiest rooms in the house.[1154] So, you may want to take more precautions there than in other rooms. For example, you may wish to reduce both magnetic *and* electric fields in the bedrooms but, to save money, you may only concentrate on magnetic-field reduction in the rest of the house. Electrically sensitive people often shut the power off to their bedroom at night to reduce electromagnetic fields to a minimum. This can be done easily by turning off the circuit serving that room at the main power panel (Be sure you aren't also accidentally turning off something else that should be left running—like the refrigerator.), or by installing a demand switch on the bedroom circuit.

For years, electric blankets were made with a single wire woven into them in a serpentine fashion. This lead to strong magnetic fields whenever the blanket was turned on. (Waterbed heaters were made similarly.) In 1989, Sunbeam was the first to redesign their blankets, and other manufacturers soon followed. Sunbeam's innovation was to simply run two wires in a serpentine fashion instead of one. By separating the wires by a mere $^1/_{32}$", the fields in the wires cancel each other, resulting in a 95% reduction in field strength.[1155] But even reduced-field electric blankets can bathe your body in a 1-3 mG. field so, to be extra cautious, you may want to do without them completely. With waterbeds, you can unplug a heater having a strong magnetic field at night, when you're in bed, then plug it back in during the day.

There are electrically conductive shielding fabrics on the market (**Less EMF, Inc.**) that can be grounded to minimize the strength of electric fields (but not magnetic fields). They are sometimes used under a mattress, or under the sheets of a bed, to minimize electric fields while sleeping.

What to Look for Outdoors

People are most concerned about outdoor power lines, but there are a number of other sources of electromagnetic radiation outside of a house that can affect the electromagnetic environment indoors. To be extra safe, houses should be at least a half mile from microwave transmission towers, radar installations, television and radio transmitters, and cellular phone towers. Some of these devices transmit a beam of electromagnetic radiation. For example, at airports, radar beams are aimed at incoming planes. A house should never be located within the path of such a radar beam. When in doubt, you should actually measure the fields to see if they are excessive. Most devices that act as *receivers* (such as home satellite dishes and television antennas) are not a problem.

Overhead Power Lines

Negative health effects associated with overhead power lines seem to have gotten far more press coverage, and generated far more public concern, than any other aspect of electromagnetic radiation. To understand just when they pose a risk, you must realize

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1154 Mary Cordaro and Katherine Metz, "The Low EMF Bedroom," *Interior Concerns Newsletter* (March/April 1995): 5-9.

1155 J.A. Raloff, "The Electric Blanket Syndrome," *Science News* (August 21, 1993): 126.

several things.

First, all power lines are not created equal—those carrying more voltage have higher fields than those carrying lower voltage. The most concern surrounds 500,000 volt (500 kilovolt [kv.]) and 765 kv. transmission lines. The 120 and 240 volt lines that bring power into our homes have much lower fields. High-voltage lines typically have wide utility easements, so houses are built some distance away from them—but sometimes not far enough away. And, just because you have low-voltage lines in your neighborhood doesn't mean they are safe. One of the earliest electromagnetic-field studies found a higher incidence of leukemia when houses were near certain wiring configurations commonly found in neighborhoods.[1156]

The field strength near a particular power line will vary at different times of day, depending on how much current is being used. Magnetic-field strength will be highest on a hot summer day when everyone is using their air conditioner. To get the best understanding of your exposure, you should measure the field at least several times of day.

The strength of the field is strongest directly under a power line (because that's where you're most likely closest to it), and it diminishes as you move away from it. This explains why the interference you hear on your car's radio is loudest directly under a transmission line. If two lines carry the same amount of current and voltage, and one is mounted on taller poles, or is further away from you, your exposure to its fields is less. Remember, all fields decrease with distance. So, just because a transmission line is visible doesn't mean it's dangerous.

Below are some typical magnetic-field measurements at different distances from power lines.[1157] These are the mean magnetic field strength as calculated for 321 power lines in 1990. The peak field strength (which occurs about 1% of the time) could be as much as twice as high as the mean strength, while the minimum field strength might only be half of the mean. All the measurements are in milligauss (mG.).

	Beneath	**50'**	**100'**	**200'**	**300'**
115 kv	29.7	6.5	1.7	0.4	0.2
230 kv	57.5	19.5	7.1	1.8	0.8
500 kv	86.7	29.4	12.6	3.2	1.4

The duration of your exposure is very important. For example, the magnetic field right next to an electric can opener in your kitchen could easily be over 1,000 mG., but it would only constitute a brief exposure. A much lower 10 mG. field in your bedroom, due to a nearby transmission line, is of much more concern, because you will be bathed in

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[1156] Nancy Wertheimer and Ed Leeper, 1979.

[1157] National Institute of Environmental Health Sciences (NIEHS), *Questions and Answers About Electric and Magnetic Fields Associated with the Use of Electric Power* (Washington, DC: NIEHS, n.d.): 46. #DOE/EE-0040.

that 10 mG. for 8 hours or more.

Summary

There are several health considerations to keep in mind when designing and installing an electrical system in a house, but the most important thing is to minimize the danger of electrocution. Fortunately, this is adequately addressed by electrical codes and it is not a problem in most houses. Electromagnetic fields are another matter.

Exposure to electromagnetic fields is universal. In fact, we are all exposed to them, in varying strengths, every day. Yet a comprehensive understanding of their health effects is far from complete.[1158] Still, it is possible—and often relatively easy—to reasonably minimize your exposure. But, because there are so many variables, you cannot guess about electromagnetic field strength—you must actually measure the fields to get a true understanding of your exposure. You may be justifiably concerned about power lines in your back yard, or the wiring inside your house, but if you don't measure the fields with a Gaussmeter, you will only be speculating—you won't know for sure if your health is in any potential danger.

[1158] Louise Kosta, "EMFs in Your Personal Environment, Part II: Biological Interactions and Health Effects," *The Human Ecologist* (Summer 1995): 1.

24. Central Vacuums

A central-vacuum system consists of a motor/vacuum unit with a dust-collection chamber, one or more wall inlets, a flexible hose, and various cleaning tools. Plastic tubing and various fittings connect the central unit to the wall inlets. While central vacuums are routinely being installed in houses with wall-to-wall carpeting, they can be very useful even in houses without carpeting. Hardwood and ceramic-tile floors do not generate dust like carpeting, but any dust that falls on them is more visible. In other words, there may not be as much dust in a house without carpeting, but you'll be able to see it easier.

Filters and Exhausts

Most portable vacuum cleaners are not only awkward to use, but they tend to blow dust around the house because they have inefficient filters. As a portable vacuum sucks dust up from the floor and dumps it into a collection bag, some of the finest particles of dust pass through the filter and the bag and are exhausted back into the room. These very fine particles can be easily inhaled deeply into the lungs whenever you are cleaning. You can often see this fine dust while you are vacuuming, as it is reflected in the sunlight streaming through a window.

With a central vacuum, some of the dust still passes out an exhaust. But most central vacuums have an exhaust pipe that directs the dust outdoors—so it isn't blown into your face. Central vacuums do not have particularly efficient filters, so units with indoor exhausts should be avoided, and an outdoor exhaust shouldn't be directed into a basement.[1159]

There are portable vacuums that have better-than-average filters—some use HEPA filters.[1160] Manufacturers include **Eureka Co.**, **Euroclean**, **Miele, Inc.**, **Nilfisk-Advance America, Inc.** and **Vita-Mix Corp.** In addition, **The Hoover Co.** makes a WindTunnel model with a special light sensor to indicate when the area you're vacuuming is clean. For a different approach, **Rexair, Inc.** sells the Rainbow vacuum that has a water filter. Water vacuums tend to be heavier than other models and less efficient. These portable vacuums all exhaust air into the room—it's just highly filtered air. This exhaust air, even though it's clean, can disturb dust that hasn't been cleaned up yet. So, while these units have very efficient filters, they can still contribute to airborne dust. These more-efficient portable units sometimes cost nearly as much as a central system.

To save money, do-it-yourselfers can usually install a central vacuum themselves, and many people feel that central vacuums are more convenient to use than portable models. Some central units can be fitted with a muffler to reduce the noise. On the down side, some motor/vacuum units have an odor when running that can bother some sensitive people—but, so do some portable models. This is generally due to the outgassing from

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[1159] Jim White, "The dangers of vacuuming" (letter), *Environmental Building News* (July/August 1996): 3.

[1160] Vacuums: Clearing the air," *Safe Home Digest* (January/February 1992): 1.

the motor and plastic components when they get warm. To minimize occupant exposure to this outgassing, a central unit can be mounted in a garage, basement, or inside a closet that is ventilated.

Inlets and Tubing

The wall inlets supplied with central-vacuum systems are usually made of plastic but, as with light-switch covers, they aren't significant outgassing sources. Some manufacturers offer metal inlets. The plastic tubing connecting the inlets to the central unit is usually run within walls or other building cavities. This is easier to do in new construction but, with a little thought, the piping can also be run in existing houses.

The plastic tubing is assembled with the same cleaning solvent and glue used with plastic plumbing systems, so the area must be ventilated thoroughly until all the odor dissipates. Glues and cleaners are quite noxious, but they outgas quickly—usually within a few hours. The plastic piping itself can outgas somewhat, but it's usually not significant problem. Outgassing can be minimized by purchasing the tubing and fittings early in the construction process an letting it outgas before it's installed, or by wrapping it with household aluminum foil after installation.

Accessories

All central-vacuum systems (like many portable vacuums) have flexible plastic hoses and plastic tools. The hoses for central units are available in a variety of lengths—up to 40' long. Long lengths allow you to clean several rooms without moving the hose to a different inlet. But a hose that's too long can be unwieldy. A 30'-long hose is often a good compromise. But sometimes an extra hose that's only 10-12' long can be useful. New plastic hoses often have a very strong odor that's bothersome to sensitive people. Again, if the hose is purchased early, most of the outgassing will dissipate before it's time to use it. Many sensitive people simply hang their new hose outdoors, in a location protected from the weather, until it's tolerable.

With most central vacuums, when you plug the hose into an inlet, the vacuum is automatically turned on. Then, you unplug the hose to turn the unit off. If you're at the end of a 40' hose, and need to turn the unit off for just a short period of time—to answer the telephone, for example—you must walk clear back to the inlet and unplug the hose. This can be inconvenient, but there is a simple solution. Some manufacturers offer a hose with a handy on/off switch on the handle. If you have a multiple-story house, you probably only need one central-vacuum unit, but it's often useful to have a hose on each floor.

Beam Industries Inc. offers a useful attachment called a Vac-pan—a vacuum powered dustpan. A Vac-pan is made to be mounted close to the floor. When you bump it with your tow, the vacuum turns on and a small door opens so you can sweep dust into it with a broom.

Beam Industries Inc. also has a SensorClean electronic dust monitor that simply attaches to the wand of a central vacuum or a canister model to let you know when the vacuum cleaner is no longer picking up dirt. It uses a 9 volt battery and has a red and a green indicator light. If the red light is lit, you need to keep vacuuming, if the green light is glowing, no more particles are being picked up and you are finished cleaning. This type of indicator device is now available as a built-in feature of some portable vacuum cleaners.

Suppliers

Central vacuums can be noisy, especially if mounted inside the living space—even when inside a closet. Some manufacturers offer mufflers as an option. **Beam Industries Inc**. has several models, including one of the quietest central vacuums on the market. Other central-vacuum manufacturers include **Broan Mfg. Co., Inc.**, **Electrolux**, **Eureka Co.**, **The Hoover Co.**, and **NuTone, Inc.** In addition, **Vacs America, Inc.** has a Cubby Vac that mounts in a 16" stud space of an existing house without installing any PVC tubing inside walls.

Part 4: DETAILED EXAMPLES

25. An In-Depth Evaluation of Six Common Pollutants

There have been many different indoor pollutants covered in this book, some of which are more common than others. This chapter will go into more depth in discussing six that occur with some regularity, and about which many questions are asked: lead, asbestos, radon, mold, combustion by-products, and VOCs.

Lead

People have known for hundreds of years that lead was toxic but, until fairly recently, it was mistakenly believed that we didn't need to worry about minor exposures. Now, as researchers learn more and more about the insidious effects of lead, they have concluded that lead is a much bigger problem than anyone realized.

Lead Poisoning

Children are especially at risk of being poisoned by lead because their bodies absorb lead more readily than was once suspected. According to the **CPSC**, lead poisoning in children can result in irreversible brain damage, mental retardation, slowed physical development, and reduced attention span. It can also impair mental functioning. Developing fetuses are especially vulnerable when pregnant women are exposed to lead.

Early symptoms of lead poisoning in children include persistent tiredness, irritability, loss of appetite, stomach discomfort, reduced attention span, insomnia, and constipation. These are common symptoms in many children, and it's easy to confuse them with other illnesses, or even with normal development. However, if a child does have excessive lead in his or her system, early treatment is mandatory in order to avoid permanent damage.

In the 1970s, the **Centers for Disease Control** (**CDC**) defined lead poisoning in children as occurring when the level of lead in the blood reached 30 micrograms per deciliter (30 μg/dl). But by October 1991, the **CDC** established 10 μg/dl as being a more meaningful limit. Blood levels below 10 μg/dl are not considered serious. A blood level is between 10 and 14 μg/dl is considered border-line, and should be monitored to see if it rises. If a child's blood has a lead level between 15 and 19 μg/dl, they are at risk for decreases in IQ of up to several points, and other subtle effects. Blood-lead levels between 20 and 69 μg/dl are very serious. Children with this much lead in their blood should be scheduled for a complete medical workup, and their environment should be carefully evaluated to determine where the lead is coming from. If the blood-lead level in a child is above 70 μg/dl, it's considered a medical emergency, and medical and environmental management should begin immediately.[1161]

It's now believed that 8.9% of children under the age of 6 in the U.S. have lead

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[1161] U.S. Centers for disease Control (CDC), *Preventing Lead Poisoning in Children* (Atlanta, GA: CDC, October 1991): 29-30.

levels in their blood above 10 mg/dl.[1162] And it's been estimated that for each 1 μg/dl of lead in the blood, a child's lifetime earning ability will be decreased by $1,147.[1163] Statistically, that means a child with a lead level of 10 mg/dl will earn $11,470 less in his or her lifetime than a child with a lead level of zero. According to the **CDC**, "lead poisoning is one of the most common and preventable pediatric health problems today."[1164]

If so many children are affected, why don't more adults display symptoms? The answer is that a great many adults probably are affected—although the symptoms aren't always readily apparent. David Bellinger, a lead researcher at Harvard University has said "I guess (if none of us were exposed) we all might have been a little smarter than we turned out."[1165] Lead poisoning in adults can result in symptoms of irritability, poor muscle coordination, and increased blood pressure. Damage to nerves controlling the body, joint pain, memory loss, headaches, and kidney damage are also possible, as are reproductive problems such as a reduced sperm count.

Who Should Be Tested?

Every child in the U.S. is at risk of lead poisoning, but some are at greater risk than others. Younger children are at the most risk, so initial testing is generally recommended between the age of 6 months and 6 years. If a child lives in, or regularly visits, a house built before 1960, and there is recent, ongoing, or planned remodeling, or if that house is in deteriorating condition, they are at increased risk. They are also at risk if they have a playmate or sibling who has lead poisoning, or if a member of the household works at a lead-related hobby or occupation, or if they live or play near a lead-related industry. Bright children may be at more risk because their curiosity prompts them to feel and taste objects in their environment.[1166]

If you suspect lead poisoning, you should first have a screening test done to determine how much lead is in your child's, or your own, blood. Inexpensive tests are sometimes available through local health departments. A limitation of blood tests is the fact that they only reflect recent exposure. Other tests, like L-line X-ray fluorescence, can determine how much lead has accumulated in the body over a lifetime.

If you, or your child, have elevated lead levels, your doctor will advise you to first reduce your exposure. Then he or she may recommend one of several treatment methods. Intravenous chelation therapy has been the standard approach for some time, but there are now oral medications available.

[1162] D.J. Brody and others, "Blood Lead Levels in the U.S. Population," *JAMA* 272 (1994): 277-283.

[1163] U.S. Centers for disease Control (CDC), *Strategic Plan for the Elimination of Childhood Lead Poisoning* (Atlanta, GA: CDC, February 1991): 29-30.

[1164] CDC, *Preventing Lead Poisoning*, 1.

[1165] Steven Waldman, "Lead and your kids," *Newsweek* (July 15, 1991).

[1166] Louise Kosta, "The sad legacy of lead," *The Human Ecologist* (Fall 1990): 12-14.

Sources of Lead

Lead can be a component of many different materials (*e.g.* paint, gasoline, solder), and it can contaminate air, water, food, soil, *etc*. While a single low-level exposure may not be a concern, lead can build up in the body, so several low-level exposures can add up to equal a single larger exposure. Therefore, all possible routes of exposure should be identified and remedied. Just because paint is the number one source, doesn't mean you can't be exposed to excessive quantities from your water supply, or lead glazes on imported dinnerware. Lead gets into our bodies primarily through ingestion and inhalation.

Lead-Based Paint

In the past, some residential lead-paint formulations contained as much as 50% lead. The percentage of lead in paint started to decline in the 1950s, and in 1978 the **CPSC** banned the manufacture of paint containing more than a trace amount (0.06%) of lead for residences, toys, and furniture. Still, there are about 3 million tons of lead paint on the 57 million housing units in the U.S. built prior to the lead-paint ban. Fourteen million of those housing units are believed to contain paint in deteriorating condition.[1167] Lead-based paint can be found on virtually any surface of a house. If it weren't for the negative health consequences, it made for excellent paint.

Children can certainly be poisoned by ingesting small chips of lead paint, or chewing on painted materials, but this is not the most common way they get lead paint into their systems. A more likely route of exposure involves lead-contaminated dust. For example, many exterior lead-based paints were designed to chalk off as a self-cleaning process. This results in lead dust in the soil around a house. Children playing outdoors on contaminated soil invariably get this lead dust on their hands. Then, through normal hand-to-mouth activity, they get lead dust in their mouths. Lead-based paint can also be found on bridges, water towers, and playground equipment.

A common route of indoor exposure to lead paint involves windows. As a window sash is raised and lowered over the years, the lead paint erodes, leaving a layer of fine lead dust on the sill, or on the floor. Again, children get the dust on their hands, and they invariably put their fingers into their mouths. Normal, repetitive, hand-to-mouth activity is considered a major contributor to lead poisoning in children.[1168] Ingestion in this way is more commonly implicated than inhalation of lead dust.

The risk of poisoning from lead-based paint is related to the condition of the

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[1167] Department of Housing and Urban Development (HUD), *Comprehensive and Workable Plan for the Abatement of Lead-Based Paint in Privately Owned Housing: Report to Congress* (Washington, DC: HUD).

[1168] R.L. Bornschein and others, "Exterior surface dust lead, interior surface dust lead and childhood lead exposure in an urban environment," in D. Hempill, Ed. *Trace Substances in Environmental Health* (Columbia, MO: University of Missouri, 1986): 322-332.

paint.[1169] In other words, lead-based paint is a problem primarily when it's deteriorating—or repeatedly being worn or abraded, as on a window sash.

Many cases of lead poisoning in children, and adults, are the result of remodeling. If lead-painted materials are damaged, sanded, or removed carelessly during a home-repair or renovation project, both adults[1170] and children[1171] can easily be poisoned. Older homes should always be checked for the presence of lead prior to doing any remodeling. If lead paint is found, it should be treated with respect, and not disturbed without taking proper health-and-safety precautions. Correctly done, lead-paint abatement can reduce the risk of lead poisoning considerably.

Soil and Dust

Soil and dust can become contaminated because of lead paint, leaded gasoline, and industrial or occupational sources. Lead will not dissipate, biodegrade, or decay. So, once it contaminates soil or dust, the contamination lasts forever—unless the lead is purposefully (and properly) cleaned up. While leaded gasoline is no longer a problem, there are an estimated 4-5 million metric tons of lead in soil and dust as a result of the leaded gas we used in the past.[1172]

It's often only the upper inch or two of soil that is contaminated with lead, but gardens, or other areas where the soil is disturbed, can be contaminated to greater depths. The soil near a roadway or a house painted with lead paint can be contaminated with as much as 10,000 parts per million (ppm) of lead. The soil around smelters can be as high as 60,000 ppm.[1173] Children can be natural explorers, so they often come in contact with lead-contaminated soil. The more contaminated the soil, the more likely poisoning will occur.

To reduce the risk associated with heavily contaminated soil, the upper few inches can be removed, but removal can be expensive if the soil is deeply contaminated. Costs will also depend on where the soil is to be disposed—after all, it's considered hazardous waste. Risk can also be reduced by covering the soil with several inches of uncontaminated soil, bark chips, concrete, or gravel. If properly maintained, grass may be

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[1169] Agency for Toxic Substances and Disease Registry (ATSDR), *The nature and extent of lead poisoning in children in the United States: A Report to Congress* (Atlanta, GA: ATSDR, 1988).

[1170] Leila Schneitzer and others, "Lead Poisoning in Adults From Renovation of an Older Home," *Annals of Emergency Medicine* 19 (April 1990): 415-420.

[1171] Susana Rey-Alvarez and Theresa Menke-Hargrave, "Deleading Dilemma: Pitfall in the Management of Childhood Lead Poisoning," *Pediatrics* 79 (1987): 214-217.

[1172] ATSDR.

[1173] Environmental Protection Agency (EPA), *Air Quality Criteria for Lead* (Research triangle Park, NC: EPA, 1986). #EPA/600/8-83/028aF.

an effective way to limit exposure.[1174]

A great deal of lead dust can be tracked indoors on shoes, so simply removing shoes at the door can help minimize lead contamination in the rest of the house. In one study, the concentration of lead in the rugs of houses where shoes were removed was 440 micrograms per square meter ($\mu g/m^2$), but in houses where shoes remained on, levels were 12,600 $\mu g/m^2$. In houses where shoes were left on, but there was a long walk-off mat at the entry doors, the levels were 2,900 $\mu g/m^2$.[1175]

Drinking Water

Lead concentrations in natural water supplies are usually low. So, lead contamination of water usually takes place while water is traveling through the distribution system. Specific sources include lead fittings, lead pipes, lead-containing solder, lead parts in some water coolers and fountains, and brass fittings. Sometimes, lead-lined cisterns have been used to store water. The 1986 Safe Drinking Water Act banned the use of lead in public-drinking-water systems and limited the use of lead in brass to 8%. So, water systems installed before 1986 are more likely to be contaminated than newer installations.

Adults who drink lead-contaminated water absorb 35-50% of the lead, while children can absorb more than 50%.[1176] While this can be a significant route of exposure in children, poisoning from lead-based paint is more common.

Occupations and Hobbies

An adult's clothing, hair, and body can become contaminated with lead at work and they can bring that contamination home where it can poison their children. Industries where lead is common include smelting, storage-battery processing, brass or copper foundries, glassmaking, chemical processing, and paint manufacturing. Workers can also contaminate their homes if they bring scrap or waste materials home.

Lead exposure is also associated with furniture refinishing, stained glass and other hobbies involving soldering, pottery making, firearms, and various art materials. Burning of lead-painted wood can release lead fumes into the air and the ash will contain lead dust. Some candle wicks contain a lead core as a stiffener that can release undesirable lead fumes into the air when the candle is burned.[1177]

[1174] G. Jenkins, C. Murray, and B.H. Thorpe, "Lead in Soil: The Ontario Situation," in B.E. Davies and B.G. Wixon, Eds. *Lead in Soil: Issues and Guidelines* (Northwood, ON: Science Reviews Ltd. 1988): 235-245.

[1175] John Roberts, David Camann, and Thomas Spittler, "Monitoring and controlling lead in house dust in older homes" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 2, Characteristics of Indoor Air*, 1990): 435-440.

[1176] ATSDR.

[1177] Howard Sobel, Peter Lurie, and Sidney M. Wolfe, "Lead exposure from candles," *JAMA* (July 12, 2000): 180.

Air

In the past, most airborne lead was the result of leaded gasoline. This constituted a significant exposure to lead, but as the amount of lead in gasoline was reduced in the 1970s and 1980s, lead levels in the air dropped tremendously. Therefore, airborne lead is no longer the threat it once was. However, there can be localized sources of airborne lead around smelters, battery-manufacturing plants, solid-waste incinerators, or where lead-based paint is being sandblasted. Soldering with lead-based solder releases lead fumes which can easily be inhaled.

Food

During the 1980s, the amount of lead in our diet decreased significantly, primarily because of restrictions on the use of lead solder to seal cans. In 1980, 47% of the food and soft-drink cans in the U.S. were assembled with lead-based solder, but by 1989 it was down to 1.4%. Some imported food cans still contain lead solder.

Lead can also get into our food from lead-contaminated rain or lead-contaminated air. Also, food grown in urban gardens, where the lead content in soil is particularly high, can be contaminated with lead. There are a number of factors that determine how much lead food takes up from the soil, so it's important to have such food tested to determine if there is a problem. Check with your County Agricultural Extension Service for guidance.

Containers made of lead crystal, or ceramic containers with lead glaze, should not be used to store food for prolonged periods of time because the lead can leach out.[1178] Some ceramic cookware (especially antique or imported pieces) has lead in the glaze.[1179] Occasionally, food supplements, cosmetics, hair-coloring materials, and non-traditional medicines are contaminated with lead.

Looking for Lead

There are several methods of determining whether or not a material contains lead. Inexpensive do-it-yourself kits are often available in hardware stores. The LeadCheck Swabs are manufactured by **HybriVet Systems Inc.** These tests aren't perfect, because they can't detect very low levels of lead, so you may still want to contact a professional to perform a more accurate (and more expensive) test. A test for lead dust is the most revealing test to have performed.

If you plan to hire a professional to do a risk assessment, or to actually inspect your property, they should be accredited by your state or by the **EPA**. If they have done work according to the **U.S. Department of Housing and Urban Development**'s (**HUD**'s) 1990 public-housing guidelines, they may be particularly well qualified. Your local board of health might be able to recommend a company, or you can contact the **Lead Listing** (which is sponsored by the **National Lead Assessment and Abatement Council** and **HUD**) to locate a certified lead contractor in your area.

If you are looking for a laboratory to analyze a material for the presence of lead, choose one accredited by the **EPA**'s National Lead Laboratory Accreditation Program.

1178 "Lead, again," *Safe Home Digest* (March 1991): 8.

1179 Judith Finn, "Lead in ceramicware: Buyer beware," *East West* (January 1991): 23.

Your local board of health may be able to suggest such a laboratory, or referrals can be obtained from the **American Association for Laboratory Accreditation** or the **American Industrial Hygiene Association**.

For more information about lead, contact the **National Lead Information Center**. Canadian sources of information about lead can be found in a booklet titled *Renovation: Lead in your home*,[1180] which is available from **Canada Mortgage and Housing Corp.**

Risk Assessment

If you find lead in, or around, your home, you should analyze the situation carefully before deciding to remove it. This is very important if you are to avoid unnecessary expense and unnecessary exposure to lead. Completely deleading a house can be expensive, and it's not always necessary. In many cases, the presence of lead doesn't constitute a risk. For example, if lead-based paint is not deteriorating, it may be something you can live with.

We all do risk assessments every day. We know there's a risk of having an accident every time we drive an automobile, yet most of the time we accept that risk as minimal. If roads are hazardous, because of an ice storm, we may decide to stay home, and not take the risk. Lead is only dangerous if it's inhaled or ingested. So, if there is no lead dust to become airborne, then there is no way for it to get into your lungs or stomach, and it poses no threat. Lead doesn't outgas like volatile chemicals—in many cases it just sits there.

A complete risk assessment by a professional might include filling out a questionnaire, a walk-through visual inspection of the house, a more detailed evaluation of deteriorating surfaces, and laboratory sampling. A professional's report will typically list the locations of lead, the condition, the risk, and abatement options. If lead paint exists, but isn't hazardous, a report may suggest a program of ongoing monitoring—so you can determine if a problem develops in the future.

What to Do About Lead Paint

If lead paint is a problem in your house, there are several ways of dealing with it. Lead abatement means eliminating the hazard. In most situations, a combination of the following strategies works well. After any lead abatement has been completed, it's very important to perform a follow-up inspection to determine if there is any residual lead dust or debris that wasn't properly cleaned up. After the job is complete, a lead-abatement contractor will issue a certificate of compliance, documenting what was done.

In some cases, doing nothing is a viable option.[1181] However, this is only appropriate if the lead paint is not deteriorating and not contributing to lead levels in house dust.

[1180] Canada Mortgage and Housing Corp. (CMHC), *Renovation: Lead in your home* (Ottawa, ON, Canada: CMHC, n.d).

[1181] Canada Mortgage and Housing Corp. (CMHC), *Lead Precautionary Measures* (Ottawa, ON, Canada: CMHC, December 1, 1992): 12.

Component Replacement

Sometimes the easiest thing to do with lead-painted materials is to remove them and replace them with new materials. For example, baseboard trim and door or window casings can sometimes be removed and replaced at a lower cost than other abatement options. If moldings are particularly attractive, or have historic significance, encapsulation or paint removal may be more appropriate.

To replace building components safely involves several steps. Workers should wear protective gear and the work area should be prepared carefully so the rest of the building isn't contaminated, and occupants aren't exposed. Lead-painted components to be removed should be misted with water to control dust (unless an electrical circuit is nearby), and painted seams should be scored with a sharp knife. After the components are removed, and nails are bent over or removed, contaminated materials should be sealed in plastic bags and disposed of properly. Then new components can then be installed. Finally, the area should be properly cleaned and evaluated to see if the process was successful.

Enclosure

Enclosure involves covering lead-painted surfaces with a rigid, durable material so the lead paint is no longer exposed to the occupants. Enclosure materials should last for at least 20 years. If you select this option, it's important to identify lead-painted surfaces so future occupants will know of their presence. Two approaches are generally employed: actually stamping or labeling the surface itself, or attaching a durable drawing to a utility-room or closet wall showing the locations of lead paint.

You should first prepare the work area, and evaluate the various enclosing materials, then choose the one most appropriate. Enclosing materials include: wood paneling, plastic laminates, ceramic tile, and drywall. You should first repair any unsound structural members or deteriorating surface materials. To actually install the enclosing material, you'll likely need caulking, adhesives, and screws or nails. Enclosing materials should be installed in an airtight manner, so air cannot travel behind them and bring lead dust or chips into the occupied space. Once the job is complete, the area should be cleaned-up and evaluated to determine if it is without risk.

Encapsulation

Encapsulation involves sealing a lead-painted surface with a specially formulated paint or coating, or gluing a wall-covering-like material over the surface. An encapsulant is a flexible material that is fully bonded to the lead paint. Enclosure materials, on the other hand, are rigid materials fastened primarily with mechanical fasteners. For encapsulation to be successful, all the layers of the existing paint must be bonded to each other—and to the base material. If the paint layers are delaminating, encapsulation isn't a good option, and it isn't suitable for surfaces prone to wearing, such as window jambs, nor for metal surfaces apt to rust.

Before deciding on encapsulation, the painted surface must be tested to see if it's in good enough shape. If it is, the work area should be prepared, and the process can begin. Damaged areas should be repaired, surfaces should be cleaned of dirt, grease, chalking paint, mildew, *etc*., and shiny surfaces may need to be deglossed.

Liquid coatings should be applied per the manufacturer's recommendations with regards to coating method, curing time, worker protection, and ventilation requirements. After cleanup, and inspection, the owner should monitor the condition of the encapsulant after 6 months, then every 12 months, to make sure it's in good shape. Careful record keeping is necessary to insure that future repairs can be made safely. There are a number of manufactures of contractor-grade lead-paint encapsulants, including **Fiberlock Technologies, Inc.** This company also has a consumer product called Child Guard, which is a coating for lead-based paint that meets or exceeds all requirements for covering lead-based paint on interior and exterior surfaces. They also have a consumer product called LeadSafe Wipes for use in removing hazardous lead dust from surfaces, prior to applying a coating.

Paint Removal

Removing lead paint can be expensive because it involves careful procedures, worker protection, and proper disposal. Removal is usually the best way of dealing with lead because it's a long-term solution, and future monitoring isn't necessary. Lead paint should never be removed by heating the paint with an open flame or a high-temperature heat gun, nor by dry sanding, dry scraping, sand blasting, or power washing—unless proper containment methods are used. Welding should never be done on lead-painted surfaces, and the use of chemical paint removers containing methylene chloride is discouraged.

If feasible, one of the best approaches is to take lead-painted materials out of a residence and remove the paint elsewhere. This can often be done at a commercial paint stripper. If the paint must be removed on site, the area should be properly prepared to prevent contamination of the rest of the house. If low-temperature heat guns are used, fire extinguishers should be made available. Dry sanding, dry scraping, sand blasting, and power washing should be done in a way that will prevent lead dust from being spread. Dry methods require special vacuum attachments with HEPA filters.

If chemical stripping is necessary, you should determine if the stripper will damage the surfaces under or near the lead paint. Proper worker protection is vital, and eye-wash stations are recommended. Some paint strippers work slowly and must set overnight. If this is the case, the area should be secured to prevent people from accidentally coming in contact with a project in progress. Once the job is done, the area should be cleaned up and inspected for compliance. Manufactures of paint strippers used in lead abatement work include **Dumond Chemicals** and **Fiberlock Technologies, Inc.**

Routine Maintenance

If there is lead paint in your home, but deterioration is minimal, careful removal of lead dust may reduce your exposure substantially. Conventional cleaning methods (vacuuming, sweeping, mopping, *etc*.) have been used with varying degrees of success.[1182] Cleaning with a conventional vacuum cleaner is usually not a good way to remove lead dust because the finest particles can pass through the filter and become airborne. **Nilfisk-Advance America Inc.** is one manufacturer that produces commercial HEPA vacuums both for lead-abatement contractors and for residential use.

[1182] Canada Mortgage and Housing Corp. (CMHC), *Effectiveness of clean-up techniques for leaded paint dust* (Ottawa, ON, Canada: CMHC, December 1992).

The best approach to cleaning is to wash hard surfaces, such as wood and vinyl floors, window sills, baseboards, *etc*., with a high phosphate solution (at least 5%). Trisodium phosphate (TSP) works well, as can some dishwashing detergents. TSP can be purchased in paint and hardware stores. You should also wash your child's hands and face before they eat, and wash toys and pacifiers frequently.

Do-It-Yourselfers

Because of the high cost of lead abatement, a homeowner may decide to do the remediation work themselves. Because of the hazards associated with removing lead paint, organizations like the **CPSC** and **CDC** generally recommend hiring an experienced contractor who has all of the proper safety equipment, knows how to do the work correctly, and will dispose of the waste in accordance with all applicable environmental regulations.

If you want to abate a lead-paint problem yourself, keep in mind the fact that improper procedures can definitely create a bigger problem than existed in the first place. Both adults and children have been poisoned as a direct result of the removal process.[1183] [1184] If you plan to do any work that can stir up lead dust, separate the area securely with plastic sheeting and tape, so the rest of the house doesn't become contaminated. Pregnant women and children should be kept away from the work area. Workers should wash their hands and clothes thoroughly, and wear the proper respiratory-protection equipment. Clean up and disposal are of prime importance. Lead paint that has been removed is hazardous waste and shouldn't be disposed of with your household garbage.[1185] [1186]

HUD has a document titled *Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing*[1187] that covers all aspects of lead-paint and lead-in-soil abatement. It is highly recommended for anyone planing to deal with lead abatement themselves.

Asbestos

Asbestos is a mineral that can be separated into fibers. The fibers can be used as reinforcing in a variety of products—much like fiberglass is used to reinforce some

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[1183] Muriel Wolf, "Lead poisoning from restoration of old home," *JAMA* 225 (July 9, 1973): 175-176.

[1184] Yona Amitai and others, "Hazards of 'deleading' homes of children with lead poisoning," *AJDC* 141 (July 1987): 758-760.

[1185] Philip Dickey, "Paint, Putting it on and taking it off with safe products" *Green Alternatives* (July/August 1993): 39-43.

[1186] Steve Hillenbrand, "Pollution prevention: Painting and paint stripping," *Pollution Prevention News* (July/August 1992): 7.

[1187] U.S. Department of Housing and Urban Development (HUD), *Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing* (Washington, DC: HUD, June 1995).

materials today. Asbestos fibers are not combustible so they have been useful, when woven into yarn and cloth, to protect objects and people against heat. Between 1900 and 1980 about 30 million tons of asbestos were put in place in the U.S.[1188]

Asbestos and Lung Damage

As asbestos-containing materials age, they can be abraded, become worn, degrade, or otherwise break down. This releases asbestos fibers into the air, where they can be inhaled. Microscopic asbestos fibers, and asbestos dust particles, can remain airborne for extended periods of time. If inhaled, they can lodge in the lungs. Asbestos is very durable, so it can remain in the lungs for a very long time—often until death.

Various medical studies have found that inhaling high concentrations of asbestos fibers for extended periods (such as poorly protected workers in asbestos-producing industries) can lead to various lung diseases.[1189] Other studies have found lung disease in workers who occasionally work with asbestos—*e.g.* plumbers and pipe fitters.[1190] Because asbestos has been used in so many different products, we are all exposed to small amounts of it at different times in our lives. Most of us don't suffer any health problems as a result of our exposures, but asbestos-related health problems can be quite serious, so we should always minimize our exposure whenever possible.

Asbestos can cause asbestosis, a chronic, fibrotic, lung disease that makes breathing difficult, and can lead to death. Lung cancer is the most common asbestos-caused disease. If you smoke, and are also exposed to asbestos, your lung-cancer risk increases substantially—between 50 and 90 times that of someone who doesn't smoke, and isn't exposed to asbestos. Asbestos can also cause mesothelioma, a rare cancer of the lining of the lung or abdominal cavity. This results in shortness of breath and abdominal and chest pain. Mesothelioma almost never occurs without asbestos exposure. In addition, asbestos exposure can lead to the formation of pleural plaques, a benign lung condition. Occasionally other cancers, primarily of the digestive tract, are attributed to asbestos.

Asbestos-caused diseases tend to take 20-40 years to develop. So, newly reported cases in the 1990s are the result of exposures between the 1950s and the 1970s.

Where is Asbestos Found?

Because of its negative health effects, and because of a few instances where it was banned by the government, the use of asbestos has decreased considerably in recent years. By the 1970s it had virtually disappeared from new building products. But, because it is a very long-lasting material, it's still a potential problem in older houses, as

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[1188] Environmental Protection Agency (EPA), *Asbestos Fact Book* (Washington, DC: EPA, August 1985).

[1189] Safe Building Alliance, *Asbestos in Buildings: What Owners and managers Should Know* (Washington, DC: Safe Building Alliance, n.d.).

[1190] Nancy Sprince, L. Christine Oliver, and Theresa McCloud, "Asbestos-related disease in plumbers and pipefitters employed in building construction" *Journal of Occupational Medicine* 27 (October 1985): 771-775.

well as older commercial buildings and schools. It's been estimated that 20% of all buildings have some type of asbestos-containing materials.[1191]

Floor Tiles

Asbestos was added to some vinyl, asphalt, and rubber flooring (both individual tiles and sheet flooring) to give it strength. It is often a component of the backing, held in place with some type of binder. Sometimes asbestos was also a component of the adhesive used to attach the tile to the floor. Without realizing that asbestos was present, one contractor removed a client's vinyl floor and sanded the mastic off the subfloor—and contaminated the whole house with asbestos fibers. It required $50,000 to decontaminate the house.[1192] In some cases, just buffing an asbestos-containing tile floor can release fibers.[1193]

Walls and Ceilings

Some manufacturers used asbestos in drywall and plasterboard, but more commonly it was a component of joint-finishing and patching compounds. This use was banned by the **CPSC** in 1977.[1194] Some textured paint also contained asbestos.

Materials that were sprayed or troweled onto ceilings or walls to add texture, or for soundproofing, sometimes contained asbestos. This was more common in large buildings, but asbestos has been found in residential ceilings as well—some of which are crumbly and releasing fibers into the air. Most asbestos-containing ceiling coatings were installed between 1945 and 1978.

Stoves and Furnaces

Various asbestos-containing materials have been used around heating devices to protect combustible materials. For example, asbestos paper and millboard have been used under, and behind, wood stoves to insulate the walls and floor. Asbestos insulation was also used in conjunction with older oil, coal, and wood-burning furnaces. Some of the door gaskets on furnaces, stoves, and ovens contained asbestos. These gaskets are subject to damage and wear, and they release fibers as they become worn. Some artificial ashes and embers for use in gas fireplaces also contained asbestos, but this use has been banned.

Pipe and Wall Insulation

Between 1920 and 1972 hot-water and steam pipes were often insulated with molded, pre-formed, asbestos-containing insulation—primarily to prevent heat loss, but

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[1191] "Asbestos Abatement Industry Estimated at $100 billion," *Indoor Air Quality Update* (September 1988): 13-14.

[1192] Ann Marie Moriarty, "Asbestos Fallout," *Remodeling* (March 1989): 104-109.

[1193] A. Edwards, J.R. Kominsky, and R.W. Freyberg, "Airborne Concentrations During Spray-Buffing of Resilient Floor Tile," *Applied Occupational and Environmental Hygiene* 9 (1994): 132-138.

[1194] Consumer Product safety Commission (CPSC), *Asbestos in the Home* (Washington, DC: CPSC, August 1982).

also to protect combustible surfaces from high temperatures. Some pipes were wrapped with asbestos paper or an asbestos blanket. Some forced-air heating ducts were also insulated with these types of materials.

Some homes built between 1930 and 1950 contain asbestos insulation inside their wall cavities or in the attic. Prior to 1990, a great deal of vermiculite insulation was contaminated with up to 5% asbestos. These materials can seriously contaminate the air in a house if it's exposed during remodeling or renovation.

Roofing and Siding

Asbestos was used to reinforce cement-board products that were used for roofing, shingles, and siding. These asbestos-cement products tend to be quite inert—unless damaged. Asbestos was also a component of roofing mastics. If you plan to remove any of these products, do so with care.

Appliances

Some appliances (*e.g.* toasters, popcorn poppers, broilers, slow cookers, dishwashers, refrigerators, ovens, ranges, clothes dryers, and electric blankets) contained asbestos as a component of some parts. Although not totally banned for these uses, asbestos is not nearly as common as it once was. It's unlikely that today's appliances contain asbestos in amounts, or ways, that would constitute a significant health risk. Prior to 1979, some hair dryers were made with asbestos-containing heat shields that had the potential to release fibers. Current hair-dryer models are not a problem.

Asbestos has also been used for fireproof gloves, in hot pads, stove-top pads, and ironing board covers.

Automobiles

Automobiles continue to be one of the most significant sources of asbestos fibers in the environment. This is because automotive brake linings, as well as clutch discs, contain asbestos fibers. Millions of tons of asbestos-containing dust from worn brakes and clutches contaminate the countryside—especially in urban areas, and also along roadways. Automobile-repair workers can be exposed to this dust and bring it home on their clothing.

Identification

If you suspect you have an asbestos-containing material in your home, you should find out for sure before you do anything. If you know the manufacturer and the age of a product, they should be able to tell you if asbestos was used in it. Plumbers and heating contractors who have worked around asbestos may be able to make a reasonable determination just by looking at a material. However, the only way to be 100% positive about whether a material contains asbestos or not is to have it tested. Keep in mind the fact that not all laboratories are accredited, so just because a local laboratory does asbestos testing, it doesn't mean that they have met established standards. To locate an accredited laboratory that can test for asbestos, contact your local or state board of health, or the **National Voluntary Laboratory Accreditation Program**.

In commercial buildings and schools, a survey is often done to determine if and where asbestos was used. Such a survey begins with a review of building records (plans and specifications), then proceeds with a thorough visual inspection of any materials that are likely suspects, with a focus on materials that are in poor shape. (Asbestos materials that are deteriorating are said to be *friable*.) Then, the suspect materials are sampled, and all asbestos-containing materials are listed or mapped, then evaluated. A written report will suggest what corrective action is necessary. Your local or state board of health should be able to recommend an approved asbestos abatement contractor in the area.

Risk Assessment

Asbestos has gotten a great deal of press coverage in recent years. This is in part because of lawsuits and legal-liability issues. As with any legal hot potato, there are two opinions regarding the risk of asbestos. On one side are those who say asbestos exposure in buildings is usually "insignificant" and "will almost never pose a health risk to building occupants."[1195] According to another source, asbestos exposure in buildings is 162 times less risky than home accidents, 38 times less risky than riding a bicycle, and 27 times less risky than eating 4 tablespoons of peanut butter daily.[1196] Some school corporations have decided that the risk is minimal, and left asbestos alone.[1197]

On the other hand, the **EPA** says "there is no level of exposure to asbestos fibers that experts can assure is completely safe."[1198] Asbestos can, indeed, be dangerous, and it should be treated with respect. While it's probably true that asbestos isn't a serious problem in most houses—it certainly can be, especially if it's friable. In many applications, the asbestos is bound up inside a material, and fibers aren't being released. If you don't inhale the fibers, you are in no danger. But if asbestos-containing materials are deteriorating, you can be exposed, and your risk goes up.

Many experts today see lead poisoning as more of a health problem than asbestos.

What to Do

If you find asbestos in your home, don't do anything until you're sure it is releasing fibers. If it isn't, the best thing to do may be nothing.[1199] [1200] Leave it alone, don't disturb it, and it won't harm you. Of course, it may harm someone in the future if they don't realize it's there. That's why some real estate agents ask if a building contains asbestos. It's better to know—so you can evaluate the situation—than to be ignorant and be needlessly exposed.

1195 *Report of the Royal Commission on Matters of Health and Safety Arising from the Use of asbestos in Ontario* (1984).

1196 H. Weill and J. Hughes, "Asbestos as a Public Health Risk," *Annals and Reviews in Public Health* 7 (1986): 71.

1197 Jay Mathews, "To yank or not to yank?," *Newsweek* (April 13, 1992): 59.

1198 CPSC, *Asbestos in the Home*, 4.

1199 Dan McLeister, "What to do about Asbestos?," *Professional Builder* (February 1989): 92.

1200 Dan McLeister, "Health and Houses: What to do about Asbestos?," *Professional Builder* (February 1989): 81.

If asbestos must be dealt with, there are four abatement approaches.

Enclosure

Enclosure means constructing a rigid airtight barrier around an asbestos-containing material. This can mean building a wall around, or in front of, a friable material. Covering a friable ceiling material with a layer of drywall is another example of enclosure. Drywall is a good material to use, but tongue-and-grooved boards can also work—as long as all seams are carefully sealed or caulked. Lay-in panels in a dropped ceiling cannot be made airtight, so they are not suitable for enclosing asbestos. Installing a new vinyl floor over one containing asbestos is a good example of enclosure.

Care should be taken during any enclosure process so the asbestos isn't disturbed, and clean-up should be done with HEPA vacuums. Once the job is complete, a record of exactly what was done should be left with the building owner. In many cases, a sign is posted noting that asbestos-containing materials are behind the enclosure.

One creative homeowner had a unique solution to enclosing asbestos. Faced with an ancient furnace that was thoroughly contaminated with asbestos, removal was considered—but an asbestos abatement contractor estimated it would cost several thousand dollars. Instead of removal, the homeowner built a temporary wooden form around the furnace, had a concrete truck back up to the basement window, and filled the form to the ceiling with concrete. The furnace is now enclosed in a long-lasting concrete tomb. Asbestos shouldn't be a problem as long as the concrete lasts—which is a long time.

Encapsulation

Encapsulation refers to coating an asbestos-containing material with a sealant. If done properly, the sealant will bind together the friable asbestos and help minimize future damage. Sealants are evaluated as to their impact resistance, flame spread, smoke generation, whether they release toxic gases when burned, and their adhesive/cohesive strength.[1201]

Encapsulation materials include latex paint—if it has a high-solids content (at least 60% by weight) and at least 25% by weight of vehicle resin. It should be applied considerably thicker than you would apply a decorative coating. Sealants are generally applied with airless spray equipment—first a mist coat, then a heavier coat(s). Proper respiratory protection is required.

After the encapsulation process, the area should be cleaned, and a record of what was done should be left so the material isn't inadvertently disturbed. Usually, warning labels are attached to the encapsulant. There are a number of asbestos-encapsulant manufacturers, including **Fiberlock Technologies, Inc.**, **Franklin International**, and **Mon-Eco Industries, Inc.**

Repair

Some damaged asbestos-containing materials can be repaired. For example,

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[1201] Environmental Protection Agency (EPA), *Evaluation of encapsulants for sprayed-on asbestos-containing materials in buildings, Summary* (Cincinnati, OH: Office of Research and Development, EPA, 1980). #EPA-560/12-80-004.

damaged insulation on pipes, boilers, ducts, and tanks can often be mended with non-asbestos plaster.

Removal

Removal of asbestos-containing material is always the best solution, because it is permanent, and you don't have to worry about someone disturbing the material in the future. However it can be expensive. A typical removal process involves first isolating the area with a containment barrier so fibers can't travel to other parts of the building. This often means plastic sheeting that is well taped to various surfaces. Care must be taken to prevent the containment barrier from getting damaged. Sometimes the inside of the work area is kept under a negative air pressure and the exhaust air is passed through a HEPA filter.

Asbestos workers typically wear disposable clothing and respiratory protection. During the actual removal, the asbestos-containing materials are treated with water and a wetting agent to prevent the release of fibers. After the materials are removed, they are placed in "leak-tight containers" such as 6 mil polyethylene bags or 55 gallon drums. Disposal of the asbestos, the containment barrier, and the worker's clothing must done be in an approved manner.

On small projects, such as removing insulation around a plumbing valve, the valve itself can be contained inside a clear plastic bag that has plastic gloves attached. The worker dampens the asbestos inside the bag, inserts his or her hands in the gloves, removes the asbestos, then removes the bag, the gloves, and the asbestos together and disposes of them accordingly. Small jobs like this can often be done at a reasonable cost.

Do-It-Yourselfers

Asbestos abatement is best left to professionals who are trained to deal with it safely. If you have asbestos containing materials that are in good shape, leave them alone—do not saw, sand, scrape, or drill holes in them. If debris contains asbestos, don't sweep, dust, or vacuum it up—moisten it first—to prevent fibers from becoming airborne—then clean it up with a wet mop. Don't use abrasive pads or brushes, or try to sand flooring containing asbestos. If you (or your contractor) remove asbestos incorrectly, and contaminate your house, your insurance company may not pay for clean up.[1202]

Radon

We discussed earlier how radon enters a house from the soil, and what steps can be taken in designing and constructing a new foundation to prevent it from entering. In this section, we'll go into a little more depth on radon, discuss testing, and some options for existing houses with high levels.

Sources of Radon

Uranium is a radioactive element. This means it's unstable, and it will go through a natural, nuclear transformation until it becomes stable. As it transforms itself, uranium gives off various particles and radiation, evolving into over a dozen other unstable

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[1202] F. James Donnelly, "Danger: Asbestos," *Remodeling* (January 1993): 53.

elements before becoming stable. While it starts out as uranium, it changes into elements like protactinium, thorium, radium, bismuth and polonium, before finally becoming a stable form of lead. Some changes take thousands or millions of years, but other changes occur in days, minutes, or fractions of a second. In every step, except one, the element is a solid. The exception is radon, which is a gas.

Uranium, and its various incarnations, can be found virtually everywhere on the planet. Of course, there are some places where the concentrations are quite high, but small amounts exist all over the place—even in your backyard. When these radioactive elements exist in very small amounts, and they are in solid form, they generally aren't a problem. But radon, being a gas, can be a problem.

Radium, one of the intermediate elements, exists in tiny amounts in soil, rock, and water—where it slowly changes into radon gas. As it does so, the gas migrates from the soil into the air. Radon doesn't last very long—only a few days—before it starts decaying into a series of very short-lived elements called radon progeny, or radon daughters. Several of these changes take place in less than an hour. At each step in this evolution, particles or radiation are given off (alpha particles, beta particles, gamma radiation). If you happen to inhale some radon gas, there's a good chance that some of these changes will take place inside your lungs. And that's what can lead to lung cancer—the decaying of radon, and the damage caused by the radon progeny to the living tissue inside your lungs.

The Soil

The primary source of radon is the tiny amount of radium in the soil that evolved from uranium. Most of the time, the radon gas leaves the soil and dissipates into the atmosphere, where it decays into various solid elements, eventually falls out of the air, and becomes part of the soil again. The radon in the atmosphere is diluted a great deal, so we only inhale tiny amounts of it when we're outdoors. But, radon can pass from the soil, into the living space, and build up to higher concentrations than typically exist in the atmosphere. It's when we're exposed to these higher concentrations indoors that we're at increased risk of contracting lung cancer.

In Pennsylvania, a geologic formation known as the Reading Prong contains higher-than-normal amounts of radium. It was here the radon problem first received widespread media attention when a worker at a nuclear power plant triggered radiation alarms. It was found that his radiation exposure was not from the power plant, as first suspected. Instead, he was exposed to excessive amounts of radon at home. Experts estimated that he, and his wife, were being exposed to enough radon to be the equivalent of 455,000 chest X-rays per year.[1203]

Phosphate rock can contain higher levels of radium, as can the by-products and waste from phosphate mining. As a result, phosphate fertilizer can sometimes contain radon. In Florida, some houses with high radon levels have been found on reclaimed land

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[1203] Ronald Taylor, "Your House May Be a Death Trap," *U.S. News and World Report* (March 17. 1986).

that was once a phosphate strip mine.[1204] Houses with high radon levels have also been found on sites that used to be home to radium processing plants.

As we discussed earlier, radon gas is often sucked indoors from the soil when the lower part of a house becomes depressurized. This depressurization can be the result of a variety of phenomena, such as the wind, exhaust fans, or duct leakage. Precisely how much radon enters a house depends on many different factors, so it can be very difficult to predict if a given house will have a high concentration. In fact, it isn't unusual for one house to have a high indoor concentration of radon, while the house next door has a low concentration.

Construction and Decorating Materials

Building materials derived from soil or rock can contain tiny amounts of uranium or radium, so they can release radon. For example, if concrete is made with aggregate containing radium, the concrete will release radon. Actually, concrete is the building material that is most often implicated in elevated radon levels but, in the vast majority of cases, concrete isn't a problem. Where high radon concentrations have been found in concrete, it's generally because a radium-rich aggregate was used—such as tailings from a uranium mine. From 1953 to the mid-1960s, uranium tailings were commonly used in parts of Colorado for landfill and backfill—and in concrete.[1205]

In one rather unusual case, sand containing radium waste was used to make concrete, plaster, and stucco in a Philadelphia suburb in the 1920's.[1206] Seventy years later, a number of these homes still have high radon levels, requiring mitigation. While tiny amounts of radium (and radon) have been found in gypsum-board products, drywall compounds, and plaster, these products are generally not significant sources of radon.

Water and Heating Fuels

In some geologic formations, radium (and radon) can be released from rocks and accumulate in ground water. If this radon-containing water runs from your faucet, or shower head, radon can dissipate into the room. The amount released into the air depends on the water pressure, temperature, and whether the water is aerated. Plants and foliage that take up radium-contaminated water can also release radon into the air.[1207] The concentration of radon in water is often considerably higher than in the air, but because

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[1204] C.R. Phillips, S.T. Windham, and J.A. Broadway, "Radon and Radon Daughters in Buildings: A Survey of Past Experience" (*Proceedings of a Roundtable Discussion of Radon in Buildings*. National Bureau of Standards, 1979). Special Publication #581.

[1205] R. Colle and P.E. McNall, "Radon in Buildings," (*Proceedings of a Roundtable Discussion of Radon in Buildings*. National Bureau of Standards, 1979). Special Publication #581.

[1206] Jim Beek, "Massive EPA search uncovers freak radon hazard in Philadelphia suburbs," *Indoor Air Review* (February 1992): 1.

[1207] National Council on Radiation Protection and Measurements (NCRP), "Evaluation of Occupational and Environmental Exposures to Radon and Radon Daughters in the United States," *NCRP Report #78*, (May 1984).

the water is typically exposed to the air for only a short period of time before going down the drain, a high concentration in water doesn't always translate into a high airborne concentration. Of course, an extremely high concentration in water *can* be of concern.

Radon is generally not a problem with surface water (*i.e.* lakes and rivers). Well water is much more likely to be contaminated. The **EPA** requires that all public water utilities test for radon in water, even though most water supplies in the U.S. have low radon concentrations. The State of Maine is a notable exception, having some of the highest radon-in-water concentrations in the country.

Natural gas, liquefied petroleum (l-p) gas, and heating oil can contain radon that can be released as a by-product of combustion. With unvented heaters, all the combustion by-products—including the radon—are released into the indoor environment. However, if the combustion by-products are properly expelled from the house (*e.g.* by way of a chimney), the radon from the combustion by-products can't build up indoors.

Risk Assessment

Radon causes lung cancer and, as far as anyone knows, nothing else. It's colorless, odorless, and tasteless, and there are no reports of hypersensitive people being bothered by radon in any unusual way. With carcinogens, like radon, there is no 100%-safe level, but the more you are exposed to, the greater your risk.

Radon is measured in units of picoCuries per liter (pC/l), and the **EPA** suggests that if you are exposed to more than 4 pC/l in your home, you should consider doing something about it. They call 4 pC/l an *action level* and, while 4 pC/l isn't 100% safe, the **EPA** feels it's a reasonable risk for most people. Every time we walk down a sidewalk, there is a chance of being hit an automobile—but we usually accept that as being a reasonable risk. If you're a regular risk taker—for example, if you routinely dart across the street in heavy traffic—you may be willing to accept the lung-cancer risk associated with more than 4 pC/l of exposure to radon. Although extremely high levels are unusual, indoor radon concentrations have been recorded as high as 3,000 pC/l.[1208]

It's been estimated that 10,000 pC/I in water can translate to about 1 pC/l in the air.[1209] So, high concentrations in water aren't usually a significant problem. In fact, radon in water isn't generally considered a problem by the **EPA** unless the concentration in the water is above 300-3,000 pC/l. However, the National Resources Defense Council feels that those levels constitute too much risk.[1210]

According to the **EPA**, non-smokers who are exposed to 4 pC/l over their lifetime have a risk of dying from radon about equal to their risk of drowning. If 1,000 non-smokers are exposed to 4 pC/l over their lifetime, about 2 of them will be expected to get

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1208 "Industry News," *Radon News Digest* (January 1989): 4.

1209 Terry Brennan, "Radon in water, a concern, not a panic," *NESA Newsletter* (October 1988): 12.

1210 Tim Hickey, "NRDC report finds radon in water threat exceeds EPA estimates," *Indoor Air Review* (January 1996): 3.

lung cancer.[1211]

If you smoke, you already have a greater chance of contracting lung cancer than a non-smoker. If you smoke *and* are exposed to 4 pC/l over your lifetime, your risk of dying from radon is about 100 times greater than your risk of dying in a plane crash. If 1,000 smokers are exposed to 4 pC/l over their lifetime, about 29 of them will get lung cancer.[1212]

Some people don't feel the **EPA**'s risk assessment about radon is valid. After all, their statistics were extrapolated from lung-cancer rates in underground miners—people who are exposed to far more radon than homeowners (well over 4 pC/l). The lower radon levels in houses may not be as risky as **EPA** estimates suggest. In fact, one study compared non-smoking women who had lung cancer, with non-smoking women who didn't have lung cancer, and found no evidence that higher radon levels caused an increase in cancer.[1213] But there are other reports that back up the **EPA**'s risk evaluation.[1214] Some studies suggest that the risk is higher than the **EPA**'s estimates,[1215] and there are people who think there might be delayed effects that aren't well understood, or studied.[1216] All in all, 4 pC/l is probably a good action level.

Testing for Radon

The EPA has prepared a map of the U.S showing the geologic potential for radon in different parts of the country.[1217] However, all houses are constructed differently, and how a house is built has a significant impact on indoor radon levels. So, you must actually perform a radon test to determine if you have a problem or not. Today, it's easier to test for radon than for many other environmental pollutants. In fact, test kits are often sold in hardware stores. **North American Detectors** (American Sensors), is one manufacturer. **Allergy Relief Shop, Inc.**, **American Environmental Health Foundation**, **Befit Enterprises Ltd.**, and other catalog suppliers offer radon test kits by mail. You can opt for either long-term testing (over 90 days) or short-term testing

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[1211] Environmental Protection Agency (EPA), *Home Buyer's and Sellers Guide to Radon,* (Washington, DC, EPA, March 1993). #402-R-93-003.

[1212] *Ibid*.

[1213] "Study finds little association between radon and lung cancer," *Indoor Air Review* (February 1995): 21-22.

[1214] "Swedish study strengthens radon link to cancer," *Indoor Air Review* (March 1994): 12.

[1215] Douglas Gordon, "Science academy study reveals greater radon cancer risk," *Architecture* (February 1988): 28.

[1216] Jim Beek, "Researchers say radon exposure may trigger a new kind of radiation injury," *Indoor Air Review* (March 1992): 1.

[1217] Lynne Durham, "EPA develops preliminary radon potential map of the U.S." *Indoor Air Review* (February 1992): 27-28.

(sometimes only a few days). Because radon concentrations fluctuate at different times of the year, a long term test will give you a better idea of your average exposure over an extended period of time.

There are a variety of testing devices available: alpha-track detectors, charcoal canisters, electret-ion-chamber detectors, charcoal-liquid-scintillation devices, and continuous monitors. Whichever type of testing device you choose, it should be placed in the lowest floor of the house that is suitable for occupancy. Because most radon comes from the soil, and the lowest part of a house is closest to the soil, that's where the highest concentration is normally encountered. If you use a do-it-yourself test kit, follow the instructions carefully. You can also hire a professional to perform the test for you. Radon-testing services are listed in the telephone book.

If you decide on a relatively quick short-term test, the **EPA** recommends that you perform two such tests over a 48-hour period. That way, if one test gives you a reading that is unusually high or unusually low, you can average the results and get a better picture of your risk. Still, if you have the time, a long-term test is preferred. If the test results are over 4 pC/l, you should consider remedial work.

Even though radon is usually not a problem with stone materials such as granite countertops, in rare cases it can be. If you suspect a stone material is releasing excessive radon, it can be tested. The simplest way is to place a testing device, such as a charcoal canister, on the stone and cover it with a bowl (or some other impervious object). Securely tape the bowl to the stone and follow the rest of test-kit manufacturer's instructions. What you are doing is testing the atmosphere directly adjacent to the stone—a closed atmosphere that will be contaminated by radon only if the radon is released from the stone.

What to Do

The radon concentration in a house can be lowered in a number of ways. In general, they fall into three categories: diluting the concentration of radon once it's in the living space, sealing sources and entry points to keep the radon from entering the living space, and diverting the radon directly to the atmosphere before it can enter the living space. Each approach has advantages and disadvantages. A radon-testing service will generally be able to recommend which method will be most effective in a particular house. Installation costs can vary from nothing to as much as $3,000. The following approaches all have a number of variations.

Diluting

You can dilute the concentration of radon in the indoor air by simply opening the windows. This natural ventilation costs nothing to install, but it can result in high heating or air-conditioning bills in some climates. It can also be uncomfortable.

Mechanical ventilation is generally more reliable than natural ventilation. It involves using one or more fans to exchange the indoor and outdoor air, thus diluting the concentration of radon. Mechanical ventilation can also affect your heating and cooling bills, plus you'll have an installation cost, and an operating cost.

If you live in a harsh climate, mechanical ventilation with heat-recovery may be a more economically viable way to ventilate your house to dilute radon concentrations. It can have a higher installation cost, but your heating/cooling bills won't be affected as much.

Sealing

If you know what the source of the radon is—for example, a concrete floor slab is made of aggregate containing radon—you can seal the surface of the slab with a coating that functions as a diffusion retarder. If a bare-dirt basement floor is a radon source, you might seal it under a new concrete slab. Two coats of oil or emulsion paint have been found to reduce emissions by about 15 times. However, several nails penetrating the paint can lower the reduction rate from 15 to 4.[1218]

The largest quantities of radon enter living spaces from the soil through cracks in the foundation when the lower portion of the house is depressurized. So, if you seal those cracks, you can prevent the radon from finding its way indoors. This often involves using caulking or aerosol foam insulation wherever you find a gap or crack in basement walls and floors, or in the floor system over a crawl space. With tight construction, there are no entry paths, so radon from the soil won't be a problem. Radon can also enter the living space from the soil by diffusing through solid concrete floors and walls, but diffusion accounts for far less radon entry than radon movement through gaps because of depressurization. One study estimated that, in a typical situation, 3-6 pC per second can enter because of diffusion, while up to 150 pC per second can enter through cracks when the lower level of a house is depressurized.[1219]

Diverting

Most existing houses aren't airtight and, while you can seal some of the entry points, it's difficult—usually impossible—to seal them all. Radon is generally sucked from the soil, through those entry points, and into the living space, whenever the living space is depressurized.[1220] So, if you can prevent the depressurization, you can minimize radon entry. For example, you might install a make-up air supply for a powerful kitchen exhaust fan to minimize house depressurization.

If your home's foundation is surrounded by underground drains, those drains can be used to divert radon into the atmosphere. In many houses, the drains are connected to a sump pit in the basement. If you put a lid on the sump pit, connect an exhaust fan to the lid, then connect an exhaust pipe between the fan and the outdoors, you can often reduce a radon problem by 99%. Here's how this approach works. When the fan is running, it sucks air from the drain tiles and blows it into the atmosphere. The drain tiles are under a negative pressure, so the radon seeps into them—and is blown outdoors—rather than entering the living space.

If you don't have a sump pit, but the basement walls are made of hollow concrete blocks, you have another option. You can drill holes into the blocks at various places,

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[1218] L. Morawska, "Influence of Sealants on Radon Emanation Rate from Building Materials," *Health Physics* 44 (April 1983): 416-418.

[1219] Ronald Bruno, "Sources of indoor radon in houses: A review," *Journal of the Air Pollution Control Association* 33 (February 1983): 105-109.

[1220] Jon Traudt, "Preventing dangerously low indoor air pressure," *Indoor Air Review* (September 1992): 29-30.

insert pipes into the holes (sealing them in well), hook an exhaust fan to the pipes, then connect the fan to the outdoors. With this approach, the inside of the block wall becomes depressurized, so radon goes into the wall, then is blown outdoors—instead of entering the living space. If there isn't room for a fan indoors, it can be mounted outdoors. Some installers locate the fan in an underground, weather-resistant housing, and exhaust the air into the atmosphere through a goose-neck vent.[1221]

Another approach is to drill holes in a concrete floor slab, insert pipes in those holes and connect them to the outdoors with an exhaust fan. This does the same thing as above. It creates a depressurized area under the slab, so radon goes there, and is then blown outdoors, before it can be pulled into the living space.

When you try to divert radon from the soil into the atmosphere, before it can enter the living space, you must design the system so the depressurization in the drain tiles (or in the block wall, or under the floor slab) is more powerful than any depressurization that might occur in the living space. Too much depressurization can pull excessive amounts of air from the living space, as well as through the soil. If a radon-removal system actually causes the living space to become depressurized, it's important to make sure it doesn't cause any chimneys to malfunction.[1222] [1223] It's sometimes possible to design a radon-removal system that doesn't use a fan.[1224] Unpowered systems use what is called a *passive stack*, and they have their applications, but fan-powered systems are generally more effective.[1225] If you are interested in this approach, you should install a passive system in such a way that it can be upgraded to a powered system if the passive approach isn't effective enough.

It's also possible to pressurize the basement with a forced-air furnace or air conditioner to keep the radon from entering,[1226] but this approach only works when the air-handler fan is running. It should only be done if all the ramifications of the basement pressurization are well-thought-out. For example, when the basement is pressurized with a forced-air furnace/air conditioner, the upper level will generally be depressurized, and this will affect infiltration, moisture migration, *etc*.

[1221] Thomas Hatton, "A fan-mounting strategy that works," *Indoor Air Review* (June 1991): 22.

[1222] Myron Edelkind, "EPA Taking Wrong Approach to Radon Mitigation and Backdrafting," *Indoor Air Review* (December 1992): 25.

[1223] "The possible role of indoor radon reduction systems in back-drafting residential combustion appliances," *Inside IAQ* (Spring/Summer 1998): 18.

[1224] Jennifer Silverman, "EPA-supported study examines use of passive stacks in Washington state," *Indoor Air Review* (January 1993): 25.

[1225] Teddi Barron, "Colorado study compares effectiveness of mitigation systems," *Indoor Air Review* (June 1991): 17.

[1226] "Forced-air furnace slows radon entry in basements," *Indoor Air Review* (June 1991): 26.

Do-it-Yourselfers

Many radon-control methods are within the ability of do-it-yourselfers. Often, with some suggestions from a radon-testing service, a homeowner can install a radon-mitigation system with little difficulty. The **EPA**'s *Application of Radon Reduction Techniques*[1227] contains a great deal of information that can be used to analyze a radon problem, and to design a mitigation strategy. For more information on dealing with radon in existing houses see the **EPA**'s *Radon Reduction Techniques for Detached Houses*[1228] and *Sub-slab Depressurization for Low-Permeability Fill Material*.[1229] For new construction, the **EPA** has a booklet titled *Radon-resistant Construction Techniques for New Residential Construction*.[1230]

It's important to understand how and where radon is entering before you attempt a mitigation strategy. While you can solve many problems with a big fan, that isn't always the best solution. Even some professional mitigators try to remedy hard-to-solve cases with high-capacity fans, when a small fan will work just as well if it's combined with sealing cracks and sealing concrete-block cores.[1231] An oversized fan costs more to purchase and to operate, so small fans are preferred—but only if they do the job.

Once a system is in place—whether done by a homeowner, or a professional—it's important to perform a follow-up radon test to see if the radon levels have, in fact, been reduced.

Several companies offer radon mitigation equipment such as fans and sealants. One of the more complete mail-order catalogs is available from **Radon Control, Inc.**

Mold

Mold is a common allergen that can grow in many locations inside or outside a house. It can also be found thriving inside building cavities. Mold is a very common indoor contaminant, and a common cause of illness. In a study of several hundred typical Tennessee homes, 49% had airborne concentrations of fungi greater than the

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1227 Environmental Protection Agency (EPA), *Application of Radon Reduction Techniques* (Washington, DC: EPA, August 1988). #EPA/625/5-88/024.

1228 EPA, *Radon Reduction Techniques*.

1229 Environmental Protection Agency (EPA), *Sub-slab Depressurization for Low-Permeability Fill Material* (Washington, DC: EPA, July 1991). #EPA/625/6-91/029.

1230 Environmental Protection Agency (EPA), *Radon-resistant Construction Techniques for New Residential Construction* (Washington, DC: EPA, February 1991). #EPA/625/2-91/032.

1231 "Selecting a radon fan," *Indoor Air Review* (June 1991): 20.

concentration considered by some allergists to be acceptable to sensitive individuals.[1232]

There are actually a wide variety of biological contaminants that can cause ill health—viruses, bacteria, protozoa, algae, as well as fungi (mold, mildew, yeast, mushrooms, *etc*.). People can also be bothered by biological particulates released by plants (pollen), animals (dander), insects such as cock roaches, and arachnids like dust mites. Plus, there are biological factors to consider in the health of a building—termites, carpenter ants, and decay organisms can all damage the structure. However, the focus of the following discussion will be on fungi—in particular, mold.

Even though there are literally thousands of different types of mold, only a few dozen are commonly found in houses. Molds reproduce by releasing spores into the air. Spores are extremely small, sometimes on the order of one micron (1 micron = 0.000039"). Mold counts are often 1,000 times higher than pollen counts.

An allergic person can react to the parent mold—if tiny parts of the colony become airborne and are inhaled—but inhaling the airborne spores, which are microscopic in size, is more often the problem. An allergic reaction involves a biological response to mold protein, and that protein can be either alive or dead. So, dead mold can cause the same allergic symptoms as live mold. This is why simply killing mold may not be an effective solution.

When a mold colony is growing, it can have a distinctive odor. This odor consists of various gases (VOCs) that are by-products of the natural metabolism of growing mold.[1233] The most common VOC is ethanol, but over 500 compounds have been identified from fungi of various kinds.[1234] The characteristic odor of baking bread is due to the VOCs released by the growing yeast, which is also a fungus. Some molds can consume arsenic compounds, and release a garlic-like odor.[1235] The various gases released by mold can bother some sensitive people. Thus, mold can be a problem because of airborne particulates *and* airborne gases.

Health Effects

Different species of mold have different health effects ranging from mild

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[1232] R.L. Tyndall and others, "Microflora in the typical home" (Berlin: *Proceedings of the 4th International Conference on Indoor Air Quality & Climate, Vol. 1, Volatile Organic Compounds, Combustion Gases, Particles and Fibers, Microbiological Agents*, 1987): 617-621.

[1233] Dan Giosta, "Study points to 'microbial VOCs' as new sick building culprit," *Indoor Air Review* (January 1996): 1.

[1234] J. David Miller, "Fungi as contaminants in indoor air" (Toronto: *Proceedings of the 5th International Conference on Indoor Air Quality & Climate, Vol. 5, Plenary Lectures*, 1990): 51-64.

[1235] Charles Thom and Kenneth P. Raper, "The Arsenic Fungi of Gosio," *Science* 76 (December 9, 1932): 548-550.

symptoms to death.[1236] The common symptoms of mold allergy include allergic rhinitis, bronchitis, sneezing, runny nose, congestion, Eustachian tube obstruction, itching of the nose or eyes, fatigue, and weakness. Although mold allergy is common, some researchers have concluded that molds can provoke symptoms by non-allergic means.[1237] [1238] Mold spores can enter the lungs causing asthma, a build-up of mucus, wheezing and breathing difficulties. These symptoms are often quite uncomfortable, and in the case of a full-blown asthmatic attack, they can be devastating. Dermatological and intestinal symptoms are also well-documented.

Cerebral symptoms related to mold can include: catatonic state, depression, crying, anger, confusion, fear, dizziness, anxiety, irritability, hostility, inability to concentrate, headaches, and hyperactivity.[1239] Some people with mold allergies also react to such foods as mushrooms, cheese, dried fruits, vinegar, *etc*., because of their mold content.

A number of fungi-related diseases can be very serious. For example, some varieties of the mold *Aspergillus* can infect the entire body in an individual who has lung damage or another serious underlying illness. Aflatoxins, which are sometimes associated with peanuts, may be a cause of liver cancer. In a study of 27 houses with possible moisture problems, 15 houses contained toxigenic molds.[1240]

In Cleveland, Ohio in 1993 there were at least 34 cases of infants with a condition that involves bleeding in the lungs that were related to *Stachybotrys atra* mold contamination. At least 10 deaths were recorded. This particular type of mold grows on water-soaked cellulose-based materials such as wood, newspaper, ceiling tiles, newspapers, cotton, and gypsum wallboard.[1241] Houses that have been flooded can be particularly susceptible to mold. Of more than 114 homes in a community in Manitoba

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[1236] R.S. Tobin and others, “Significance of fungi in indoor air: Report of a Canadian working group” (Berlin: *Proceedings of the 4th International Conference on Indoor Air Quality & Climate, Vol. 1, Volatile Organic Compounds, Combustion Gases, Particles and Fibers, Microbiological Agents*, 1987): 718-722.

[1237] R.E. Dales and others, “Respiratory health effects of home dampness and molds among Canadian children,” *American Journal of Epidemiology* 134 (July 1991): 196-203.

[1238] R.E. dales, R. Burnett, and H. Zwanenburg, “Adverse health effects among adults exposed to home dampness and molds,” *American Reviews of Respiratory Disease* 143 (March 1991): 505-509.

[1239] Lawrence D. Dickey, ed., *Clinical Ecology* (Springfield, IL: Charles C. Thomas, 1976): 259.

[1240] Canada Mortgage and Housing Corp. (CMHC), *Molds in finished basements*, (Ottawa, ON, Canada: CMHC, April 1996).

[1241] “Black mold linked to deaths in Cleveland,” *Environmental Building News* (March 1998): 4-5.

that were flooded in 1997, at least 34 were contaminated with *Stachybotrys atra*.[1242]

Spores from some molds, or fungus-like bacteria, can result in a lung disease known as hypersensitivity pneumonitis. This condition usually resembles a generalized viral infection. Chills, fever, weakness, muscle pains, cough, and shortness of breath are typical symptoms but, if allowed to progress, there can be lung and heart problems. Hypersensitivity pneumonitis is usually associated with certain occupations where there is considerable contact with mold. Farmer's-lung disease, mushroom-picker's lung, and maple-bark-stripper's lung are typical examples. However, hypersensitivity pneumonitis is also being diagnosed more and more in office buildings that have moisture/mold problems in their ventilation systems.[1243]

Histoplasmosis is a fungal disease that primarily affects the lungs, but it can also be systemic. An infection is often mild—sometimes unnoticed—however, if a person's resistance is low, it can cause fever, coughing, sweating, and weight loss. Some cases have resulted in death. The condition has been found worldwide, but is particularly common in the Ohio-Mississippi basin. It's caused by *Histoplasma capsulatum*, a fungus that often resides in the soil, but is also associated with bird droppings. Remodelers and insulation installers who are working in attics that have been home to pigeons, or other birds, can be at risk.

The metabolic gases given off by growing mold can be responsible for headache, mucous-membrane irritation, or a variety of other reactions in sensitive people.

Aerotech Laboratories, Inc. offers a variety of tests by mail that can be used to identify the specific species of mold present, including a kit to sample mold inside a wall cavity. **Allerx**, **American Environmental Health Foundation**, **Befit Enterprises Ltd.**, and **Gazoontite** also offer mold test kits by mail. There are also often local labs who can test for mold. Check with your local board of health for a referral.

Where Does Mold Grow?

You can find mold practically everywhere. Different species are found deep underground, and as high up as 10,000' in the air. Varieties can be found in a dry desert or at a wet seashore, in either a cold or hot climate. Mold can grow on rotting logs, in shady areas, on compost piles, *etc*. On farms, grains are subject to mold growth, so grain bins and silos are often problem areas for people with mold allergy. Workplaces such as bakeries, breweries, dairies, greenhouses, paper mills, upholstery shops, and woodworking industries all have the potential to trigger mold allergy.

If windows are routinely kept open, you can expect similar species of mold both indoors and outdoors. In a house that is usually closed up, there can be entirely different species inhabiting the indoor environment than are found outdoors. The indoor and outdoor climates are different, therefore they support different types of organisms.

Mold requires five things to grow: 1) food, 2) air, 3) a surface to grow on, 4) a suitable temperature, and 5) moisture. If you want to control mold, you must eliminate at

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[1242] "Mold problems in flood areas," *Solplan Review* (November 1998): 5-6.

[1243] Phillip R. Morey and others, "Environmental Studies in Moldy Office Buildings: Biological Agents, Sources and Preventative Measures," *Ann. Am. Conf. Gov. Ind. Hyg.* 10 (1984): 21-35.

least one of these 5 requirements. However, there is only one that can be reasonably controlled—moisture. From a practical standpoint, there is little that can be done to control the first 4 requirements. For example, while different species of mold have different food requirements, the common molds found in houses tend to eat the things of which we build houses: wood, wallpaper, paint, *etc*. They can also eat dust and gases in the air. So, it's virtually impossible to eliminate mold's food supply. It's also virtually impossible to eliminate air and growing surfaces. And, without air, people wouldn't survive either, and without growing surfaces, we wouldn't have houses. You can control the temperature in a house—but usually not by very much. After all, we like to keep our houses comfortable—and what is comfortable for us is also comfortable to many species of mold. So, we're left with moisture. If you're going to control mold in houses, you must control the moisture it needs to live. No moisture—no mold.

Relative Humidity

In order to learn how to control mold, an understanding of relative humidity is important. This is because even a dry house can have micro climates of high relative humidity where mold can thrive.

For all practical purposes, air always contains some moisture, and the maximum amount it can hold depends on the temperature of the air. For example, a cubic foot of air at 70°F can contain no more than about 0.00118 pounds (about $^{1}/_{10}$ teaspoon) of water vapor, but a cubic foot of air at 0°F can only contain a maximum of about 0.00006 pounds (about $^{1}/_{180}$ teaspoon) of moisture. This is because warm air can hold more moisture than cold air.

When air contains as much moisture as it can hold, it's *saturated*. If a cubic foot of 70°F air contains 0.00059 pounds of moisture, it's half-saturated. If a cubic foot of 0°F air contains 0.00003 pounds of moisture, it's half-saturated. Another way of saying air is saturated is to say it's at 100% relative humidity (RH). If air is at 50% RH, it's half saturated. While these tiny amounts of water per cubic foot of air don't seem very large, they can add up. For example, the air in a 2,000-sq.-ft. house at 70°F and 50% RH will contain a little over a gallon of water.

The actual amount of moisture in the air (so many pounds of moisture per cubic foot of air, for instance) is called the *absolute humidity* of the air. *Relative humidity* refers to the amount of moisture in air, compared to the maximum amount of moisture air at that temperature can contain. As it turns out, in most cases, it's more useful to know air's relative humidity than its absolute humidity.

If you warm air up or cool it down, the RH changes. The actual number of water molecules in the air (the absolute humidity) remains the same but, because the maximum amount of moisture air can contain varies with temperature, the RH changes. As an example, consider a cubic foot of air at 70°F and 50% RH. It will contain 0.00059 pounds of moisture. If you cool the air down to 60°F and measure the RH, it will be 70%. (The cubic foot of 60°F air still contains 0.00059 pounds of moisture, so its absolute humidity hasn't changed.) If you cool the air even further, down to about 51°F, the RH will be 100%—the air will be saturated. If you warm the original batch of 70°F air (with its 50% RH) up to 80°F, you'll be able to measure its RH at 35%. Because warm air has the capacity to hold more moisture, it's now only 35% saturated.

When air is saturated (100% RH) it's said to be at its *dew point*. If air is cooled below its dew point, condensation or dew (or sometimes fog) will form. In the above example, the dew-point temperature for 70°F air at 50% RH is 51°F, because if you cool the air to 51°F it will be saturated. Cooling this air further will result in condensation.

All this is important to understand because the temperature is never uniform in every part of the house. Consider a glass of iced tea with water condensing on the outside. The air in most of the room might be 70°F @ 50% RH, but because condensation has formed on the glass, the temperature of the air close to the glass must be below the dew point (below 51°F). What's happening is this: the ice has cooled the tea and the glass, but it has also cooled the air surrounding the glass below the dew point, and moisture from the air has condensed on the cold surface. This is why moisture condenses on cold windows in the winter—the temperature of the microclimate next to the glass is below the dew point of the air in the room. When the temperature drops outdoors on a very humid day, the result can be rain—the cool air can't hold as much moisture, so it simply unloads it in the form of a shower.

A certain amount of moisture in the air is desirable for human health and comfort, but too much results in mold growth, and often a proliferation of dust mites.[1244] In general, a relative humidity below 70% doesn't support excessive mold growth—at least with the types of mold that are common in houses. However, if you measure 70% RH in the middle of a room during a cold winter, there are certainly going to be cool surfaces that are surrounded by micro climates of much higher relative humidity. For example, if water is condensing on windows, the RH near them is 100%. But, there will undoubtedly also be many places where surfaces aren't quite as cold, and the RH is between 70-100%. That can be good news to mold. For instance, when its cold outdoors, closets (especially when they're located adjacent to exterior walls) are almost always cooler than other parts of a house, so they tend to have a higher RH inside them. This makes them more susceptible to mold growth. (Dust mites can't live easily when the RH is below 40-50%.[1245])

Before getting into how to deal with the problem of high RH in micro climates, let's look at where mold often grows.

Mold Outside the House

Chronic high outdoor relative humidities can often lead to serious mold problems, especially if a house is located in an area of limited sunlight and there is little wind. For example, a house deep in a forest can be subject to mold growth. It should be no surprise that in the Southeastern U.S., from the Carolinas to Texas, and on the west coast of

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1244 Ib Andersen and Jens Korsgaard, "Asthma and the Indoor Environment: Assessment of the Health Implications of High Indoor Air Humidity," *Environment International* 12 (1986): 121-127.

1245 Preston Sturgis, "How to Control Dust Mites," *The Human Ecologist* (Spring 1999): 18-20.

Oregon, decay often occurs in above ground structures.[1246] This is because of the humid, damp climate.

In the area surrounding a house, almost anything can support mold growth. For example, trees, shrubs, grasses, flowers, gardens, *etc*., all contain different types of mold at different times of the year. Compost piles can be very significant sources of mold—if disturbed, there can be visible clouds of spores rising into the air. The outdoor factors having the greatest effect are: high levels of shade, high levels of organic debris, and uncared-for or natural landscaping.[1247]

Small organic particles from leaves, twigs, insects, *etc*., can accumulate on a roof. If the roof is perpetually shaded by large trees, it can remain damp enough for mold to grow. Occasionally there is enough organic matter to not only support mold, but also moss. Wood roofs can be especially susceptible if they are allowed to remain damp, so manufacturers often recommend fungicidal treatments—chemicals that can be problematic for some sensitive people. Gutters often contain an accumulation of damp, rotting leaves and mold. This can form a rich organic medium that larger plants—even trees—can take root in.

There are many ways rain can penetrate the exterior skin of a building, leading to mold growth. For example, a driving rain can find its way into small cracks and crevices in the exterior siding or trim. Capillary action can allow rain to be drawn between pieces of siding, resulting in wetting on the back as well as the front of the siding. Metal flashings around windows, doors, chimneys, *etc*. are often installed incorrectly (or missing completely). Electrical or telephone wires entering a house can divert rainwater into the structure if entry holes aren't properly sealed.

North-facing walls are more susceptible to mold than walls on the south side of a house because, being shaded from the sun, they can remain damp after a shower. The north side of a house is also cooler than the south side, so there is a higher RH there.

Absorbent building materials, such as wood siding, remain damp longer than non-absorbent materials like metal siding. The exterior siding on a poorly insulated, air-conditioned building can be cool in the summer, resulting in condensation and mold growth.

Mold Inside the Living Space

There are many places inside a house where the RH can be high enough to support mold growth. The most obvious places are where water can be seen, either condensing on surfaces, or standing in pools.

Moisture that originates outdoors (*e.g*. from roof leaks, around leaky chimney flashings, or through open windows) can easily lead to mold indoors if the problem isn't corrected. Plumbing leaks can also lead to indoor mold growth, as can any spilled water

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[1246] Rodney C. De Groot, "Wood Decay Ecosystem in Residential Construction," in *Trees and Forests for Human Settlements* (Proceedings of papers presented during P1.05-00 Symposia in Vancouver, BC on 11-12 June 1976 and in Oslo, Norway on 22 June 1976 at the XVIth IUFRO World Congress): 345.

[1247] Peter P. Kozak and others, "Factors of Importance in Determining the Prevalence of Indoor Molds," *Annals of Allergy* 43 (August 1979): 93.

that sits unnoticed under a piece of furniture. Leaks and spills are usually not everyday events so they tend to be corrected quickly.

Moisture that originates indoors can sometimes be a chronic problem. For example, there can be a routinely high RH in bathrooms, especially after taking showers. Some grouts and caulking materials used around bathtubs and showers are susceptible to mold growth if allowed to remain damp. Toilet tanks, cold water pipes, and uninsulated exterior walls in the winter are often cool enough to have water condensing on them. The RH can also be high in a laundry room on washday, particularly if clothes are dried on indoor lines or racks. Clothes dryers should always be vented to the outdoors, otherwise they add undesirable amounts of moisture to the indoor air. Excess moisture can build up in a kitchen due to cooking and dishwashing. Because of the moisture sources, these service rooms are more prone to mold growth than other rooms.

Moisture is routinely added to the air inside houses simply because people live there. In fact, it's been estimated that a typical family of three produces about twenty pounds of water vapor per day, most of it from respiration and perspiration.[1248]

After recent remodeling or construction, humidity levels inside a house can be very high as the various building materials dry out. New wood, plaster, drywall compound, and latex paint all contain significant amounts of water that slowly evaporate over several weeks. Sometimes it can take an entire heating season to rid a house of this excess moisture.

One of the principle by-products of combustion is water vapor. So, unvented combustion appliances (*e.g.* space heaters and gas kitchen ranges) can add a considerable amount of moisture to the air (as well as other undesirable pollutants). Fuel-burning furnaces, boilers, and water heaters can introduce moisture into a house if the chimney is not performing correctly.

Good housekeeping practices are important—garbage pails and dirty refrigerators are great places for mold to grow, as are dirty clothes in a laundry hamper, or shoes damp with perspiration. Mold also likes leftover food, potted house plants, dried flowers, and Christmas trees. If tap water is allowed to stand for a few hours, mold will soon begin to grow in it.

Carpeting has been shown repeatedly to be a home for mold.[1249] Both carpeting and the padding can remain damp for some time after a water leak, or if they have been urinated on by pets. Shampooing is often done in an attempt to solve a mold problem in carpeting—with the result that the freshly shampooed carpet remains damp for several hours, compounding the problem. Children are usually more susceptible to moldy carpet than adults simply because they are shorter and closer to it, and they often play on their hands and knees.

A concrete-slab floor is often several degrees cooler than the rest of the room, so it can be another location for high RH and mold growth. Rugs tend to aggravate this problem by insulating the floor from the living space, so the slab will be even cooler. If a

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[1248] Anton Tenwolde and Jane Charlton Suleski, "Controlling Moisture in Houses," *Solar Age* 9 (January 1984): 34-37.

[1249] Peter P. Kozak and others, "Currently Available Methods of Home Mold Surveys. II. Examples of Homes Surveyed," *Annals of Allergy* 45 (September 1980): 167-176.

slab does not have a diffusion retarder beneath it, such as plastic sheeting, moisture from the soil can rise up through the porous concrete by capillary action, causing the surface to be damp.

Other mold sources inside a house include old furniture or picture frames, mattresses, clothing, and stored books or magazines. Wicker, especially plant baskets, can be an unusually bad source of mold. Sometimes, the growth on furnishings is so excessive they must be removed and disposed of.

In the winter, there are a variety of places where the RH can be high enough for mold to grow. For example, clothes closets and built-in cupboards located on outside walls will contain cooler air in the winter and, consequently, a higher relative humidity. A piece of heavy furniture located on an outside wall can insulate the wall, resulting in a lower temperature behind it, thus a high RH, and mold growth. Draperies can insulate a wall, resulting in a lower temperature—and high RH—behind them. Sometimes, poor air circulation results in one part of a room being somewhat cooler than the center of the room. Corners are often cooler than the middle of walls.

Basements are notorious for fostering mold growth. If a basement has inadequate dampproofing or waterproofing, moisture can migrate into it from the soil. This can be exacerbated by cracks in the basement floor or walls. Basements are also where plumbing leaks and water spills end up. And basements are often unheated, so they're cooler than the rest of the house, therefore they can have a higher RH. In most cases, mold in a basement results from a combination of factors.

Moisture from damp soil can lead to a high RH in a crawl space which, in turn, often leads to moisture migrating into the living space. Some crawl spaces have standing water in them. Occasionally, a broken pipe can empty raw sewage directly into a crawl space, something that can go unnoticed for days.

Unless a house is built extremely tight, mold spores originating in a crawl space (or basement), will eventually find their way upstairs into the living area. Personal belongings should never be stored in moldy crawl spaces or basements because they will soon become food for mold.

We often add moisture to the air deliberately with humidifiers or by setting pans of water out to evaporate. In the winter, some houses get extremely dry and it can be necessary to add moisture to the air for health and comfort. But humidifiers often harbor a variety of harmful organisms. Various kinds of fungi, bacteria, and amoebae have all been known to grow in the warm, wet environment—and be blown into the air along with the desirable moisture.

Mold Inside Building Cavities

If moisture gets inside roof, floor, or wall cavities, it can not only lead to mold growth, it can lead to structural damage in the form of rot. Damp wood is also more susceptible to termite attack and carpenter-ant invasion. If mold is growing within the walls of a house, it will release thousands of spores, some of which will certainly find there way into the interior of the house—unless the house is built in an airtight manner.

Moisture can easily get into a building cavity because of rain penetration, a leaky roof or gutters, or plumbing leaks.[1250] In cold climates, moisture can also enter building

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1250 Oxley, *Dampness*.

cavities because of ice damming in the winter. With ice damming, you can sometimes see water dripping from the ceiling inside the living space, but it can also drip hidden inside the wall cavity. In either case, mold growth can result. This problem is often found in where attic insulation has been installed improperly, and in unvented cathedral ceilings that have been built incorrectly. Ceilings—vented or unvented—should always be tightly constructed to minimize moisture migration between the attic from the living space.[1251]

Moisture can also migrate from the living space into an attic space, where it can condense, or freeze, on the underside of the roof in the winter—just like moisture condenses on a cold window pane. This can easily lead to mold growth, rot, or insect damage. If a ceiling has a lot of penetrations (*e.g.* there are a number of recessed ceiling lights), a great deal of moisture can get into the attic.

When air passes through the structure of a loosely built house, it carries moisture with it. As moisture-laden air passes through an insulated wall (or floor, or ceiling) it changes temperature—and RH. For example, if cold winter air moves inward through a wall, it will warm up as it nears the interior. As the air warms up, it can hold more moisture, so it's RH goes down—and there are no problems. Moisture problems occur when warm air moves through a building cavity toward a cold surface—for example, when warm air passes from the outdoors, through a building cavity, toward an air-conditioned interior. In such a case, the warm air will get cooler—and its RH will go up—as it gets closer to the cool surface. If it gets below the dew-point temperature, there will be condensation inside the building cavity. The same type of thing also happens in the winter in cold climates when warm indoor air passes through a building cavity toward the exterior.

Moisture inside building cavities can result in wet insulation and framing lumber. When insulation gets wet, it loses much of its ability to insulate and when lumber gets wet it can support rot or mold growth. Insulation containing a formaldehyde resin will release formaldehyde gas more readily when damp. Urea-formaldehyde foam insulation has been shown to support mold growth.[1252] Exterior paint failure is often a sign of a moisture problem inside the wall cavity. As the excess moisture tries to escape through the siding, it causes paint to blister.

Burning green wood in a fireplace can generate excessive amounts of moisture in a chimney. This can drip down and collect in the ash clean-out pit—a good place for mold to grow. A stainless steel chimney liner can help to increase the velocity of the flue gases, and reduce the potential for condensation. Chimneys without caps can allow rain to enter, resulting in a similar problem.

What to Do

Dealing with mold is a three step process: First, analyze the situation. Second, prevent the mold from growing. Third, clean it up. According to one expert, to control mold, "the number one thing is controlling moisture…not only liquid-water availability,

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[1251] Bill Eich, "Tight Cathedral Ceilings," *Journal of Light Construction* (May 1990): 16-18.

[1252] Bowen, *Urea-Formaldehyde Foam Insulation: Problem Identification*, C1.

but also preventing high relative humidity." [1253]

Analyzing the situation is very important. You must define the problem carefully in order to fix it permanently. This means understanding exactly why mold is growing. Most of the molds found in houses require a surface with an RH of over 70% to grow. So, your task is to figure out why moldy surfaces are surrounded by 70% RH. Perhaps the overall RH in the house is too high. Perhaps the surface is cool enough that moisture is condensing on it, or it's surrounded by a high-RH microclimate. Perhaps water is dripping onto, or behind, the surface. Whatever the reason, you must understand it before you can fix it.

When you're trying to analyze a situation, it's often helpful to know just what the RH is, and that means measuring it. Several types of fairly inexpensive instruments (hygrometers) are available for measuring RH. Dial-type relative-humidity gauges often contain a spiral-wound material that senses humidity fluctuations. They are called strain hygrometers and they're widely available in department and hardware stores. **Airguide**, **Radio Shack**, and **Therma-Stor Products** each offer digital meters. The big drawback to all inexpensive instruments is that they can be inaccurate. For reasonable accuracy, a meter should be within 5% but some are off by as much as 30%.[1254] You can test the accuracy of a humidity meter by placing it outdoors, about 4' off the ground, in the shade, on a sunny day of high pressure. Then compare its reading with a local weather office.[1255]

Some inspectors who do pre-purchase home inspections carry wood-moisture meters. These are more costly than relative-humidity meters, but they can be helpful to determine precisely how much moisture a surface (wood, drywall, plaster, *etc.*) contains, thus the likelihood of mold growth or rot.[1256] The **Professional Equipment** catalog handles several brands of wood-moisture meters.

Once you know why a surface has a high RH, you need to prevent the mold from growing. The most effective way of doing this is to lower the RH near the moldy surface. There are two ways of doing so. You can prevent moisture from getting to the surface. Or you can raise the temperature of the surface, thus lowering the RH next to the surface. Either approach can work—just as long as the RH remains somewhat below 70% at the surface. Remember, the RH is almost never consistent throughout a house. It may be 40% in the center of a room, and 75% at a cool surface.

When the RH has been lowered near surfaces, the mold will stop growing. If it isn't growing, it won't produce allergenic spores or metabolic VOCs, so it's as good as dead. It may take it a while to stop growing because one of mold's metabolic by-products is water—so it can produce some of the very moisture it needs to survive. But, as the

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[1253] Tim Hickey, "Moisture control tops list of microbial problems, An interview with Philip Morey," *Indoor Air Review* (January 1996): 9-10.

[1254] "Warning on the accuracy of low-cost digital humidity meters," *Energy Design Update* (March 1994): 8-9.

[1255] Jason Fry, "Canadian study: Cheaper humidity meters are best," *Indoor Air Review* (August 1994): 6.

[1256] Jim Tolpin, "Builder's guide to moisture meters," Tools of the Trade (Summer 1994): 41-45.

surface dries out, the mold *will* become dormant. A portable fan or electric hair dryer can be used to hasten the drying process—but fans can blow spores around the room. A portable radiant heater is usually a better choice. Once dry, the surface should be cleaned with soapy water to remove any residual spores. Don't clean up with a conventional portable vacuum cleaner because many of the microscopic spores will pass through the vacuum's filter and be blown around the room. A portable vacuum with a high-efficiency filter, or a central-vacuum system with an outdoor exhaust, will work much better. Washing will also improve the surface's appearance if it's gotten stained or discolored, but be careful not to get the surface overly wet. If it's not possible to remove all the stains, a wall might require repainting, a floor refinishing, or tile regrouting.

Many people feel they must kill the mold. This isn't necessary—nor is it often helpful. If the mold is dormant, it won't be producing any allergenic material, and if you clean up any residual spores, you won't have a problem. If you kill the mold, but don't clean it up, you can easily be affected by the dead spores. This is because people are allergic to particular proteins, and your system will react to them even if they're dead. If you kill the mold on a surface, but don't cure the high RH problem, there are always enough stray mold spores floating around ready to start a new colony. So, even if you kill the mold, you must still solve the moisture problem and clean everything thoroughly anyway. But if you've done that, there was no need to kill it in the first place. Many mold-killing products aren't good for people to be around, particularly sensitive people.

If there's a chance the surface you're cleaning will remain damp for an extended period of time, it can be a good idea to use a *mild* fungicide in the cleaning solution. This will prevent any residual mold from growing until the surface dries completely. Many sources suggest bleach, and it works very well for this purpose, but it can easily bother sensitive people, and it can damage some surfaces. A product called Zephiran has been recommended for sensitive individuals, but it also has a fairly strong odor. Zephiran can be ordered through pharmacies or by mail from **N.E.E.D.S.** Hydrogen peroxide, which is available at pharmacies and grocery stores, also works very well, and it has very little odor, so it's often recommended for sensitive people. Borax or vinegar can also be used. Detailed clean-up guidelines for dealing with mold on specific materials can be found in the booklet *Clean-up Procedures for Mold in Houses* from **Canada Mortgage and Housing Corp.**[1257]

If you suffer from mold allergy, minimizing your exposure to mold, and mold spores, is paramount. Thorough cleaning, ventilation, and dehumidifying can help, but getting rid of active mold colonies that are producing spores is very important. In the workplace, personal respirators can be useful but, in some cases, a change of jobs is necessary.

What to Do Outdoors

If the outdoor RH is routinely above 70%, there isn't much you can do to avoid mold—except move to a dryer climate. However, there are ways to, at least partially, dry out a damp location. For example, if trees and shrubbery are contributing to a problem, they can be cut down. While this can seem like a radical solution, it can sometimes be

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[1257] Canada Mortgage and Housing Corp. (CMHC), *Clean-up Procedures for Mold in Houses,* (Ottawa, ON, Canada: CMHC, n.d.).

very helpful.

Trees shade a house, protecting it from the heat of the sun. But, the lowered temperature can mean a high RH surrounding the house. Shrubbery that's overgrown can further insulate a house, allowing it to be cooler and more damp than it would be without shrubs. Plus, both trees and shrubs prevent wind from easily passing over the house to help dry it after a rain. In a damp climate, exposing a house to both sun and wind is one of the best ways to minimize mold problems on the exterior. Don't leave piles of damp leaves around because they will soon get moldy.

In addition, gutters should be kept clean, and in good repair, and down spouts should direct water well away from the house to prevent rain water from running down into the ground and finding its way into the basement or crawl space. The roofing, siding, and flashings should also be kept in good repair. A covered entryway will prevent rain from entering the house when the door is opened. An ample overhang over windows will allow them to be opened during a shower without letting rain enter the living space. Damp window sills are good places for mold to grow.

What to Do Indoors

To lower the RH near surfaces indoors, you have two choices. You can prevent moisture from getting to the surface, or you can raise the temperature of the surface to lower the nearby RH. The first thing you should do is minimize the most significant moisture sources.

Plumbing leaks should always be repaired promptly. If you have experienced a flood, the degree of damage will depend partially on what kind of water was involved. For example, a leak in a water supply line will contain fairly clean water, but a sewer leak can fill a basement with water loaded with bacteria. Floods from overflowing rivers should be considered as serious as sewer leaks because rivers—especially rivers at flood elevation—often contain waste from flooded sewage-treatment plants, along with a great deal of mud and debris. After a flood, porous building materials, and furnishings, are generally too contaminated to be cleaned, so they must be discarded and replaced. According to one industrial hygienist, "There is virtually no way to guarantee that flood-damaged carpets, upholstered chairs, or ceiling tiles are clean after a flood—no matter what you do."[1258] Even when there has not been a flood, porous materials are often impossible to clean after they have been contaminated with mold. The **CPSC** recommends throwing out all porous materials like mattresses, straw baskets, and wicker that have been water-damaged or contain mold because they are impossible to clean. If they can't be decontaminated by steam cleaning or hot-water washing and thorough drying, carpets, stuffed toys, drapes, upholstered furniture, and ceiling tiles will also have to be discarded.[1259]

High-humidity rooms (*e.g*. bathrooms and kitchens) should always have a way to expel excess moisture quickly before it can migrate into the rest of the house. Always vent clothes dryers to the outdoors, and don't dry clothes indoors on lines. To avoid the

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[1258] Gail Melson, "Cleaning up after a Flood," *INvironment* 3 (Spring 1993): 2-6.

[1259] Consumer Product Safety Commission (CPSC), *Biological Pollutants in Your Home* (Washington, DC: CPSC, 1990).

water vapor in combustion by-products, unvented combustion appliances should never be used indoors, and problems with malfunctioning chimneys should be remedied. The use of humidifiers should be avoided if at all possible.

In a new house, or one that has undergone significant remodeling, it's important to provide for extra ventilation until the new materials have given up a significant amount of moisture.

Mold can grow in the soil of house plants. Plants also release moisture into the room—the water poured on plants doesn't just disappear, much of it evaporates into the air. If you don't want to get rid of plants completely, succulents and cacti are better choices, because they thrive in drier soil. Or, you might consider keeping plants in a sealed terrarium.

Moisture problems in damp basements and crawl spaces can be complex, so they should be analyzed carefully. If moisture is migrating into them from the soil, repairs can be costly. Remedies can involve installing new drainage tiles, a dampproof coating, ventilation, raising the air temperature, *etc*. If moisture is migrating up through a concrete floor slab, it can be coated with a sealer that functions as a diffusion retarder. Sealers can be problematic for some sensitive people, so they should be tested prior to use. Carpeting, or heavy area rugs, should not be used over a problematic concrete-slab floor because they can become damp. Wall-to-wall carpeting should especially be avoided in high-humidity rooms like kitchens and bathrooms.

A dehumidifier can be useful for lowering the RH in the summer—especially in basements—but it's usually better to perform some of the above measures first. A large-capacity, automatic model is usually recommended for a damp basement or crawl space. A dehumidifier must either be hooked up to a drain, or have its reservoir pan emptied regularly. If water is allowed to stand in a reservoir pan, it can support mold growth—but the potential is much less than having a very damp basement.

Air conditioning is a form of dehumidification. It often helps someone with mold allergy for three reasons—it results in a drier environment that's less hospitable to mold, it requires the windows to be closed (so the outdoor mold remains outdoors), and air conditioners often have filters.

Cold surfaces can be warmed up in a variety of ways. For example, adding insulation to a wall will result in the interior surface being warmer in the winter. Replacing windows with energy-efficient units having multiple layers of glass will also mean higher interior surface temperatures.

In the winter, the corners of a room are often colder than other parts of a room. Improving air circulation can help minimize such cold spots. This might be accomplished by rearranging furniture. In some cases, it can be helpful to position a small fan in a room to keep the air circulating. In cold weather, draperies should be kept open to prevent a microclimate of low temperature, and high RH, behind them.

If closets are moldy, it's often because they're cooler that the rest of the living space, thus they have a higher RH. Louvered doors can sometimes help warm them up. Leaving a light on in a closet will raise the closet's air temperature, and lower the RH.

If you use a humidifier in the winter, the only method of controlling mold growth inside it appears to be frequent and thorough cleaning. However, once a humidifier becomes contaminated, routine cleaning and disinfecting may not be enough to inhibit the mold growth. Steam-type humidifiers are not as problematic as cool-mist, atomizing humidifiers,[1260] nor are ultrasonic humidifiers. Mold will grow in standing water, so any humidifier can be contaminated if it is not run for a while. On restarting, ultrasonic models have been shown to kill the mold in them. However, dead mold particles can be spewed into the air, causing allergic reactions.[1261] In general, humidifiers are not a good idea.

To avoid microclimates above 70% RH, the air in the center of a room will need to be kept at an RH that's somewhat lower. How much lower depends on the climate, and the amount of insulation in a house, but there are some general guidelines. In very cold climates (*e.g*. Minneapolis), the RH in most of the living space will need to be below 25% to avoid microclimates above 70%. In moderately cold climates (*e.g*. Cincinnati), an RH of 35% in most of the house will avoid microclimates above 70%. In less-severe climates, the heating-season RH can be as high as 45%. If the indoor RH is allowed to fall below 20%, respiratory membranes can become excessively dry, and the body's defenses against infection can become compromised.[1262]

Various air filters have been shown to significantly reduce mold levels in the air,[1263] but they have no effect on the RH, so mold spores can still be produced. Some air cleaning devices produce ozone, and mold has been found growing on charcoal granules in some air filters—but studies done in submarines have not found this to be a significant problem.[1264] Portable filters work best when run continuously in a closed room. Whole-house filters also work best when run continuously. But filters are a band-aid approach if you haven't controlled the mold at its source first.

What to Do About Building Cavities

To deal with mold inside building cavities, you must first determine how the cavities got wet, and prevent any more moisture from getting into them. For example, if ice damming on the roof has resulted in water dripping down into a wall cavity, you must solve the ice damming problem. If a house is chronically pressurized in the winter (or depressurized in the summer), causing humid air to be pulled into, and condense, inside building cavities, you may need to alter the pressure dynamics of the house. Or, if you can tighten the house sufficiently, there will be no pathways for moisture to migrate into building cavities because of air-pressure differences. If a wall or ceiling doesn't contain a diffusion retarder, one can be added in the form of a diffusion-retarder paint. If there are not enough roof vents—add some. If a plumbing leak is a problem—fix it.

Once the moisture source has been taken care of, the cavity should start to dry. However, drying can be a slow process—sometimes taking several months, especially if the building materials are very wet. In some cases, you may need to open up the cavity

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[1260] A.V. Assendfelt and others, "Humidifier-Associated Extrinsic Allergic Alveolitis," *Scandinavian Journal of the Work Environment* 5 (1979): 35-41.

[1261] "Ultrasonic Humidifiers," *Consumer Reports* (November 1985): 679-683.

[1262] Lstiburek, *Moisture Control*.

[1263] Kozak, "Factors of Importance," 91.

[1264] Small, *Indoor Pollution*, 149.

and dry it with fans or heaters. This can be done by removing some of the drywall or siding.

If there's a severe mold problem within a building cavity, drying everything out will definitely prevent the situation from getting worse, but it may not solve your problem. When a building cavity is completely dry, the mold inside it will be dormant, so it won't be producing any spores. However, there can be a tremendous reservoir of spores left over from when the mold was actively growing, and they could continue migrating into the living space for months after the mold has become dormant and ceased reproducing. The solution for a severe problem is to open up the building cavity and clean out all vestiges of both mold and spores. If you've already opened up the cavity to dry it out, you can clean it at the same time. Porous materials will generally need to be replaced.

Calcium chloride can sometimes be used to dry out a damp cavity. It's often available in hardware stores in winter months for melting snow and ice. Placed in trays or pans, it acts like a sponge, absorbing moisture from the air. Calcium chloride is best used as a temporary measure to dry an area. It's not practical for a continuing problem because, as it becomes saturated, it needs to be replaced regularly.

Combustion By-Products

One of the chief combustion by-products of common heating fuels is water vapor—almost a pound of water vapor is released by a pound of burning fuel. This translates to about one gallon of water per 100,000 BTU's of energy.[1265] If this moisture isn't expelled from the house—preferably up the chimney—it can easily contribute to a high indoor humidity problem.

Other combustion by-products include carbon monoxide (CO), carbon dioxide, formaldehyde, nitrogen oxides, particulates, sulfur oxide, and various hydrocarbons. In general, burning wood or oil is more polluting than burning natural gas or liquefied-petroleum (l-p) gas. However, even though natural gas tends to burn fairly cleanly, it can also produce deadly CO—especially if an appliance is out-of-tune.

If a combustion appliance (furnace, water heater, space heater, boiler, kitchen range, *etc*.) that burns gas or oil is tuned up and working properly, there should not be a significant amount of CO being produced. CO production is only high when there is incomplete combustion of the fuel. A gas appliance should have a blue flame—a yellow flame indicates incomplete combustion and high CO production. Burning wood always produces CO, especially when there are glowing embers and no flame is present. Even candles can sometimes be problematic.

Health Effects

Carbon monoxide (CO) is by far the most deadly combustion by-product, so it is what you should be the most concerned about. Being colorless, odorless, and tasteless, it's virtually impossible to detect with your senses.

Small amounts of CO in the air are deadly because the gas is so easily absorbed

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[1265] Bruce Eugene Davis and John Wujcik, "Mother hen, chicks, and combustion safety," *EEBA Excellence* (Fall 1994): insert.

into our bodies. When air containing CO enters your lungs, the blood cells are always attracted to the CO molecules more readily than to oxygen molecules. As more CO is taken up by the blood, less oxygen gets absorbed. While not many houses have CO levels high enough to be deadly, excessive CO in houses does kill several hundred people each year in the U.S.

At levels that aren't considered deadly, CO can cause flu-like symptoms such as headache, dizziness, nausea, vomiting, diarrhea, weakness, general malaise, or shortness of breath. People with heart disease are more susceptible to these symptoms. One study reported that 23.6%—nearly a quarter—of patients reporting flu-like symptoms were actually suffering from low-level CO poisoning.[1266]

Many more people are probably affected but, no doubt, assume that when they get sick each heating season, they have the flu. A national survey conducted in 1974 estimated that as many as 700,000 houses in the U.S. have elevated CO levels during the winter months.[1267] Researchers call this *occult* carbon-monoxide poisoning because the cause is hidden and not readily obvious. Studies in medical journals have found that between 3-5% of emergency-room complaints of headache and dizziness are attributable to occult carbon-monoxide poisoning. The **Consumer Product Safety Commission** estimates that 10,000 people a year seek medical advice or miss one day of work—without realizing they have low-level CO poisoning.[1268]

Following are some CO exposure levels and their health effects. If you're exposed to 200 parts per million (ppm) of CO over 2-3 hours, you will probably have a slight headache, experience fatigue, feel dizzy or nauseous. At a level of 400 ppm, you will likely get a headache in 1-2 hours, and a 3-hour exposure could be life-threatening. Forty-five minutes at 800 ppm can result in dizziness, nausea, and convulsions, and if you're exposed for a couple of hours at this level, you'll likely lose consciousness—death would occur in 2-3 hours. If levels are as high as 1,600 ppm, you'll experience headache, dizziness, and nausea within 20 minutes, and be dead within an hour. At 3,200 ppm, headache, dizziness, and nausea develop in 5-10 minutes, and death will occur in about a half hour. At 6,400 ppm, you'll get symptoms within a minute or two, and be dead in 10-15 minutes.[1269]

Carbon monoxide isn't the only combustion by-product that can cause health problems—it's just the worst. You should also be concerned with heavy metals like mercury, chromium, and arsenic, which are found in natural gas. Nitrogen dioxide is suspected of affecting the lungs and liver, as well as immunological function, blood-cell

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[1266] Michael C. Dolan, Thomas L. Haltom, George H. Barrows, Craig S. Short, and Kathleen M. Ferriel. "Carboxyhemoglobin Levels in Patients with Flu-like Symptoms," *Annals of Emergency Medicine* 16 (July 1987): 782/87–786/91.

[1267] A.F. Schaplowsky, F.B. Oglesbay, J.H. Morrison, R.E. Gallagher, and W. Berman Jr., "Carbon Monoxide Contamination of the Living Environment, A National Survey of Home Air and Children's Blood," *Journal of Environmental Health* 36 (1974): 569–573.

[1268] "On-set of the flu season increases danger of carbon monoxide poisoning," *Indiana Builder* (December 1994): 20.

[1269] "Unvented Combustion Appliances," *Solplan Review* (September 1996): 3-6.

count, and body weight.[1270] Although not a pollutant itself, the water vapor released by combustion can contribute to excess biological growth in a house.

Sources of Combustion By-Products

There are a number of sources of combustion by-products in houses. Some are quite common, being found in millions of residences. They don't always cause serious health problems—but they certainly have the potential to.

Unvented Combustion Appliances

Indoor air quality experts routinely argue against the use of unvented combustion appliances, whether fueled by kerosene, natural gas or liquefied-petroleum gas. Yet, these devices continue to be popular. There were 189,000 unvented (vent-free) gas heaters and fireplaces sold in the U.S. in 1986, and a whopping 520,000 sold in 1995. Its been estimated that 14 million adults in the U.S. used unvented combustion heaters between 1988 and 1994.[1271] This is despite the fact that they are banned in California, New York, Minnesota, Massachusetts, Montana, and Alaska.[1272] Yet, just because they are so widely used doesn't mean that they are a good idea.

Manufacturers of unvented gas appliances report that their units are 99.9% efficient, so CO production is minimal. They also point out that, since 1982, vent-free appliances contain automatic oxygen-depletion sensors that shut them down if oxygen levels fall below 18%. (CO production is increased when there is less oxygen.) Of course, it's possible to have excessive CO when the oxygen level is high, for example if the burner is clogged with dust or animal hair.

The American Gas Association sponsored a study that found CO was not a problem with unvented combustion appliances. However, their study assumed that appliances are installed, maintained, and operated according to manufacturer's recommendations—and many aren't. In addition, the study based its results on short "on" times (4-5 minutes) and long "off" times (10-16 minutes). This does not represent real-world operating conditions.[1273] Many people operate unvented space heaters continuously for extended periods of time.

Outdoor barbecues are sources of carbon monoxide, and should never be used indoors. The **CPSC** has described the following case: "Surprised by rain during a cookout, Nancy carried her hibachi grill into a tool shed where she continued cooking the

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[1270] Robert Weinhold, "Problems with natural gas appliances," *The Human Ecologist* (Fall 1996): 16-17.

[1271] "Using unvented combustion appliances indoors: risky but common," *IEQ Strategies* (February 1998): 15-16.

[1272] "Unsafe Gas Heaters Proliferate," *Environmental Building News* (May/June 1996): 4-5.

[1273] "Report: CO No Problem in Unvented Appliances," *Indoor Air Review* (May 1966): 2.

food. She was dead when her husband came to look for her."[1274]

Kitchen Ranges

Although they are widely used, kitchen ranges should be considered in the same category as unvented space heaters and fireplaces. They are routinely used without turning on an exhaust fan, and they often contain a standing pilot light that releases small amounts of combustion by-products continuously. With the oven and one burner operating, a kitchen range can have the same output as a typical gas room heater. If space heaters are a bad idea, so are gas-cooking devices. One article pointed out that gas ranges can release nitrogen dioxide, a gas that has a negative effect on the mucous membranes of the lungs and interferes with the transport of oxygen, and something not sensed by carbon-monoxide detectors.[1275]

When used for cooking, a gas range is typically on for no more than a few hours a day, but some people have left them on for extended periods of time to heat the living space. This can introduce excessive amounts of combustion by-products into the air you are breathing. Gas ranges should *never* be used to heat houses.

Damaged Equipment

A fuel-burning furnace has two separate chambers. One contains *circulating air* that comes from the living space to be heated. The other chamber contains combustion by-products. During operation, heat from the combustion by-products passes through a *heat exchanger* into the circulating air. Cracks can develop in a heat exchanger, allowing the combustion by-products themselves to seep into the circulating air, thus contaminating it. Sometimes, heat exchangers can get rusty or corrode, resulting in leaks—and death of the occupants.[1276]

Premature damage to a heat exchanger can be the result of a variety of factors.[1277] For example, it could be because the temperature rise across the heat exchanger is too high or to low. If a high-efficiency furnace doesn't have a totally-sealed combustion chamber, some indoor contaminates, particularly chlorine compounds, can react with the combustion by-products and corrode the inside of the heat exchanger. If the gas-flow rate is too rich, there may not be enough air for complete combustion, so the unit will run hot, produce soot and CO, and be prone to cracking. When a furnace has too much capacity, the run cycle may not be long enough to properly heat up the heat exchanger or chimney, something that can lead to condensation and corrosion.

Chimney Problems

[1274] Consumer Product Safety Commission (CPSC), *Product Safety Fact Sheet No. 13: Carbon Monoxide* (Washington, DC: CPSC, February 1980).

[1275] Helke Ferrie, "Stop cooking with gas!," *Alive: The Canadian Journal of Health and Nutrition* (December 1997): 49.

[1276] "Heating Systems can Kill," *Solplan Review* (August/September 1991): 8.

[1277] Richard Kadulski, "Carbon Monoxide and Combustion Appliances," *Solplan Review* (January 1997): 14.

Chimneys are supposed to expel combustion by-products from the living space. However, there are a variety of problems associated with chimneys that can result in combustion by-products *entering* the living space. For example, to function correctly, a chimney must be sized appropriately—neither too small, nor to large. When a house is weatherized, it has less need for heat, so a homeowner may install a smaller furnace. If this is done, the old chimney may be too large. Chimneys can be reduced in size by installing liners inside them. Liners can be made of aluminum, galvanized steel, stainless steel, clay tile, or they can be cast-in-place, and they must be compatible with the fuel being burned.[1278] A chimney professional can determine the best material for a given situation.

Condensation can be a particular problem with an uninsulated chimney on an exterior wall because it can take some time to warm up. Until such a chimney gets warm, the moisture in the combustion by-products condense on the cool surfaces—sometimes ice can form inside a chimney. This can lead to crumbling bricks, cracks, leaks, blockages, and poor draft. Condensation inside a metal chimney can result in corrosion and internal damage.

Older brick chimneys can easily become blocked by broken bricks if the chimney is deteriorating, and many older chimneys were simply built poorly in the first place.[1279] Animal nests (*e.g*. birds, raccoons, *etc*.) can also block a chimney.

Backdrafting and Spillage

Backdrafting means there is complete reversal of flow (downward) in a chimney, while spillage occurs when the combustion by-products don't go up fast enough, and some spill back into the living space. Either can happen when a house gets depressurized. Whenever you exhaust air from a building, you run the risk of depressurizing it. Depressurization can occur when you turn on a powerful exhaust fan, but clothes dryers, central vacuums, even radon-removal fans can also cause problems. Some downdraft kitchen-range exhaust fans are so powerful they are almost guaranteed to cause chimneys to malfunction. In one Canadian study, 36% of the houses were subject to excessive depressurization.

A classic example of how CO enters the living space involves a house with a wood-burning fireplace and a forced-air natural-gas furnace, each connected to a separate chimney. After supper, on a cold winter evening, the family builds a romantic fire in the fireplace. As the evening wears on, the fire dies down, and the family retires to bed. The draft in the chimney becomes weak a few seconds after the flame dies out. Only glowing embers are left and they produce a great deal of CO due to incomplete combustion. As the house cools down, the gas furnace, which is connected to a different chimney, starts up. As the furnace's combustion gases move up the chimney, and out of the house, the house becomes depressurized. (When it's expelling air from the house, a furnace's chimney is acting like an exhaust fan, so it can lead to a house becoming depressurized.)

[1278] Peter Scripture, "Is this chimney safe?," *Journal of Light Construction* (June 1993): 24-29.

[1279] "Combustion safety for residential equipment," *Solplan Review* (June/July 1992): 8-10.

Make-up air then enters the house by the path of least resistance—down the fireplace chimney. The make-up air picks up the CO from the dying embers and distributes it throughout the house. By morning, family members complain of headache and nausea. In one Nebraska house, an entire family was almost killed due to CO poisoning when this very thing happened.[1280] This scenario is most common when the fireplace has a masonry chimney on an exterior wall because such a chimney can cool off and lose its draft quickly.

One of the most common causes of house depressurization is leaky ductwork, but closing bedroom doors can also contribute to depressurization. The upward draft pressure inside a chimney is generally quite weak, and it doesn't take a great deal of depressurization to overcome it. It's been estimated that 50-80% of houses that rely on conventional chimneys have the potential for a problem.[1281] A Canadian study estimated that about half of all houses will experience enough depressurization to cause serious backdrafting or spillage when about 233 cfm of air is exhausted from them.[1282] That's more air than is expelled by an average kitchen-range hood, and clothes dryer operating at the same time, or a typical wood-burning fireplace. In small multi-family dwellings, a small bathroom exhaust fan may be all that is necessary to cause a backdrafting problem.[1283]

Backdrafting and spillage are common in fireplaces at the beginning and end of a burn cycle when the draft is weakest. The draft is strongest when there is a roaring fire, so this is when backdrafting and spillage are least likely.[1284] In 1991, **Canada Mortgage and Housing Corp. (CMHC)** decided to do a survey to see how prevalent backdrafting from wood burning appliances was. When they asked homeowners if their wood burning appliances smoked, that is, allowed combustion by-products to enter the living space, the homeowners invariable answered "No." But when interviewers said "Then let me ask you this: when the appliance is operating, have you ever noticed a nice *woodsy* smell in the house?," homeowners often replied "Yes, and we love it. It's one of the things we enjoy

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[1280] Jon Traudt, "Control of Indoor Air Pressure for Protection of Health, Preservation of Buildings, and Conservation of Energy" (Atlanta, GA: *Paper presented to the 16th World Energy Congress and 3rd Environmental Technology Exposition*, October 26-28, 1993).

[1281] Gary Nelson, The Energy Conservatory, Personal communication.

[1282] T. Hamlin, J. Forman, and M. Lubun. *Ventilation and Airtightness in New Detached Canadian Housing* (Ottawa, ON, Canada: Canada Mortgage and Housing Corp., 1990).

[1283] David Hill, "Pressure interactions in a house," *Solplan Review* (September 1998): 7-8.

[1284] "Fireplace air requirements," *Solplan Review* (August/September 1990): 8-9.

about burning wood." [1285] [1286] **CMHC** found that backdrafting and spillage were common occurrences, and that homeowners didn't associate the woodsy smell with an indoor-air-quality problem when, in fact, "that nice woodsy smell" is composed of combustion by-products. If operating a wood-burning appliance results in a woodsy smell, it isn't good for you and, even if you find it pleasant, you should do something to remedy the situation.

Garages

In the majority of houses, attached garages are not separated sufficiently from the living space. As a result, automobile exhaust gases travel into the living space through random gaps and openings in the common walls, or via leaky ducts located in the garage. The Minnesota Gas Co. found that starting a cold car in a garage can cause CO levels to soar in seconds, and that the deadly gas can seep into the house over several hours—long after the car is gone.[1287] There have been cases of CO alarms going off in houses several hours after a car has been started inside an attached garage. One of the best solutions is to have a detached garage. Existing garages can be tightened and ventilated. Forced-air heating/cooling systems should generally not be located in garages but, if they are, extreme care should be taken to seal all the ductwork, to make sure no garage air is able to leak into the duct system and, thus, enter the living space.

Other Sources

While it's important to vent all clothes dryers outdoors to expel moisture from the house, it is even more important with gas clothes dryers because they produce combustion by-products. Hobbies that require soldering, can also be sources of CO, especially if a portable gas torch is used.

Candles, incense, and smoking are also sources of combustion by-products, and their use should be discouraged indoors. These products rarely burn cleanly, so they generate a considerable amount of CO for their size. Some candles can put a great deal of soot into the air—especially cheap imported types and scented candles.[1288] Some candles also have lead wicks which can release a considerable amount of toxic lead fumes into the air.[1289]

1285 Canada Mortgage and Housing Corp. (CMHC) *That Nice "Woodsy" Smell, Combustion Spillage from Residential Wood Heating Systems* (Ottawa, ON, Canada: CMHC, March 1991).

1286 Canada Mortgage and Housing Corp. (CMHC) *That Nice "Woodsy" Smell, Combustion Spillage from Residential Wood Heating Systems, Appendices* (Ottawa, ON, Canada: CMHC, March 1991).

1287 "An attached garage may be the problem in mystery carbon-monoxide alerts," *Journal of Light Construction* (February 1997): 13.

1288 Frank Vigil, "Blow out the candles and roll up the carpet," *Home Energy* (March/April 2000): 5-6.

1289 "Candle Hazards," *ACTS Facts* (June 1999): 1-2.

Risk Assessment

The following CO levels are considered dangerous enough to require an immediate remedy: 9 ppm for an 8-hour exposure, 35 ppm for a 1-hour exposure, or 200 ppm for a single exposure. (In Canada, the guideline is 11 ppm over 8 hours, 25 ppm for 1 hour.[1290]) These guidelines are somewhat below the levels most people experience symptoms, but CO is so dangerous that exposure levels should always be as low as possible. Chemically sensitive people often react to very low levels of combustion by-products. For them, a level approaching zero is often necessary.

While it isn't good to have any combustion by-products indoors, CO is by far the most serious. Because of it's potential to kill quickly, CO alarms should be installed in all houses that contain combustion-fired furnaces, fireplaces, stoves, boilers, water heaters, space heaters, or kitchen ranges that have the potential to release combustion by-products into the living space. They are also a good idea if you regularly burn a lot of candles or use kerosene lighting. In 1994, the **Consumer Product safety Commission** began suggesting that CO alarms be required by building codes, but that requirement is not yet on the books.[1291] There are a number of CO-alarm manufacturers, including **AIM Safe-Air Products** (#696D), **BRK Brands, Inc.** (First Alert), **Kidde Safety**, **Lennox Industries**, **M.T.I. Industries, Inc.**, (Safe-T-Alert), **North American Detectors** (American Sensors), and **Quantum Group, Inc.** From **Newtron Products Co.** you can get an electrostatic air filter with a built-in carbon-monoxide detector.

Most alarms typically register CO levels no lower than 30 parts per million (ppm), but people who are at greater risk should be concerned about levels below 30 ppm. In fact, the guidelines mentioned above suggest that 9 ppm over an 8-hour period is too much. So, for most people, and especially pregnant women, children, the elderly, and those with a chronic illness, the Model 935 Low-Level Carbon Monoxide Monitor (**AIM Safe-Air Products**) would be a better choice. It will display levels as low as 5 ppm and can sound an alarm at levels above 9 ppm. However, many of the 30-ppm models have a digital display that will tell you what the actual level is, even though they won't sound an alarm. So, if you have one of these, you should check the reading regularly to see if the level is above 9 ppm inside your home.

The **Professional Equipment** mail-order catalog offers several different brands of CO-detection meters. Most of these gas-detection meters cost several-hundred dollars, so they are generally only used by professionals. There is also a less sophisticated method of evaluating a home that can be useful to homeowners. Costing only a few dollars, **Wag-Aero Group** has a CO Indicator with a chemical reagent in the center of a card that changes color in a few minutes if dangerous levels of CO are present. It's often used in aircraft, but can also be used in homes and garages. Once opened, it must be replaced every 30-60 days. A similar item is offered by **Quantum Group, Inc.** (Quantum Eye), but it will last for 18 months after opened.

What to Do

[1290] Robert Dumont, "Energy answers," *Solplan Review* (January 1998): 17-18.

[1291] John Andrews, "Carbon Monoxide Detection in the Home," *Custom Builder* (May/June 1994): 84-87.

CO poisoning is serious business. If you suspect combustion by-products are affecting your health, you should get some fresh air immediately. Open windows, turn off combustion appliances, and leave the house. Then go to the doctor and tell him or her that you suspect CO is causing your symptoms.[1292] Your doctor may perform a test to see if there is excessive CO in your blood. If there is, you should have a qualified service technician inspect and remedy the situation before returning home. Some gas companies will be able to assist you in evaluating a problem.

While low levels of CO may be tolerable for healthy people who are not particularly sensitive, it's really not a good idea to have any combustion by-products indoors. So, you should minimize your exposure to them whenever you can.

Avoid Unvented Appliances

To avoid all combustion by-products, the first thing you should do is avoid the use of all unvented fuel-burning devices, including gas kitchen ranges. You should also avoid using anything indoors that has an open flame. Ideally, this would include candles, incense, smoking, *etc*. Virginia Saleras, who is with the Technical Policy and Research Division at **Canada Mortgage and Housing Corp.**, has said simply that unvented combustion appliances "shouldn't be allowed. You've got unburned gases, partially burned gases, nitrogen oxides—there should be no unvented appliances." [1293]

Repair Damaged Equipment

If your furnace's heat exchanger is damaged, have it repaired or replaced immediately. This might mean replacing the entire furnace. Whenever a furnace is changed, make sure the chimney is sized correctly for it. Have your chimney inspected regularly, and keep it clean and in good repair. For chimneys that chronically backdraft, **Exhausto, Inc.** produces chimney fans that sit on top of a chimney to suck combustion by-products up and out of the house. **Tjernlund Products, Inc.** has a number of power-venting fans that can be used with conventional gas- or oil-fired equipment, including water heaters, furnaces or boilers. **Field Controls** also has several powered venting devices for either oil- or gas-fired equipment. Something to keep in mind is that when using these powered exhaust devices, there will be makeup air entering the house somewhere to make up for the air being exhausted. This makeup air could come down another chimney in another part of the house. In other words, you could solve a backdrafting problem in one chimney, yet cause a problem in another chimney. So, these devices should only be used after a situation has been thoroughly evaluated.

Avoid Excessive Depressurization

If your house experiences enough depressurization to cause backdrafting or spillage, you should have the situation corrected. Depressurization problems can be tricky to analyze. For example, in one Minneapolis house, a 1,500 cfm exhaust fan in the *attic* resulted in enough depressurization in the *basement* to cause the furnace and water heater

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[1292] Consumer Product Safety Commission (CPSC), *What you should know about combustion appliances and indoor air pollution* (Washington: CPSC, 1994).

[1293] "Unsafe Gas Heaters Proliferate."

there to backdraft.[1294] Solving depressurization problems could involve sealing leaky ducts, undercutting doors, adding a make-up air supply for exhaust devices, *etc*.

If you can't eliminate the depressurization, you may have to isolate the combustion device (*i.e*. furnace, boiler, water heater) from the rest of the house. This could involve building an airtight room, or placing the combustion device in a separate building. Both options are discussed in *Chapter 7, Heating and cooling*. It's also possible to replace the device with a new high-efficiency unit having a sealed combustion chamber—or with an electric unit. In new construction, there are guidelines for minimizing backdrafting problems in conventional fireplace chimneys.[1295] However, the key word is minimizing. So, for very sensitive people fireplaces generally aren't recommended.

Evaluating a chimney is best done with a draft-pressure gauge by a professional, but there is a way for a homeowner to perform a simple draft-hood test. It will reveal if air is leaving the house by way of the chimney like it is supposed to. It involves holding a match or incense stick next to the draft hood when the appliance is operating to see if air is being pulled into the chimney or being blown away from it. A guide, prepared for homeowners, is available from the Energy Information Center in Minnesota.[1296] A homeowner guide is also available from **Canada Mortgage and Housing Corp. (CMHC)**[1297] To educate professionals how to properly evaluate chimney function, **CMHC** offers an Instructor Manual[1298] and a Student Manual[1299] for a Combustion Venting Training Course.

Automobile Exhaust

If combustion by-products from your automobile's exhaust leak into the living space from the garage, you should leave the overhead door open, or allow the car to warm up outdoors, rather than in the garage. If you can tighten the common walls (and ceiling) you can eliminate pathways for the pollutants to migrate indoors. If heating, cooling, or ventilation ducts are located in the garage, they should be well sealed.

It's often helpful to have an exhaust fan in the garage to expel any combustion by-products quickly before they can enter the living space. If the fan is controlled by a crank

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[1294] "Attic fans and furnaces," *Energy Design Update*, (May 1992): 11.

[1295] John Gulland, "Successful fireplaces in tight houses," *Journal of Light Construction* (May 1999): 73-78.

[1296] Minnesota Department of Public Service, *Combustion air* (St. Paul, MN: Energy Information Center, May 1994). To obtain a copy, call 612-296-5175 or 800-657-3710.

[1297] Canada Mortgage and Housing Corp.(CMHC), *Ventilation: Health and Safety Issues* (Ottawa, ON, Canada: CMHC, 1987).

[1298] Canada Mortgage and Housing Corp.(CMHC), *Combustion Venting Training Course: Instructor Manual* (Ottawa, ON, Canada: CMHC, January 1991).

[1299] Canada Mortgage and Housing Corp.(CMHC), *Combustion Venting Training Course: Student Manual* (Ottawa, ON, Canada: CMHC, January 1991).

timer, you can set the timer to run for several hours after the car is gone and the overhead door is closed, and it will shut itself off automatically. Some people are recommending that a 100-cfm exhaust fan be running *continuously* in every attached garage. If a combustion-fired furnace or water heater is located in the garage, make sure the exhaust fan doesn't cause its chimney to backdraft. If an attached garage has a roof over it (rather than having bedrooms or other living spaces over it), you can run a pair of 6" diameter ducts from the garage ceiling up through the roof to a pair of turbine roof ventilators, such as the whirlybird ventilators made by **Lomanco, Inc.** This will continuously ventilate the garage without the electricity necessary to run an exhaust fan. Again, be sure that this won't cause a chimney in the garage to backdraft.

Do-It-Yourselfers

Anyone can decide to quit using unvented appliances, but there are other aspects of minimizing exposure that are best left to the pros. Here's why: if you have a combustion-by-product problem in your house and you fix it incorrectly, you could be dead by morning. So, it's important to analyze exactly why you have a problem, repair it correctly, then make sure you haven't made things worse.

If combustion by-products indoors are caused by pressure imbalances in a house, it generally requires special diagnostic equipment (*e.g.* blower doors, pressure gauges, CO meters, *etc.*) to analyze the situation correctly. With the right equipment and training, a technician can tell quickly why a problem exists and what to do about it. Without the equipment and training, you could easily be guessing.

Most heating technicians are trained to find cracked heat exchangers, and most chimney sweeps are good at analyzing chimney problems, but it can be difficult to locate a person trained to analyze pressure-related problems and duct leakage. In fact, a survey in Iowa found that of 104 heating contractors, 25 did not have any CO-measuring equipment and 61 didn't have appropriate training.[1300]

However, qualified technicians do exist. For example, local Community Action Programs (CAP), that are involved in weatherization of low-income housing, are very concerned about backdrafting and spillage because, when they tighten and add insulation to a house, they have to make sure they haven't caused any chimney-related problems. CAP programs often use private contractors who can, and do, work for people in all income ranges. Many state-wide CAP organizations offer training programs. Call your local CAP office for a referral. In North Carolina, **Advanced Energy** has an excellent training program.

VOCs in a Problematic New House

What do you do if you move into a new house and find that you can't tolerate it? You leave for a few hours, or a few days, and when you return, you soon start experiencing a variety of symptoms. You may get a headache, feel overly tired yet can't sleep, have inflamed sinuses, become unable to concentrate, have blurred vision, lose your sense of balance—or develop virtually any other symptom imaginable. You know

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[1300] Thomas Greiner, "CO Leaks: Causes & Cures," *Journal of Light Construction* (March 1998): 63-68.

you feel miserable, yet no one else in your family feels bad. In fact, they're quite happy with the new house. What's wrong? What do you do?

The problem may easily be due to the new building materials outgassing into the living space, where you are being exposed whenever you are in the house. There is a wide variation among people's sensitivities, so it isn't unusual for one person to be affected, while everyone else in the family feels no ill effects. If fact, this is more common than the situation where all family members are effected equally by a new house.

Defining the Problem

There are a wide variety of building products that could be causing the problem. In fact, the majority of the construction materials on the market have some known negative health effect. But some products are more noxious than others. For example, the materials you can actually see inside the house—flooring, walls, cabinets, *etc*.—are almost always the most significant outgassing sources, rather than the things that aren't directly exposed to the living space—insulation, framing, roofing, *etc*. That doesn't mean roofing, siding, and insulation can't be a problem. It's just that they aren't the most likely culprits.

Of the materials inside the living space, those with large surface areas often have more of an impact than products covering fewer square feet. Of course, some materials are more powerful outgassers than others, so they may be problematic even if they're fairly small.

Carpeting

Synthetic wall-to-wall carpeting is often implicated in these cases. In fact, the carpet fibers, the backing, the pad, and the adhesive, could all be outgassing into the air. While the carpet industry often states they haven't used formaldehyde in carpet for years, it could easily be a by-product of the manufacturing process. But, even if formaldehyde isn't outgassed from the carpeting, there are dozens—sometimes hundreds—of other VOCs that are released. If they can kill mice in a laboratory, they can affect your health.

Formaldehyde

Formaldehyde is often a problem in new houses. But the main source isn't carpeting—it's usually kitchen and bathroom cabinets. The vast majority of new cabinetry contains manufactured wood products (*e.g*. particle board, plywood, and medium-density fiberboard) produced with a potent urea-formaldehyde resin. And most cabinets are coated with an even more potent urea-formaldehyde clear finish. Other strong sources of formaldehyde in houses include closet shelving made with medium-density fiberboard, $^{1}/_{4}$" wall paneling, and particle-board underlayment under the carpeting.

Formaldehyde is relatively easy to test for. **Advanced Chemical Sensor, Inc.** offers a reasonably priced ($31) Passive Monitoring Badge that can either be worn, or placed in a room. After a certain amount of exposure time (usually at least 24 hours), the badge is returned to the manufacturer's laboratory, where it is analyzed. You can get the test results—which can detect levels as low as 0.01 ppm—by mail, phone, or FAX, usually within 48 hours. Formaldehyde test kits are also available from mail-order catalogs such as **American Environmental Health Foundation.**

Everything Else

Sensitive people also often react to the general background level of VOCs released in small amounts by many new building materials—the wall paint, construction adhesive, caulking, *etc*. **Air Quality Sciences, Inc.** has an IAQ Test Kit that will measure formaldehyde, total VOCs, and the three primary VOCs present, as well as mold from surface samples. For a $100 analysis cost, **Advanced Chemical Sensor, Inc.** has a Passive Monitoring Badge that will measure approximately 80 chemicals in the air. It is used like the formaldehyde monitor mentioned above. They also have monitors for a variety of specific chemicals.

If symptoms seem to get worse when the forced-air heating/cooling system is on, the problem might be related to raw fiberglass insulation inside ducts, backdrafting or spillage, or duct leakage drawing unwanted air from a crawl space, attic, or building cavity.

If a sensitive person seems to be getting more and more sensitive, then furnishings, cleaning products, and even clothing—all of which used to be quite tolerable—could start to become bothersome.

On top of all the problematic materials, most new houses don't have a mechanical ventilation system to bring in fresh air and expel stale air.

Risk Assessment

One of the difficulties with this type of problem is the fact that the sensitive person's metabolism may be in the process of changing. In many cases, they start being bothered by more and more things. Although the precise health effects of many indoor pollutants aren't yet fully researched and documented, anecdotal reports continue to show that sensitive people can become more and more sensitive if they don't get into an unpolluted environment.

In these cases, it's tempting to want to measure the actual concentration of all the possible air pollutants in order to determine exactly what's in the air. But, this rarely reveals any helpful information. For example, let's say you decide to measure formaldehyde. In most houses, the level of formaldehyde will be less than 0.20 parts per million (ppm), although levels 5-10 times that have been recorded. A formaldehyde concentration of 0.10 ppm is generally considered safe for most people, but sensitive people often require an environment with a concentration as low 0.03 ppm—sometimes less. So, if you measure the formaldehyde concentration, you could easily find a level that's typical in houses—and considered safe by most regulatory agencies.

If you decide to measure the concentration of everything in the indoor air, you'll likely spend thousands of dollars to do so, and end up with a list of over a hundred air pollutants—most of which haven't been studied for their impact on health. In other words, you'll know what you've got, but you won't know what it means.

To analyze the situation, it's important to simply listen to the sensitive person—and believe them. Yes, their symptoms are unusual, and nobody else in the household is having the same experience, but that doesn't mean there isn't a problem. You're dealing with someone who's more sensitive than average, and you need to create an environment *they* can tolerate, not just an environment suitable for average, healthy people. One way to evaluate how serious the situation is, is to determine how long it takes symptoms to show up when the sensitive person enters the house.

To evaluate a house, the sensitive person should first be feeling reasonably well. They should stay in a clean environment (*e.g.* outdoors or in someone else's house) until they feel well—then return home and see how long it takes for symptoms to return. If they feel symptoms coming back quickly (within minutes, or a couple of hours) then the house is affecting them much more seriously than if it takes a full day before symptoms manifest themselves. In most cases, the sooner symptoms show up, the more difficult it is to remedy the situation.

What to Do

There are several things you can do to make a problematic new house tolerable for a sensitive person. Unfortunately, all of the options are imperfect—and they all have drawbacks.

Filtration

Air filters can indeed remove contaminants from the air. But, by itself, filtration is an imperfect means of improving air quality, especially for sensitive people, because they sometimes react to the filter itself. With filtration, you're trying to remove pollutants after they've contaminated the living space. It's impossible to remove them all, because new ones are continually being generated. So you'll only be able to reduce the concentration of pollutants, you won't be able to remove them completely. To do the best job, you must use a fairly powerful filter, one that will process the air several times an hour. That's difficult to do with the widely available portable air filters because they're only designed to be used in a single, closed room. To clean up the air in the whole house, you'll need a portable filter in every room—or a powerful whole-house filter.

With new houses, VOCs are usually the biggest issue (but biological pollutants could also be present), so a filter containing activated carbon is going to be more useful than one containing a HEPA filter. But whole-house filters containing a significant amount of activated carbon aren't common.

Before installing a whole-house system, most people get a portable filter and try it in a single room to see if they get any substantial benefit. If a decent-sized portable filter doesn't help in one room, it's doubtful if a whole-house filter will help much more.

Ventilation

Adding a ventilation system can also help, but most aren't powerful enough to change the air often enough, to result in significant improvement for a sensitive person in a polluted house. Here's why. A ventilation system is best used to dilute the pollutants generated by the occupants themselves—that is, their metabolic by-products. To do so, a ventilation system may change $^1/_3$ of the air in a house every hour, or all the air every 3 hours. Because of a certain amount of mixing between fresh air and stale air, one complete air exchange really doesn't change all the air in a house. In fact, with perfect mixing, one complete air change will leave about 37% of the polluted air indoors. To do more than just dilute the occupants' metabolic by-products—to insure that the air will have as few indoor pollutants as possible, of all kinds—you may need a ventilation system capable of changing the air at least every hour, perhaps several times an hour.

Such a ventilation system can be expensive to install, and with that much air whooshing around, it can also be noisy. Plus, even the most energy-efficient system will be costly to operate, and it'll seriously affect your heating/cooling bills. If the sensitive person has become very intolerant, they may also start reacting to *outdoor* pollution sources, so you may need to combine high-speed ventilation with better-than-average filtration of the incoming air.

One study found that boosting the ventilation rate by eight times—from 0.1 air change per hour (ACH) to 0.8 ACH—only lowered the formaldehyde concentration from 0.45 ppm to about 0.20 ppm.[1301] To determine if ventilation will do the trick, you should get a fan of known capacity, and put it in a window to air out one particular room. (You may need to open a window in another room to relieve any pressure imbalance, so the fan will function well.) This is best done when the outdoor temperature is mild. The sensitive person should spend time in the ventilated room and see how they feel. By knowing the capacity of the fan and the size of the room, and the sensitive person's comments about how they feel at that airflow rate, you should be able to gauge whether it is too much or too little air, and thus, how much capacity a whole-house system should have.

Ozone, Bake-Outs

People often try to attack indoor air pollutants with ozone. Or they attempt a bake-out (heating the interior of the house, while simultaneously overventilating) to cause accelerated outgassing and drive off the VOCs stored in the building materials. Neither approach works very well for sensitive people. In fact, ozone can be dangerous if used improperly, and it sometimes results in new pollutants being generated that didn't exist before ozoning. And bake-outs aren't effective with long-term outgassing sources such as particle board and medium-density fiberboard. These are simple solutions to a complex problem that just aren't very effective.

Remove the Polluting Materials

A more effective solution is to remove all the offending materials—get them out of the house so they can't pollute the interior air. This can be a radical move, but it might be necessary when someone is very sensitive. If all the carpeting must be removed and replaced with ceramic-tile or solid-wood flooring, if kitchen cabinets must be replaced, if the heating/cooling system needs a considerable amount of reworking, and if a ventilation/filtration system is to be installed, then you're talking about a major project, and a significant expense—all in a brand new house that you've already invested your life savings in. Even if you do all this work, you still won't have an ideal healthy house—because it won't be airtight—so you won't have total control over the indoor air.

To determine if removing materials will be effective, you should first separate some of the most likely offenders from the living space. This is a temporary measure, and it's done to gain some knowledge about the scope of the problem before you commit to major remodeling. If you suspect kitchen cabinets, wrap them in aluminum builder's foil, being careful to tape all the seams. They may look like a giant gift-wrapped package, and you won't be able to use them, but after a couple of days, a sensitive person should be

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[1301] H.U. Wanner and M. Kuhn, "Indoor Air Pollution By Building Materials," *Environment International* 12 (1986): 311-315.

able to tell if there's any improvement in the kitchen air. If carpeting is suspect, it can be covered in the same way. You may have to walk on the builder's foil with your shoes off to avoid poking holes in it, but this can be a useful way to evaluate what would happen if the carpet were removed. Some people have covered all the walls and ceilings (usually in a single room) when they've suspected the paint itself as being bothersome.

Relocate

When someone has just moved into a new house—perhaps their dream house—the last thing they want to hear is that they need to move out. But that may be the most cost-effective option. It makes little economic sense to gut the interior of a new house and then rebuild it. If you're going to go to that much trouble, it's probably going to be cheaper—and more effective—to build a healthy house from the ground up.

As an option, you might look for an older house—one 20-30 years old—that has already had time to outgas. The big advantage of existing homes is that the sensitive person can actually spend time in the house and see how tolerable it is. In some cases, if the house is empty, a real-estate agent will be able to arrange for an overnight stay. Existing houses are almost never perfect, but if you are diligent in looking, it's often possible to find one that needs minimal reworking. You may look into an imperfect existing house as temporary housing, while you make plans to build a healthy new one.

Summary

If you feel your house has a problem that's contributing to your ill health, it's important to define the problem carefully before deciding to do anything. In many cases, unhealthy materials like lead paint or asbestos, just sit there without polluting the air—so they can often be left alone. If something *is* contaminating the indoor air, you should figure out exactly how and where the problem originates. Then you can work out a remedial plan. But before you actually start fixing the problem, you should think through how the proposed changes will affect the rest of the house. After all, a house acts like a system, and a change to one part of a house can easily affect another part.

26. Three Healthy Houses

There is no single way to build a healthy house. The style will depend on the particular tastes of the occupants. Some people prefer a contemporary house, others opt for a country look. The selection of construction materials will also be influenced by personal preference. For example, a brick exterior will generally be as inert as aluminum siding, but if your taste leans toward Spanish architecture, you may choose stucco.

This chapter will describe three different healthy houses. First, I'll summarize what my wife, Lynn Marie, and I did in building our first healthy house. Lynn has severe sensitivities to a wide variety of environmental pollutants, notably formaldehyde, exhaust gases, pesticides, artificial fragrances, printing ink, and outgassing from most plastics. Her reactions can be severe, so we had no choice but to build the healthiest house we could in order to protect her health. Of course there were limits to what we could use. Some materials were not available locally, and others were simply too costly. Although there were a few compromises, we completed the house in 1986 and the final result was very successful. Lynn's health improved remarkably in the time we lived there.

After moving into our first healthy house, I personally built two more. In fact, one is featured in our video, *Your House, Your Health*, and the entire construction process is fully documented in my book *Healthy House Building for the New Millennium*. After about 10 years of living in our first healthy house, Lynn and I decided to build ourselves a new home. It's built using the same principles we've advocated from the beginning, but its appearance is somewhat different from our first healthy house. This chapter will discuss our new house as well, pointing out the differences and similarities.

I feel all houses should be as healthy as possible, and there are growing numbers of builders and architects who agree with me, but there are also others who continue to build unhealthy houses day after day. Many of these contractors and designers aren't willing to make significant changes in the way they build—but they *are* often willing to make *some* compromises. For them, I offer what I call a generic healthy house—the third example in this chapter.

A generic healthy house is built in much the same way, and with many of the same materials, as most unhealthy conventional houses—but not completely. By substituting healthy materials for the worst offenders currently in use, a moderately healthy house can be built without deviating too much from typical construction practices. The indoor air quality in a generic healthy house will be considerably better than in most conventional houses—probably just fine for most healthy people—but it might not be good enough for sensitive individuals.

Our First Healthy House

When Lynn and I decided to build this house, we didn't have a great deal of money to invest. But then, we didn't want a large house with a lot of amenities. We were after a small vacation-like house that would be easy-to-maintain. Our goal was to build a very healthy house on a tight budget.

The Site

We wanted to remain in the Midwest, but we ruled out living in a city where exhaust gases and lawn chemicals proliferate, or near farm fields where agricultural chemicals are used. We finally selected a location about ten miles from Bloomington, Indiana. For us, it was important to be near a city large enough to have a good hospital, a health-food store, and the cultural events and library facilities of a large university. The home site is in the middle of a hardwood forest that was cleared out enough to allow a nice breeze to blow through. During some times of the year there can be an abundance of mold spores or pollen in the air, but in general, it's quite tolerable. Remember, no place is 100% perfect.

The actual location of the house is about 500' from a paved road, with a deep ravine in between. The driveway is crushed stone, running along the eastern side of the five-acre parcel. There's a large open area on the west side of the house where the septic field is located, and the detached garage is about 75' east of the house. This allows the prevailing wind from the west to carry away any exhaust gases near the garage or drive. All the utilities to the house are underground, so the nearest utility pole is separated from the house by about 500' of wooded land.

Basic House Design

Our particular needs were for a two-bedroom, single-bath house, with an eat-in kitchen. The final design contained 1,013 square feet, with an 8' x 12' screen porch. We decided to use sloped ceilings throughout the house to make the rooms feel larger. This, combined with the room sizes and window placement yielded a small, but airy, cottage-like home that's quite comfortable.

We wanted the house to be very energy-efficient, and decided there were definite advantages to the airtight, superinsulated designs being built in very cold climates. The particular construction technique we chose was the Airtight Drywall Approach (ADA), and we combined it with foil-backed drywall. Because the heating requirements are low in a superinsulated house, we were able to use non-polluting, hydronic, electric, baseboard heaters, and a small ductless mini-split system air conditioner. Because the house is airtight, the indoor air is exchanged mechanically. If there happens to be any air pollution outdoors, the ventilation system can be temporarily shut off, and the whole house becomes an oasis.

After a couple of years, we built a small detached office next to the house for our home-based business. It's appearance is somewhat different from the house, and we incorporated a few different materials, but we used the same basic healthy-design principles.

Foundation

We decided very early in the design process to use ceramic tile on all the floors in the house. This decision led to the selection of a concrete-slab foundation system. In order to keep the slab from absorbing moisture from the soil, and to keep radon from entering, a plastic diffusion retarder was placed between the concrete and the ground. The slab was built with three inches of extruded-polystyrene foam insulation around the perimeter and beneath it. Because these materials are well-separated from the occupied part of the house by four inches of concrete, they don't outgas into the living space.

A separate masonry foundation wall was used to support the house. It's surrounded by a perforated drainage tile to keep the foundation system dry. We figured the tile could also be used in the future to remove radon from the soil—if radon should ever become a problem (which it hasn't). Because the concrete floor slab is not connected to the foundation wall, it was easy to superinsulate it.

Framing

We elected to use a light-gauge steel-stud framing system, rather than wood, for two basic reasons. First, the natural resins in pine framing lumber can slightly contaminate the air in a house, while steel framing is odor free. Second, wood-framed houses invariably need to be treated for termites, and steel doesn't. While the cost of steel framing was slightly higher, this was offset by the savings in omitting the toxic termite treatment.

Our superinsulated design required that the walls be $10^1/_2$" thick. This was accomplished by actually building two exterior walls. The outer one is load bearing, and it supports the structure. The inner wall is made of less-costly, non-load-bearing steel studs. Its purpose is simply to provide space for more insulation, and support the drywall. The wall down the center of the house is also constructed of the load-bearing studs (to support the rafters), but the lighter-weight non-load-bearing studs were used for all the other interior partition walls. The steel roof rafters are $13^1/_2$" high. This allows for the use of 12" of insulation in the ceiling, with an $1^1/_2$" airspace above for roof ventilation.

Exterior

The exterior siding is aluminum with a baked-enamel finish. It was applied over a wind barrier of perforated aluminum builder's foil, and all the seams were taped with aluminum-foil tape. No sheathing was used. The ribbed steel roof was attached to wood purlins, so there is no plywood roof deck. Wood was used for purlins in order to maintain the desired roof line. Plus, steel purlins would have needed to be custom made—at a substantial increase in cost. Fir was chosen over pine to minimize outgassing. Because wood in this location is well separated from the living space, the slight odor of the fir hasn't been a problem, and it's far enough from the ground that subterranean termites can't reach it. The screen porch is made of aluminum.

The windows have aluminum frames—with thermal breaks to eliminate sweating and improve energy-efficiency. They're triple-glazed, having both a sealed insulated unit and an added storm window. Most of the windows are south-facing, to allow the solar heat to warm the house in the winter. The roof overhang is designed so the windows are shaded in the summer. The weather-stripping on the windows does outgas slightly but, because there are so few other components in the house that outgas, this hasn't been a problem.

The steel entry doors are insulated with foam insulation, but are sealed on all edges with a steel skin that makes outgassing from the insulation negligible. Again, the small amount of odor from the weather-stripping is minimal. The doors were painted with an exterior, water-based, latex-enamel paint early in the construction process so the paint could have plenty of time to outgas.

Inside the Walls

We chose fiberglass-batt insulation, because of its availability and reasonable cost. During installation, a strong formaldehyde odor was present, but once the insulation was covered with foil-backed drywall and the joints were sealed, the odor was no longer noticeable. The tightness of the house at this point was becoming quite apparent.

As a cost-saving measure, plastic-jacketed electrical wire, and plastic plumbing drain lines, were used throughout the house. Once these items were well-sealed behind the foil-backed drywall in the exterior walls, they didn't outgas into the interior of the house. We had some reservations about using the plastic materials within the interior walls, so we wrapped them all individually with aluminum foil. We did this as low-cost insurance and, as a result, outgassing from the plastic materials hasn't been a problem.

Interior

We decided to use drywall instead of plaster walls for two reasons—drywall is cheaper than plaster, and it's easier to seal in an airtight manner. But, before we made the final decision, Lynn tested several samples of paint to determine which would seal the drywall the best. Because she's sensitive to printing ink, we were concerned that the recycled paper on the drywall might be a problem. While the most-tolerable sample seemed to outgas in a couple of weeks, after the entire interior of the house was painted, the amount of outgassing was much more noticeable. It delayed our moving in by three months. We also used a low-odor joint-finishing compound. It was better tolerated than the paint.

All the wood trim used in the interior of the house is tulip poplar, a locally grown hardwood. Like all woods, it has a characteristic odor, but it was negligible once coated with a tolerable clear finish. All the interior doors, cabinets, and trim were custom-made of the same wood. In order to minimize the impact of the smell of the poplar, everything was coated on both sides with the clear finish. The trim was all prefinished before being installed. Tulip poplar was chosen over other hardwoods because of its availability, workability, and relatively low cost—plus we liked its appearance.

Kitchen and Bathroom

The kitchen cabinets were all built out of solid wood. The design lent itself to easy assembly, and a minimum of labor. They were finished inside and out. The countertops were custom made out of stainless steel. While this was a costly choice, it proved to be so nice to work on, that we feel the extra expense was worth it. No dishwasher was installed because of the odors associated with them, but the cabinets were designed so one could be added in the future.

The washer and dryer were located in a closet off the bathroom, so the major sources of moisture would be in the same room. This closet also contains the electric water heater and the central-vacuum unit. The bathtub is a porcelainized-steel model and the walls around the tub are covered with custom-made, porcelainized-steel panels. The caulking at the edges of these panels took a little over a week to outgas. The lavatory cabinet matches those in the kitchen and is fitted with a vitreous-china top. The toilet has an insulated tank to minimize sweating.

All water-supply lines within the house are copper, assembled with lead-free solder. Because we're on a municipal water system, we installed an activated-carbon filter on the incoming line to remove chlorine. The plumbing fixtures were chosen from locally available models with a minimum of plastic parts.

Ventilation

The heart of the ventilation system is a heat-recovery ventilator that's located above a dropped ceiling in the central hallway. This is the only part of the house that does not have a high sloped ceiling. The model we chose was selected because of its compactness and cleanability. Outdoor air is drawn in at the west end of the house and it enters the living space through a grille in the central part of the house. The fresh air passes through a thin particulate filter containing some activated carbon. The particulate filter isn't very efficient, but it does remove much of the mold and pollen that would otherwise enter the house. The activated carbon takes care of any slight odor from the fan in the heat-recovery ventilator.

Stale air is pulled from several locations in the house, directed through the heat-recovery ventilator, and discharged outdoors about 25' downwind of the fresh-air intake. The stale-air pickup points are in the kitchen, the bathroom closet, the entry closet, and the two bedroom closets. The air in the house circulates quite well and is constantly being replaced with fresh air. This system is capable of changing the air in the house every hour, but we've found that, with so few outgassing sources indoors, it only needs to run between five and eight hours a day to keep the interior fresh.

The kitchen range hood is vented outdoors, as is the clothes dryer and the central-vacuum exhaust. The house is so airtight that when one of these items is running, a negative pressure is created in the house. We found that it helped crack open a window temporarily to relieve the depressurization, and to allow the exhausting device to operate more efficiently.

Summary

Our house was designed as a system, rather than as a collection of individual parts. Airtight construction and ventilation were central to decisions about room placement. Walls were located so plumbing and ventilation ducts could be run without piercing the air-pressure retarder created by the Airtight Drywall Approach. Room placement was also influenced by window locations, and vice versa. While there were a few less-than-desirable materials used (like fiberglass insulation), they were well separated from the living space. Those materials wholly within the living space were chosen to be as healthy as possible.

While our house was built somewhat differently than most houses today, it doesn't look unusual. There is little about the exterior to suggest it was designed to be healthy. Upon entering, you notice the attractive woodwork, the sloping ceilings, spacious windows, and deep window sills. The only thing immediately noticeable that is different in appearance from other homes is the lack of carpeting—but most people comment on the attractiveness of the ceramic tile. Healthful doesn't have to look strange or ugly.

Our New Healthy House

When Lynn and I first thought about building ourselves a new house, it wasn't because we were unhappy with our existing house. In fact, we were quite pleased with its healthfulness, size, comfort, and the setting in the woods. We just felt like we were ready for something different. This time, we had a little more money to invest—but not much more—so we knew we would still have to pay attention to our budget.

The Site

Lynn's health improved quite a bit during the years we were living in our first healthy house, but she still didn't have enough tolerance to live in a metropolitan area, with its concentration of exhaust gases and background pollution. We considered moving to several different parts of the U.S., but kept comparing them to the county we already lived in. In the end, we decided to stay in the same general area, and bought 15 acres of wooded land about 12 miles from where we were living. It's in a low-traffic area, on a dead-end road, but still provides us with good access to town.

The house sits about 200' from a paved road. There's a small ridge between the house and road, so you can't see the house if you drive by. The ridge protects the house from occasional traffic odors. The nearest neighbor is about 700' away, utilities are underground, and the drive is crushed stone. One of our biggest early expenses involved the construction of a mound-type septic system. The property has marginal soil, so the County Health Department wouldn't approve a less-expensive conventional septic system. The 2-car garage is detached.

Basic House Design

This house also contains two bedrooms, one bath, and an eat-in kitchen but, at 1,232 sq. ft., it's slightly larger than our last one. The rooms are a bit larger, but most of the extra square footage went into storage space— larger closets and built-in cupboards and bookcases. In addition, there's a home office with a small bathroom on a lower level which contains 448 sq. ft. This time we decided to build the house and office together, rather than as two separate structures. So, we have a total of 1,680 sq. ft. under roof, for both living space and our home-based business.

We again opted for a superinsulated design and used the Airtight Drywall Approach to build a very tight structure. There are occasionally packages, papers, samples, and visitors in the office that are bothersome to Lynn, so we used airtight-construction techniques to separate the living space from the office. There's even a weather-stripped door at the top of the stairs, so air from the lower-level office can't leak into the upstairs. The living space has sloped ceilings throughout (except for the entry closet and central hallway, where the ventilation equipment is located), and the office has flat 8'-high ceilings.

Our heating and cooling requirements were very low again, so were able to use the same type of non-polluting, hydronic, electric, baseboard heaters, and small ductless mini-split system air conditioner we had luck with before.

Foundation

One of the most striking features of this house is its pier foundation. The building sits on a hillside, up in the air, on 12 concrete piers, each 18" in diameter. It's sort of like a tree house, and you can actually walk underneath parts of it. The foundation itself required a minimal amount of concrete, but there's a bit more structural wood in the floor system than with other designs. All in all, it ended up being a little more expensive to build than a concrete-slab foundation.

Framing

Since building our first healthy house, research has shown that, in some cases, steel framing can be very energy-*inefficient*. Whenever I had built with steel in the past, I used a double-wall system, which is one of the more energy-efficient ways of using steel studs. This time we decided to go with a hybrid approach and use both wood and steel.

The big health disadvantage to framing a house out of wood has always been that it often needs to be treated with toxic termiticides. But some less-toxic termite treatments are available today that weren't on the market a few years ago. While wood framing itself isn't a serious pollution source, Lynn is still bothered by the natural aroma of softwood lumber. But we knew from experience that airtight construction techniques would prevent a variety of odors from migrating into the living space. So what we did in this house was build the load-bearing structure out of wood. That part of the building was insulated, drywalled, and well-separated from the living space. Then, we built the interior partition walls with light-gauge, non-load-bearing steel studs.

For energy efficiency, the insulated walls were built with 2x8s. The walls aren't as thick as in our other house, but they still allow for wide window sills. The rafters and floor joists were 2x12s—for strength, and plenty of insulation. The subfloor is $^3/_4$" tongue-and-grooved construction-grade plywood. The sheets were glued to each other, and to the floor joists, with a water-based construction adhesive. This gave us an airtight, very sturdy, squeak-free floor system.

Exterior

We again used aluminum siding with a baked-on finish, and steel roofing, also with a baked-on finish. But this time we used construction-grade plywood and asphalt-impregnated fiberboard for sheathing. Again, based on past experience, we knew that it wouldn't affect the indoor air as long as the house was tightly constructed.

We also used aluminum-framed windows again—with energy-efficient thermal breaks in the frames to minimize sweating—and insulated steel entry doors. The doors were painted with a durable automotive paint early in the construction process and allowed to outgas prior to occupancy. There have been significant advances in window design in recent years, so we were able to get windows with low-E coatings and argon fill for improved energy efficiency. The slider windows are triple glazed, but our distributor was only able to supply double-glazing for the fixed-glass windows. Most of the windows were positioned to take advantage of solar heat in the winter.

Each level of the house has a redwood deck, reaching out into the woods. The two decks are connected to each other, and the ground, by a metal spiral stairway. There's an elevated walkway along the south side of each level.

Inside the Walls

We considered several insulations—primarily looking at ease of installation, cost, and availability. Again, based on past experience, we knew insulation wouldn't be a health problem as long as the house was built in an airtight manner. We finally settled on fiberglass because I could install it myself, thus saving on installation expenses. We used high-density batts in the 2x8 walls to get an R-value of 30. The ceiling and floor are insulated to R-38.

Over the years, we've tried several approaches to minimizing outgassing from plastic-jacketed wiring and plastic plumbing lines. What seems to work well, and is the easiest, is to simply buy the plastic materials early in the construction process and let them air out naturally before installing them. But, just to be safe, we used foil-backed drywall throughout the house to act as a diffusion retarder.

Interior

We again used drywall and a low-tox joint-finishing compound. A number of new low-tox paints are now on the market, and we selected one Lynn could tolerate well. We've really gotten to like the appearance of poplar wood for interior trim and doors, so we opted for it again. In our geographic area, it's cheaper than pine.

While ceramic-tile floors are probably the healthiest, hardwood floors are a close second. So, this time we used a combination of both. The tile was laid in the kitchen, entry, central hall, and bathrooms, with thin-set mortar and additive-free, home-made grout over $^1/_2$"-thick cementitious boards. The glazed surface of the ceramic tile itself acts as a very good diffusion retarder to prevent any outgassing from the plywood subfloor from migrating up into the living space. For the hardwood flooring, we had a local mill make some $^3/_4$"-thick tongue-and-groove material out of beech wood. Although not nearly as common as oak, beech is somewhat less odorous, a little cheaper, very attractive, and it looks good with the poplar trim. It was nailed down over a diffusion retarder of aluminum builder's foil—to block any outgassing from the plywood subfloor. Then it was sanded in place, and finished with a low-tox clear finish.

Kitchen and Bathroom

We had solid-wood kitchen and bath cabinets in our old house, but put steel cabinets in the model healthy house we built. Either approach can be quite attractive, and healthy. This time we decided on a hybrid approach. The cabinets are mostly solid wood (poplar again), but the wide shelves in the lower cabinets were folded out of galvanized sheet metal. The metal was easier to fabricate than wide wood shelves, and it won't warp. We used stainless-steel countertops again—there was no choice here, we really love stainless.

The laundry is, again, in a closet off the bathroom, along with the electric water heater. The central vacuum is in the entry closet this time—just because it fit there better. Rather than having porcelainized panels custom made again, we used a one-piece, fiberglass bathtub/shower to minimize caulking and seams where mold might grow. We bought it early—on sale—and had it sitting on our porch for about a year, so it was done outgassing by the time we installed it.

One of the areas where we splurged was the bathroom vanity—we used a marble top. It's a little over 6' long and cost a few hundred dollars, but it's really beautiful. Although plastic laminate would have been cheaper, the solid marble actually cost less than a synthetic solid-surfacing material.

Ventilation

We used a different brand of heat-recovery ventilator this time. As the industry has advanced in recent years, there are now many more ventilation options and features to consider. (So many that I wrote a book on the subject—*Understanding Ventilation*.) The ventilator sits above the hallway ceiling. Filtration options have also improved considerably, so we were able to filter the incoming air through a medium-efficiency particulate filter and activated carbon.

Stale air is pulled from all the upstairs closets, the bathroom, and the kitchen, and fresh air is blown into the living room. Fresh air is also blown into the office downstairs, and stale air is pulled from the downstairs bathroom. So, the entire house is ventilated, but the upstairs air doesn't mix with the downstairs air. The upstairs bathroom is fitted with a motorized grille and a timer control. When the timer is activated, the grille opens, and the HRV bumps up to high speed to air out the bathroom quickly—so we don't need a separate exhaust fan in bathroom. We did put a powerful exhaust fan downstairs, but only for occasional use—when the lower level needs to be aired out quickly.

Rather than cracking open a window to relieve the depressurization caused by the kitchen range-hood fan, we installed a motorized make-up air inlet under the stove. When the range hood is turned on and blowing air outdoors, the inlet opens automatically to allow fresh air to enter. We put another inlet near the clothes dryer that we open manually to relieve the depressurization caused by the dryer.

Summary

Designing a house as a system is important for several reasons—comfort, energy-efficiency, quietness, and health. It doesn't require a great deal of thought, but it does require some preplanning, and a little extra work on the part of the builder. We feel it's well worth it. Because of its energy-efficiency features, the house has been inspected and certified by the Energy Rated Homes of Indiana program, which makes it easier to qualify for a mortgage. Similar programs are available in many parts of the country, and most can be found through **RESNET**.

Our new house looks somewhat different when compared to most new houses being built today. After all, most houses aren't built on concrete columns, in the middle of the woods, with no lawn. But that wasn't a health decision. The design was based on what we wanted our house to look like. You can build a healthy house to look like just about anything. It can be large or small, Colonial or French provincial, brown or blue—whatever you want. Just select the materials and put them together in a way that will enhance your health, not compromise it.

A Generic Healthy House

Not everyone is chemically sensitive—in fact, many people seem to tolerate small levels of indoor air pollution just fine. While it would undoubtedly be better for them to breath the cleanest air possible at all times, that isn't always practical—or realistic. The following construction tips will result in a house with quite good indoor air quality—perhaps not good enough for sensitive people—but definitely above average.

If you have young children, or are planning a family, keep in mind the fact the young bodies are more sensitive to air pollution than healthy adults. Therefore, while you may tolerate a certain degree of impure air, your offspring may not. So, you may wish to build as healthy a house as you can afford.

Radon Control

The only known health effect of radon is lung cancer—a diagnosis everyone would like to avoid. There isn't an easy way to predict if a house will have a radon problem until it's actually tested, and testing can't be done until after the house is completed. Therefore, some type of radon control is recommended in all new construction. For example, a 4" radon-removal tube can be placed under a basement or house slab and stubbed up through the attic. Once the house is completed, if elevated radon levels are measured, the system can be activated by attaching a suction fan to the tube to pull radon from beneath the slab and blow it outdoors. This type of system works by depressurizing the area under the slab and directing the radon into the atmosphere, rather than allowing it to get into the house. If testing reveals that the house has low radon levels, the small cost of the removal tube can be considered fairly cheap insurance. So, I generally recommend installing a radon-removal tube in all new houses. The **EPA** has a number of construction-oriented booklets dealing with radon control.

Heating and Cooling Systems

Backdrafting and spillage are responsible for a variety of combustion gases entering the living space, including carbon monoxide. An easy way to avoid backdrafting and spillage is to use electric space heating and water heating systems. Both heat pumps and resistance heaters qualify. Solar heating is also a healthy choice. If there are no combustion sources in the house, there will be no combustion by-products.

Another choice is to use sealed-combustion appliances. Some of the new high efficiency gas furnaces draw all of their combustion air through a plastic pipe from the outdoors into a totally sealed combustion chamber, then the exhaust gases are directed outdoors with the help of a fan. Water heaters and gas fireplaces are also available with sealed-combustion chambers. Some models are not completely sealed. Instead, they use induced-draft fans that are capable of overcoming any house depressurization and blowing the combustion gases outdoors. Some of these options may not be suitable for very sensitive individuals, but they are healthy choices for most people. So, in a generic healthy house, I recommend using any heating system that won't result in backdrafting or spillage.

I also recommend sealing the ducts in all forced-air heating, cooling, or ventilation systems. This improves efficiency, and minimizes several health-related problems.

Floor Coverings

Although some choices are better than others, virtually any flooring material is better than synthetic wall-to-wall carpeting. When new, carpeting can release perhaps 100 different VOCs (Volatile Organic Compounds) into the air. Some are carcinogens, some are known to cause birth defects, and others are mutagens. A great deal of the outgassing lessens with time so, if you roll new carpeting out in an uncontaminated garage and let it outgas for a couple of months before bringing it indoors, the occupants will be exposed to much lower levels. Installing carpet with tackless strips rather than a highly volatile adhesive will also reduce exposure to VOCs.

Once carpeting starts to age, VOCs may no longer be much of a problem, but that's when biological pollutants proliferate. Tens-of-millions of microorganisms could easily be living in every square foot of carpeting. Included in this sea of life are mold, mildew and dust mites—all quite common allergens. Conventional portable vacuum cleaners have such inefficient filters that they simply blow the fine dust and microbes back into the room. A central system with an outdoor exhaust is more powerful and it won't recontaminate the house.

Alternatives include natural-fiber carpets such as wool and cotton—but they can be expensive, sometimes well over $100 per yard. At those prices, a homeowner can have a beautiful solid-wood floor accented with Oriental or native-American rugs. Removable, natural-fiber rugs are easier to keep clean, and they often last longer than carpet. Unfinished grade-B oak flooring, pine flooring, and seconds of ceramic tile can often be more economical. Even after adding installation costs, they are often in the same price range as a medium priced carpeting—and they are far healthier.

For a generic healthy house, my best recommendation is—anything but carpet.

Paint, Clear finishes, Adhesives

"Wet" products, such as paints, varnishes, adhesives, and caulking often outgas a variety of VOCs, but they tend to be fairly inert once they are cured. Water-based finishes usually contain fewer VOCs than solvent-based finishes so, in general, they are better choices. Volatile materials should only be used in an occupied residence when the outdoor temperature is such that all of the windows can be left open for several days. This is especially important if there are children in the household, because their bodies cannot process toxic odors as easily as adults.

There are a number of alternative paints and clear finishes on the market today that are suitable for many hypersensitive people. While these products also require a certain outgassing period, they represent the next step if someone desires a more benign finish. My generic recommendation is to avoid solvent-based products and use only water-based products.

Cabinets

Kitchen and bathroom cabinets are almost always made with unhealthy materials such as veneered plywood and particle board that are loaded with a potent urea-formaldehyde glue. Plus, most cabinets are coated with an even more potent formaldehyde-emitting clear finish. While hypersensitive people must definitely avoid all exposures to formaldehyde, healthy people should not be exposed to very much of it either. Formaldehyde is a suspected carcinogen, and it's probably been at least partially responsible for most hypersensitive people becoming sensitive. Construction-grade plywood and oriented-strand board use a less noxious phenol-formaldehyde resin and are usually fine for use by the general population—but they aren't very good-looking, so they don't lend themselves to building attractive cabinets.

To get low-outgassing cabinets, there are only a few alternatives. First of all, there are European-style steel cabinets. And, there are also a few companies that make low-formaldehyde cabinets. Or you might opt for cabinets with plastic laminate on all surfaces. Often, the best solution is to have cabinets custom made without manufactured wood products.

By letting conventional cabinets air out in an uncontaminated garage or warehouse for a few months (be sure to remove them from their cartons and open them up), you can minimize your exposure to the volatile finish. Unfortunately, while the finish will outgas relatively quickly (usually within 6 months), the particle board or plywood can emit formaldehyde for several years. Some custom-cabinet shops are willing to use an alternative finish which contains no formaldehyde. There are also some formaldehyde-free products now available that a few cabinet shops are starting to use in their casework. These are much healthier choices than the standard products, but you may have trouble finding low-formeldehyde products locally with an attractive wood veneer. Because low-tox cabinet alternatives can be expensive, this is an area that must be addressed early in the design process to insure that a project remains within the budget. My generic recommendation is to go with one of the less-toxic choices.

Plastic-laminate countertops usually have a urea-formaldehyde-containing particle-board substrate. If you are interested in a laminate countertop, I recommend covering all edges and the bottom with laminate—as well as the top. This will result in reduced emissions because the laminate acts as a diffusion retarder. It's also be a good idea to use a water-based contact adhesive, and to substitute construction-grade plywood for the particle board or, better yet, use a formaldehyde-free product.

To further avoid formaldehyde, don't use particle-board underlayment on the floor, medium-density fiberboard closet shelving, or $^{1}/_{4}$" wall paneling.

Ventilation

Finally, some type of general ventilation system should be installed. Many builders are becoming familiar with heat-recovery ventilators, but they can be expensive. They are probably only cost effective in cold climates. Because there are so many different approaches, and design considerations, it's difficult to recommend one particular strategy. Instead, I suggest installing whatever type of ventilation system is appropriate for your budget, climate, and house design—just don't ignore the issue.

Summary

There are certainly many more things you can do to build an even healthier house than the generic suggestions I've just made. For example, with water-based paints, you might opt for a *zero*-VOC paint, rather than a *low*-VOC paint. But the above suggestions will result in the most improvement in indoor air quality per dollar spent, so you should plan for them first.

There's definitely a trend afoot toward building healthier houses. Some of the changes I've suggested for this generic healthy house do have a higher up-front cost than their unhealthy counterparts. But when figured into the total cost of a house, they generally don't result in a significant overall increase in the mortgage payment. And, yet, they will definitely result in improved indoor air quality.

A generic healthy house may not be healthy enough for sensitive people but, as I said, not all of us have their requirements. Of course, many healthy people go out of their way to eat organically raised food, and they often want to build houses that are as healthy as possible. I think those are wise decisions.

Afterword

If all houses were healthy, this book wouldn't be necessary. But it is necessary—and there are several reasons why. While some Federal agencies have done an outstanding job of addressing indoor-air-quality issues, there is still a great deal of governmental foot dragging. There are manufacturers who offer healthier products, but many companies still produce unhealthy materials formulated with little concern for outgassing. Polls show consumers are interested in healthy food, healthy houses, and good health in general, but many people continue to purchase unhealthy items because they are cheaper, readily available, in style—or because they don't realize how unhealthy some products actually are.

We have the National Transportation Safety Board to insure the safety of air travel, the Food and Drug Administration to protect us from dangerous prescription drugs, and Underwriters Laboratories to evaluate electrical devices. Yet, people continue to design, build, and live in houses that are unhealthy.

This book is designed to change all that by providing designers, builders, and homeowners with the knowledge necessary to create healthy houses. Perhaps, someday, the concept of a healthy house will become obsolete—and all houses will be healthy ones.

Appendix I: Organizations and Suppliers

The suppliers and organizations that are listed below have all been referenced in one or more places in the text as offering healthier materials or information. Many of the manufacturers provide a variety of products, some of which are healthier than others. For example, a paint company may offer both low-tox, zero-VOC paints as well as less-healthy, solvent-based paints. So, just because a company is listed, doesn't mean that everything they handle is healthy. Some suppliers sell direct to builders and consumers, but many of the companies listed are manufactures who only sell through regional or local distributors.

3M
3M Center
St. Paul, MN 55144
651-733-1110
www.3m.com
Contractor's tape, stripper, filters.

Acorn Engineering Co.
15125 Proctor Ave.
City of Industry, CA 91744
626-336-4561
800-591-9050
www.neo-metro.com

ACTS
Monona Rossol
181 Thompson St. #23
New York, NY 10012-2586
212-777-0062
www.caseweb.com/ACTS
Publications and consulting.

Ado Products
P.O. Box 236
Rogers, MN 55374
763-428-7802
800-666-8191
www.adoproducts.com
Insulation baffles.

Advanced Chemical Sensor, Inc.
3201 North Dixie Highway
Boca Raton, FL 33431
561-338-3116

888-338-4230
Formaldehyde sensors.

Advanced Energy
909 Capability Dr.
Suite 2100
Raleigh, NC 27606
919-857-9000
www.advancedenergy.org
Publications, training, consulting.

Advanced Foil Systems
820 S. Rockefeller Ave.
Suite A
Ontario, CA 91761
909-390-5125
800-421-5947
www.afs-foil.com
Builders foil.

Aero Hygenics, Inc.
5247 San Fernando Rd. West
Los Angeles, CA 90039
818-246-4006
800-346-4642
www.aeroscopic.com
Air filters.

Aerotech Laboratories, Inc.
2020 W. Lone Cactus Dr.
Phoenix, AZ 85027
623-780-4800
800-651-4802
www.aerotechlabs.com
Testing.

AFM
350 West Ash St.
Suite 700
San Diego, CA 92101
619-239-0321
800-239-0321
www.afmsafecoat.com
Low-tox paints, finishes.

Agrevo USA

Div. of Aventis
Little Falls Center One
2711 Centerville Rd.
Wilmington, DE 19808
302-892-3000
800-843-1702
www.agrevo.com
Ficam-W pesticide.

AIM Safe-Air Products
1624 Headway Cir.
Austin, TX 78754
512-832-5665
800-275-4246
www.aimsafety.com
CO and gas alarms.

Aireox Research Corp.
P.O. Box 8523
Riverside, CA 92515
909-689-2781
www.aireox.com
Air filters.

Air For Life, Inc.
2901 SE 4th St.
Minneapolis, MN 55414
612-331-8286
877-331-8286
www.airforlife.com
HRVs.

Airguide
Div. of Johnson Worldwide Assoc.
1326 Willow Rd.
Sturtevant, WI 53177
262-884-1500
800-493-6686
www.jwa.com
Hygrometers.

Air Kontrol
P.O. Box 597
221 Pearson St.
Batesville, MS 38606
601-563-4736

www.airkontrol.com
Air filters.

Air-Krete Inc.
P.O. Box 380
Weedsport, NY 13166-0380
315-834-6609
www.airkrete.com
Low-tox insulation.

Air Quality Sciences, Inc.
1337 Capital Cir.
Atlanta, GA 30067
770-933-0638
800-789-0419
www.aqs.com
Air-quality testing.

Alcoa Building Products
1501 Michigan St.
Sidney, OH 45365
800-962-6973
www.alcoahomes.com
Metal siding.

Alenco Windows
Div. Reliant Building Products
319 Dividend Dr.
Peachtree City, GA 30269
800-476-8037
Aluminum windows.

Allergy Relief Shop, Inc.
3360 Andersonville Hwy.
Andersonville, TN 37705
423-494-4100
800-626-2810
www.allergyreliefshop.com
Air and water filters

Allermed
31 Steel Rd.
Wylie, TX 75098
972-442-4898
www.allermedcleanair.com
Air-filtration systems.

Allerx
P.O. Box 1119
Royse City, TX 75189
972-635-2580
800-447-1100
www.allerx.com
Portable air filters.

Allied Studco
2525 North 27th Avenue
Phoenix, Arizona 85009-1710
800-877-8823
602-272-6606
www.studco.com
Steel framing.

Allmand Bros. Inc.
P.O. Box 888
Holdrege, NE 68949
308-995-4495
800-562-1373
www.allmand.com
Portable contractor's heaters.

Alpine Engineered Products, Inc.
P.O. Box 2225
Pompano Beach, FL 33061
954-781-3333
800-735-8055
www.alpeng.com
Steel Framing.

Alsco
Div. Owens Corning Metal Systems
P.O. Box 61
Roxboro, NC 27573
336-599-2151
800-521-2930
www.alsco.com
Metal siding.

Alternative Timber Structures
1054 Rammell Mountain Rd.
Tetonia, ID 83452
208-456-2711

Solid-wood interior doors.

Alumax Bath Enclosures
1617 N. Washington
Magnolia, AR 71753
870-234-4260
800-643-1514
www.alumaxbath.com
Frameless glass shower doors.

Alumet Building Products, Inc.
227 S. Town East Blvd.
Mesquite, TX 75149
972-285-8811
Aluminum screen rooms.

Amana Heating and Air Conditioning
1810 Wilson Pkwy.
Fayetteville, TN 37334
877-254-4729
www.amana-hac.com
Sealed-combustion furnaces.

Amarant Wood Products
P.O. Box 1008
Arcada, CA 95518
707-822-4849
800-423-2205
Redwood shingles.

American Academy of Allergy, Asthma, and Immunology
611 E. Wells St.
Milwaukee, WI 53202
414-272-6071
800-822-2762
www.aaaai.org
Physician organization.

American Academy of Environmental Medicine
7701 E. Kellog
Suite 625
Wichita, KS 67207
316-684-5500
www.aaem.com
Physicians specializing in MCS.

American Academy of Otolaryngic Allergy
1990 M Street, NW
Suite 680
Washington, DC 20036
202-955-5016
www.allergy-ENT.com
Physician organization

American Aldes Corp.
4537 Northgate Ct.
Sarasota, FL 34234-2124
941-351-3441
800-255-7749
www.americanaldes.com
Full line of ventilation equipment.

American Association for Laboratory Accreditation
5301 Buckeystown Pike
Suite 350
Frederick, MD 21704
301-644-3248
www.a2la.org
Listing of lead-testing labs.

American College of Allergy, Asthma, and Immunology
85 West Algonquin Rd. #550
Arlington Heights, IL 60005
847-427-1200
800-842-7777
www.allergy.mcg.edu
Physician organization.

American ConForm Industries
1820 S. Santa Fe St.
Santa Ana, CA 92705
714-662-1100
800-CONFORM
www.smartblock.com
Foam foundation forms.

American Environmental Health Foundation
8345 Walnut Hill Ln.
Suite 225
Dallas, TX 75231
214-361-9515
800-428-2343

www.aehf.com
Air & water filters.

American Industrial Hygiene Assn.
2700 Prosperity Ave.
Suite 250
Fairfax, VA 22031
703-849-8888
www.aiha.org
Listing of lead-testing labs.

American Iron and Steel Institute
848 High St.
Chestertown, MD 21620
800-277-3850
www.steel.org
Steel trade association.

American Olean Tile Co.
Div. of Dal-Tile
7834 CF Hawn Freeway
Dallas, TX 75217
888-AOT-TILE
www.aotile.com
Ceramic tile.

American PIE
124 High St.
P.O. Box 340
S. Glastonbury, CT 06073-0340
800-320-2743
www.AmericanPIE.org
Environmental Information.

American Polysteel Forms
5150-F Edith NE
Albuquerque, NM 87107
505-345-8153
800-977-3676
www.polysteel.com
Foam foundation forms.

American Standard Inc.
One Centennial Ave.
Piscataway, NJ 08855
732-980-3000

800-223-0068
www.americanstandard-us.com
Toilets with insulated tanks.

American Water Heater Co.
P.O. Box 4056
Johnson City, TN 37602
423-283-8000
800-999-9515
www.americanwaterheater.com
Outdoor water heaters.

Ampco
P.O. Box 608
Rosedale, MS 38769
662-759-3521
800-647-8268
Metal cabinetry.

Anderson Laboratories, Inc.
Box 323
West Hartford, VT 05084
802-295-7344
www.andersonlaboratories.com
Carpet and product testing.

Apollo HydroHeat and Cooling
Div. of State Industries
500 Lindale Pkwy.
Ashland City, TN 37015
615-792-4371
800-365-5793
www.stateind.com
Combo furnaces.

Aquafin, Inc.
P.O. Box 1440
Columbia, MD 21044
410-964-1410
888-482-6339
www.aquafin.net
Foundation coatings.

Aqua Mix
P.O. Box 4127
Santa Fe Springs, CA 90670

562-946-6877
800-366-6877
www.aquamix.com
Concrete and grout sealer.

Aquathin Corp.
950 S. Andrews Ave.
Pompano Beach, FL 33069
954-781-7777
800-462-7634
www.aquathin.com
Water treatment.

Architectural Forest Enterprises
3775 Bayshore Blvd.
Brisbane, CA 94005
415-467-4800
800-4-VENEER
www.ecoforest.com
Veneered wood products.

Arctic Metal Products Corp.
507 Wortman Ave.
Brooklyn, NY 11208
718-257-5277
Metal cabinetry. (East-coast only)

Ark Seal International
2190 S. Kalamanth St.
Denver, CO 80223
303-934-7772
800-525-8992
www.arkseal.com
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see **ACTS**

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www.ecobuildings.net
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Asko, Inc.
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Richardson, TX 75081
972-644-8595
www.askousa.com
Dishwashers and clothes dryers.

Asthma and Allergy Foundation of America
1233 20th St. NW, #402
Washington, DC 20036
202-466-7643
800-7-ASTHMA
www.aafa.org
Patient support group.

Asthma and Allergy Network, Mothers of Asthmatics, Inc.
2751 Prosperity Ave.
Suite 150
Fairfax, VA 22031
703-641-9595
800-878-4403
www.aanma.org
Patient support group.

ATAS International, Inc.
6612 Snowdrift Rd.
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610-395-8445
800-468-1441
www.atas.com
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www.comclin.net/augustalumber/default.htm

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www.austinair.com
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www.southshore.com/~crbslf
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800-543-1938
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www.bbjenviro.com
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www.berkomeh.com
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800-231-8127
www.berridge.com
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Best Paint Co., Inc.
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206-783-9938
Low-tox paints.

Beyond Pesticides/National Coalition Against the Misuse of Pesticides
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Washington, DC 20003
202-543-5450
www.beyondpesticides.org
Less-toxic pesticide information.

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Bio-Integral Resource Center (BIRC)

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www.birc.org
Least-toxic pest control information.

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BIRC, see **Bio-Integral Resource Center**

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www.cmhc-schl.gc.ca
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CDC, see **Centers for Disease Control**

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Center for Resourceful Building Technology (CRBT)
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406-549-7678
www.crbt.org
Publications.

Center for Universal Design
North Carolina State University

School of Design
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Raleigh, NC 27695-8613
919-515-3082
800-647-6777
www.design.ncsu.edu/cud
Information on accessible design.

Centers for Disease Control (CDC)
1600 Clifton Rd.
Atlanta, GA 30333
404-639-3311
800-311-3435
www.cdc.gov
Information about lead poisoning and other health issues.

Central Boiler, Inc.
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Valley Forge, PA 19482
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800-233-8990 (Contractors)
800-782-8777 (Consumers)
www.certainteed.com
Fiberglass insulation, Fiber cement siding.

Chemical Injury Information Network (CIIN)
P.O. Box 301
White Sulphur Springs, MT 59645
406-547-2255
www.ciin.org
MCS support group, newsletter.

Chemical Specialties, Inc.
200 E. Woodlawn Rd.
Suite 250
Charlotte, NC 28217
704-522-0825

800-421-8661
www.treatedwood.com
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ChemRex, Inc.
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www.chemrex.com
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Chem-Safe Products Co.
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Chicago Adhesive Products Co.
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630-679-9100
800-621-0220
www.chapco-adhesive.com
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Chicago Metallic Corp.
4849 S. Austin Ave.
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708-563-4600
800-323-7164
www.chicago-metallic.com
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CIIN, see **Chemical Injury Information Network**

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www.dynamicfastener.com
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www.earthtechinc.com
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www.earthweave.com
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Mebane, NC 27302
919-563-5911
800-880-6788
www.kiddesafety.com
Smoke alarms, CO detectors.

Kinetico Water Systems
3880 Pendleton Way, Suite 200
Indianapolis, IN 46226
317-542-8888
800-444-1387
www.kinetico.com
Water filters.

Kingco Adhesives
Div. of TACC
Air Station Industrial Park
Rockland, MA 02370
800-233-8171
www.taccint.com
Duct-sealing mastic.

KitchenAid
P.O. Box 218
Benton Harbor, MI 49085
800-422-1230
www.KitchenAid.com
Dishwashers

Kitchens and Baths by Don Johnson
Merchandise Mart, Suite 1375
Chicago, IL 60654
773-KITCHEN
www.healthycabinets.com
Low-tox cabinetry.

Klean Strip
Box 1879
Memphis, TN 38101
901-775-0100

800-235-3546
www.kleanstrip.com
EasyOff paint stripper.

Knauf Fiber Glass
One Knauf Dr.
Shelbyville, IN 46176
317-398-4434
800-825-4434
www.knauffiberglass.com
Fiberglass insulation.

Robert Kobet, AIA
Hanson Design Group
2333 E. Carson St.
Pittsburgh, PA 15203
412-488-8840
www.hansondesigngroup.com
Design and consulting.

Koch Waterproofing
800 Irving Wick Dr.
Heath, OH 43056
740-788-8847
800-DRY-BSMT
www.kochwaterproofing.com
Foundation drainage boards.

Koetter Woodworking, Inc.
533 Louis Smith Rd.
Borden, IN 47106
812-923-8875
www.koetterwoodworking.com
Interior hardwood doors.

Kohler Co.
444 Highland Dr.
Kohler, WI 53044
920-457-4441
800-4-KOHLER
www.kohlerco.com
Toilets with insulated tanks.

K-Products
724 Commerce St.
Aberdeen, SD 57401

605-226-0919
800-843-1660
Receptacle cover plates.

Mary Kraus
Kraus-Fitch Architects, Inc.
110 Pulpit Hill Rd.
Amherst, MA 01002
413-549-5799
www.krausfitch.com
Design and consulting

Kurfees Coatings, Inc.
Div. of Progress Paint
201 E. Market St.
Louisville, KY 40202
502-587-8685
800-626-6407
www.progresspaint.com
Zero-VOC paints.

Jim LaRue
The HouseMender, Inc.
15818 Chadbourne Rd.
Shaker Heights, OH 44120
216-991-1088
Home evaluations.

Laticrete International Inc.
1 Laticrete Park N.
Bethany, CT 06524
203-393-0010
800-243-4788
www.laticrete.com
Thin-set mortar.

Lead Listing
c/o QuanTech
1815 Fort Myer Dr.
Suite 908
Arlington, VA 22209
703-312-7837
888-532-3547
www.leadlisting.org
List of lead inspectors.

Leahy-Wolf
1951 N. 25th Ave.
Franklin Park, IL 60131
847-455-5710
888-873-5327
Concrete form-release oil.

Lee Rowan
900 S. Highway Dr.
Fenton, MO 63026
636-343-0700
800-325-6150
www.leerowan.com
Metal wire closet organizers.

Lennox Industries
2100 Lake Park Blvd.
Richardson, TX 75080
800-9-LENNOX
www.lennox.com
Sealed-combustion furnaces.

Less EMF, Inc.
26 Valley View Ln.
Ghent, NY 12075
518-392-1946
888-LESS-EMF
www.lessemf.com
Electromagnetic field reduction.

Lipidex Corp.
50 Franklin Ter.
Duxbury, MA 02332
781-834-1600
www.aircycler.com
Fan controller.

The Living Source
P.O. Box 20155
Waco, TX 76702
254-776-4878
800-662-8787
www.livingsource.com
Air & water filters.

Livos Phytochemistry, Inc.

P.O. Box 1740
Mashpee, MA 02649
508-477-7955
www.livos.com
Natural paints.

Loewen Windows
1228 American Way, Suite 100
Libertyville, IL 60048
847-362-1600
800-245-2295
www.loewen.com
Wood windows.

Lomanco, Inc.
P.O. Box 519
2101 West Main St.
Jacksonville, AR 72076
501-982-6511
800-643-5596
www.lomanco.com
Roof ventilators.

LongLac Wood Industries, Inc.
2000 Argentina Rd.
Plaza One, Suite 200
Mississauga, ON, Canada L5N 1P7
905-542-2700
888-566-4522
www.longlacwood.com
Low-emission wood products.

Louisiana-Pacific
PO Box 16657
Duluth, MN 55816-9930
800-580-4296
www.smartguard.lpcorp.com
SmartGuard wood treatment.

Low Energy Systems Supply Co., LLC
W. 1330 Happy Hollow Rd.
Campbellsport, WI 53010
920-533-8690
www.lessco-airtight.com
Lessco electrical box holders.

Ludlow Coated Products
P.O. Box 10
Adrian, MI 49221
517-263-8881
800-345-8881
www.simplex-products.com
Thermo-ply

Ludowici Roof Tile
Div. of Certainteed
4757 Tile Plant Rd.
P.O. Box 69
New Lexington, OH 43764
740-342-1995
800-945-8453
www.ludowici.com
Roof tiles.

Lumiram Electric Corp.
179 Westmorland Ave.
White Plains, NY 10606
914-328-0533
800-354-5596
www.lumiram.com
Full-spectrum lighting.

Macklanburg-Duncan
P.O. Box 25188
Oklahoma City, OK 73125
405-528-4411
800-654-8454
www.mdteam.com
Aerosol foam insulation.

Madawaska Doors, Inc.
P.O. Box 938
Barry's Bay, ON, Canada K0J 1B0
613-756-2641
800-263-2358
www.madawaska-doors.com
Solid-wood doors.

Magnetic Sciences International
367 Arlington St.
Acton, MA 01720
978-266-9906

800-749–9873
www.magneticsciences.com/store
Publications, gaussmeters.

Masonite Corp.
One S. Wacker Dr.
Suite 3600
Chicago, IL 60606
312-750-0900
800-323-4591
www.masonite.com
Hardboard.

Masterchem Industries, Inc.
P.O. Box 368
Barnhart, MO 63012-0368
636-942-2510
800-325-3552
www.kilz.com
KILZ primer sealer.

Master Home Environmentalist Program
American Lung Association of Washington
2625 Third Ave.
Seattle, WA 98121
206-441-5100
800-732-9339 (WA only)
www.alaw.org
Training and publications.

MaxiTile
849 E. Sandhill Ave.
Carson, CA 90746
310-217-0316
800-338-8453
Fibrous cement siding.

Maxxon Corp.
920 Hamel Rd.
Hamel, MN 55340
763-478-9600
800-356-7887
www.maxxon.com
Underlayment, radiant floors.

J. May Home Inspections, Inc.

Jeffrey May
1522 Cambridge St.
Cambridge, MA 02139
617-354-0152
www.jmhi.com
Home inspections, consulting.

McCormick Paints
2355 Lewis Ave.
Rockville, MD 20851
301-770-3235
877-PAINT-55
www.mccormickpaints.com
Zero-VOC paint.

McElroy Metal, Inc.
P.O. Box 1148
Shreveport, LA 71163
318-747-8000
800-950-6531
www.mcelroymetal.com
Metal roofing.

McGill AirSeal Corp.
2400 Fairwood Ave.
Columbus, OH 43207
614-443-5520
800-624-5535
www.mcgillairseal.com
Duct-sealing mastic.

Robert K. McLellan, MD, MPH
Medical Director
Center for Occupational and Environmental Health
Exeter Hospital
P.O. Box 1050
11 Court St.
Exeter, NH 03833
603-778-6510
www.foreveryday.com
Physician.

MCS Referral & Resources
508 Westgate Rd.
Baltimore, MD 21229
410-362-6400

www.mcsrr.org
Information about MCS.

W.R. Meadows, Inc.
P.O. Box 338
Hampshire, IL 60140-0338
847-683-4500
800-342-5976
www.wrmeadows.com
Form-release agents.

Meadowood Industries, Inc
P.O. Box 257
Belmont, CA 94002
650-637-0539
www.meadowoodindustries.com
Rye-straw board.

Merida Meridian
643 Summer Street
Boston, MA 02210
617-464-5400
800-345-2200
Natural-fiber carpet.

Metal Building Components, Inc.
14031 West Hardy St.
P.O. Box 38217
Houston, TX 77238
281-445-8555
www.mbci.com
Metal roofing.

Metal Sales Manufacturing Corp.
7800 St. Rd. 60
Sellersburg, IN 47172
812-246-1935
800-999-7777
www.mtlsales.com
Metal roofing.

Met-Tile, Inc.
P.O. Box 4268
Ontario, CA 91761
909-947-0311
800-899-0311

www.met-tile.com
Metal roofing.

Michigan Maple Block Co.
P.O Box 245
Petosky, MI 49770
231-347-4170
www.mapleblock.com
Hardwood countertops

Midwest Veneer & Pressing, Inc.
5201 260th St.
Wyoming, MN 55092
651-462-4389
www.midwestveneer.com
Custom veneered products.

Miele, Inc.
9 Independence Way
Princeton, NJ 08540
609-419-9898
800-843-7231
www.mieleusa.com
Portable vacuum cleaners.

Miles Industries, Inc.
829 W. 3rd St.
North Vancouver, BC, Canada V7P 3K7
604-984-3496
800-468-2567
www.valorflame.com
Direct-vent fireplaces.

Norma L. Miller
5321 Wooten Dr.
Fort Worth, TX 76133-1932
817-292-2022
Information on less toxic schools.

Miller Paint Co.
12812 NE Whitaker Way
Portland, OR 97230
503-255-0190
www.millerpaint.com
Low biocide paint.

Mitsubishi Electric
HVAC Division
3100 Avalon Ridge Pl.
Suite 200
Norcross, GA 30071
770-613-5840
800-433-4822
www.mrslim.com
HRVs, air conditioners.

Moen, Inc.
25300 Al Moen Dr.
North Olmstead, OH 44070
440-962-2000
800-289-6636
www.moen.com
Water filters.

Mon-Eco Industries, Inc.
5 Joanna Ct.
East Brunswick, NJ 08816
732-257-7942
800-899-6326
Duct-sealing mastic.

MonierLifetile
P.O. Box 19792
Irvine, CA 92623
949-756-1605
800-571-8453
www.monierlifetile.com
Roof tiles.

Monitor Products, Inc.
P.O.Box 3408
Princeton, NJ 08543
732-329-0900
800-524-1102
www.monitorproducts.com
Space heaters.

Moultrie Manufacturing Co.
1403 GA Hwy. 133 S.
Moultrie, GA 31768
912-985-1312
800-841-8674

www.moultriemfgco.com
Aluminum columns.

Mohawk Industries
Image Carpets
P.O. Box 12069
160 S. Industrial Blvd.
Calhoun, GA 30703
800-2-MOHAWK
www.mohawkcarpet.com
Carpet from recycled PET bottles.

M.T.I. Industries, Inc.
31632 N. Ellis Dr. #301
Volo, IL 60073
847-546-9001
800-383-0269
www.safe-t-alert.com
Carbon-monoxide alarms.

Multi-Pure Corp.
7251 Cathedral Rock Dr.
Las Vegas, NV 89128
702-360-8880
800-622-9206
www.multipure.com
Water filters.

Munksgaard International Publishers Ltd.
Commerce Place
350 Main St.
Malden, MA 02148
781-388-8273
www.munksgaard.dk
Publications

Murco Wall Products, Inc.
300 NE 21st St.
Ft. Worth, TX 76106
817-626-1987
800-446-7124
www.murcowall.com
Paint and drywall compound.

National Antimicrobial Information Network (NAIN)
Oregon State University

333 Weniger Hall
Corvallis, OR 97331-6502
800-447-6349
www.ace.orst.edu/info/nain
Information on antimicrobials.

National Association of Home Builders (NAHB)
1201 15th St. NW
Washington, DC 20005
202-822-0200
800-368-5242
www.nahb.com
Builders' trade group.

National Blind & Wallpaper Co.
200 Galleria Office Centre
4th Floor
Southfield, MI 48034
215-351-8703
800-260-1987
www.nbwf.com
Metal mini blinds.

National Center for Environmental Health Strategies, Inc. (NCEHS)
Mary Lamielle
1100 Rural Ave.
Voorhees, NJ 08043
856-429-5358
www.ncehs.org
MCS advocacy organization.

National Electromagnetic Field Testing Association (NEFTA)
628-B Library Place
Evanston, IL 60201-5534
847-475-3696
www.theramp.net/nefta
Listing of professionals.

National Fenestration Rating Council (NFRC)
1300 Spring St.
Suite 500
Silver Spring, MD 20910
301-589-6372
www.nfrc.org
Publications.

National Home Mortage Co.
4407 Swinson Rd.
Rhodes, MI 48652
517-689-6369
www.mcsrelief.com
Lending for the chemically sensitive.

National HVAC Products
5 Sandhill Ct. Unit C
Brampton, ON, Canada L6T 5J5
905-790-8667
www.airex.on.ca
Ventilation equipment.

National Lead Assessment and Abatement Council
P.O. Box 535
Olney, MD 20832
800-590-6522
www.leadlisting.org
Trade Organization.

National Lead Information Center
EPA Office of Pollution Preventiuon and Toxics
800-424-LEAD
www.epa.gov/lead/nlic.htm
Lead information.

National Oak Flooring Manufacturers Assn.
P.O. Box 3009
Memphis, TN 38173
901-526-5016
www.nofma.org
Wood flooring literature

National Pesticide Telecommunications Network (NPTN)
Oregon State University
333 Weniger Hall
Corvallis, OR 97331-6502
800-858-7378
www.ace.orst.edu/info/nptn
Information on pesticides.

National Sanitation Foundation (NSF)
P.O. Box 130140
Ann Arbor, MI 48113
734-769-8010

800-NSF-MARK
www.nsf.org
Certification of water systems.

National Technical Information Service (NTIS)
5285 Port Royal Rd.
Springfield VA 22161
703-605-6000
800-553-6847
www.ntis.gov
Technical publications.

National Testing Laboratories
6555 Wilson Mills Rd.
Suite 102
Cleveland, OH 44143
440-449-2525
800-458-3330
www.watercheck.com
Water testing.

National Voluntary Laboratory Accreditation Program
National Institute of Standards and Technology
100 Bureau Dr.
Stop 2140
Gaithersburg, MD 20899-2140
301-975-4016
http://ts.nist.gov/nvlap
List of asbestos testing labs.

National Wood Flooring Assn.
16388 Westwoods Business Park
Ellisville, MO 63021
636-391-5161
800-422-4556 (US)
800-848-8824 (Canada)
www.woodfloors.org
Wood flooring literature.

National Wood Window & Door Association
1400 E. Touhy Ave.
Suite 470
Des Plaines, IL 60018
847-299-5200
800-223-2301
www.nwwda.org

Trade organization.

Natural Fibre
PO Box 165
Minneapolis, KS 67467
785-827-7270
Wheat-fiber board.

Natural Home by Natürlich
P.O. Box 1677
Sebastapol, CA 95473
707-824-0914
www.naturalhomeproducts.com
Natural-fiber carpet, pads, cork, linoleum.

Nature's Living Products
P.O. Box 428758
Cincinnati, OH 45242
513-791-7295
Healthy products retailer.

NCAMP, see **Beyond Pesticides/National Coalition Against the Misuse of Pesticides**

NCEHS, see **National Center for Environmental Health Strategies**

N.E.E.D.S.
6010 Drott Dr.
East Syracuse, NY 13057
800-634-1380
www.needs.com
Filters, low-tox paints, meters.

Neff Kitchen Manufacturers Ltd.
6 Melanie Dr.
Brampton, ON Canada L6T 4K9
905-791-7770
800-268-4527
www.neffweb.com
Low-tox cabinetry.

Neuert Electric & Electromagnetic Services
P.O. Box 8308
Santa Rosa, CA 95407
707-578-1645
800-638-3781
Consulting and mitigating.

Nevamar
8339 Telegraph Rd.
Odenton, MD 21113-1397
410-551-5000
800-638-4380
www.nevamar.com
Solid-surfacing countertops.

Newtron Products Co.
P.O. Box 27175
Cincinnati, OH 45227
513-561-7373
800-543-9149
www.newtronproducts.com
Electrostatic air filters.

Nigra Enterprises
5699 Kanan Rd.
Agoura, CA 91301
818-889-6877
Air and water filters.

Nilfisk-Advance America, Inc.
300 Technology Drive
Malvern, PA 19355
610-647-6420
800-645-3475
www.nilfisk-advance.com
Portable vacuum cleaners.

Nisus Corp.
215 Dunavant Dr.
Rockford, TN 37853
865-577-6119
800-264-0870
www.nisuscorp.com
Boron-based termiticides.

Nord
Div. Jeld-Wen
300 W. Marine View Dr.
Everett, WA 98201
425-259-9292
800-900-6673
www.jeld-wen.com

Doors.

W.F. Norman Corp.
P.O. Box 323
Nevada, MO 64772
417-667-5552
800-641-4038
Metal ceilings, roofing, siding.

North American Detectors
100 Tempo Ave.
Toronto, ON, Canada M2H 3S5
416-493-9168
800-387-4219
www.nadi.com
Gas detectors and alarms.

NTIS, see **National Technical Information Service**

Nu-Fab Building Products Ltd.
701 45th Street West
Saskatoon, SK, Canada S7L 5W5
306-244-7119
www.nufab.com
Foam-core panels

NuHeat Industries Ltd.
8145 130th St., Unit 9
Surrey, BC, Canada V3W 7X4
604-599-4052
800-778-9276
www.nuheat.com
Radiant heating.

Nutech Energy Systems, Inc.
511 McCormick Blvd.
London, ON Canada N5W 4C8
519-457-1904
800-494-4185
www.lifebreath.com
Ventilation equipment.

Nutone
Madison and Red Banks Roads
Cincinnati, OH 45227-1599
513-527-5100

800-543-8687
www.nutone.com
Ventilation equipment, central vacuums.

N-Viro Products Ltd.
610 Walnut Ave.
Bohemia, NY 11716
631-567-2628
Nematodes for termite treatment.

Nycon, Inc.
101 Cross St.
Westerly, RI 02891
401-596-3955
800-456-9266
www.nycon.com
Concrete reinforcing.

Oatey Co.
4700 West 160th St.
Cleveland, OH 44135
216-267-7100
800-321-9532
www.oatey.com
Plastic pipe cleaners and glue.

Kathleen O'Brien
O'Brien & Company, Inc.
PO Box 10705
Bainbridge Island, WA 98110
206-842-8995
www.obrienandco.com
Consulting.

Mary Oetzel
Environmental Education and Health Services, Inc.
P.O. Box 92004
Austin, Texas 78709-2004
512-288-2369
Consulting.

Old-Fashioned Milk Paint Co.
436 Main St.
Groton, MA 01450
978-448-6336
www.milkpaint.com

Casein paint.

OSI Sealants
7405 Production Dr.
Mentor, OH 44060
800-321-3578
www.osisealants.com
Construction adhesive.

Osmose, Inc.
980 Ellicott St.
Buffalo, NY 14209-2398
770-233-4200
800-877-POLE
www.osmose.com
Advance Guard wood treatment.

Outwater LLC
Architectural Products
22 Passaic St.
Wood Ridge, NJ 07075
973-365-2002
800-789-5322
www.outwater.com
NuMetal laminate.

Owens-Corning Fiberglas Corp.
One Owens Corning Pkwy.
Toledo, OH 43659
419-248-8000
800-GET-PINK
www.owenscorning.com
Fiberglass insulation.

Ozark Water Service and Environmental Services
114 Spring St.
Sulphur Springs, AR 72768
501-298-3483
800-835-8908
Air & water testing & treatment.

Pace Chem Industries
3050 Westwood Dr., Unit B10
Las Vegas, NV 89109
702-369-1424
800-350-2912

Low-tox paints and sealants.

Painter's Warehouse
2190 S Bundy
West. Los Angeles, CA 90064
310-820-3336
Zero-VOC paints.

Panasonic
1 Panasonic Way
Secaucus, NJ 07094
201-348-7231
www.panasonic.com/building
Quiet exhaust fans.

Parsec
10345 Brockwood Rd.
Dallas, TX 75225
214-341-6700
800-527-3454
Reflective insulation.

Pease Industries, Inc.
7100 Dixie Highway
Fairfield, OH 45014
513-870-3600
800-88-DOORS
www.peasedoors.com
Entry doors.

Pemko, Inc.
4226 Transport St.
Ventura, CA 93003
805-642-2600
800-283-9988
www.pemko.com
Weather-stripping.

Penn Ventilator Co.
1370 Welsh Rd.
North Wales, PA 19454
215-619-8800
www.pennvent.com
Fans, speed controls.

Perfecto Mfg. Co.

20975 Creek Rd.
Noblesville, IN 46060
317-773-6627
888-773-6627
www.perfectomfg.com
Aquarium-grade caulking.

Perma-Door
631 N. First St.
P.O. Box 457
West Branch, MI 48661
517-345-5110
800-248-3600
www.perma-door.com
Steel entry doors.

PermaGrain Products, Inc.
4789 West Chester Pike
Newton Square, PA 19073
610-353-8801
877-771-6470
www.permagrain.com
Flooring.

Permatron Corp.
11400 Melrose St.
Franklin Park, IL 60131
847-451-0999
800-882-8012
www.permatron.com
Air filters.

Perstop Flooring, Inc.
P.O. Box 1775
Horsham, PA 19044
800-337-3746
www.pergo.com
Pergo wood flooring.

Pinecrest
2118 Blaisdell Ave.
Minneapolis, MN 55404
612-871-7071
800-443-5357
www.pinecrestinc.com
Ceiling tiles, doors, shutters.

Pittsburgh Corning Corp.
800 Presque Isle Dr.
Pittsburgh, PA 15239
724-327-6100
800-624-2120
www.pittsburghcorning.com
Glass block.

Planitary Solutions
2030 17th St.
Boulder, CO 80302
303-442-6228
www.planetearth.com
Various building suplies.

Polecare
Div. Chemical Specialties, Inc.
P.O. Box 1330
Harrisburg, NC 28075
800-355-6615
Ultra Rods.

PPG Architectural Finishes, Inc.
One PPG Place
Pittsburgh, PA 15272
412-434-3131
800-441-9695
www.ppgaf.com
Paints and finishes.

Porcelain Enamel Institute
4004 Hillsboro Pike
Suite 224-B
Nashville, TN 37215
615-385-5357
www.porcelainenamel.com
Trade organization.

Prairie Forest Products
200 S. Obee
Hutchinson, KS 67501
316-665-7000
Wheat-fibre board.

Primeboard, Inc.

2111 N. 3M dr.
Wahpeton, ND 58075
701-642-1152
800-943-2823
www.primeboard.com
Straw particleboard.

Professional Equipment
90 Plant Ave. Suite 3
Hauppauge, NY 11788
800-334-9291
www.professionalequipment.com
Testing devices.

PSA Design
Preston Sturgis
707 Whitlock Ave. SW
Building A-37
Marietta, Georgia 30064
770-499-8384
Design and consulting.

Purafil, Inc.
2654 Weaver Way
Doraville, GA 30340
770-662-8545
800-222-6367
www.purafil.com
Purafil adsorption material.

Pure Air Systems, Inc.
1325 Church St.
Clayton, IN 46118
317-359-4097
800-869-8025
www.pureairsystems.com
Central air-filter systems.

Pure Water Place, Inc
3347 Longview
Longmont, CO 80504
303-776-0056
888-776-0056
www.purewaterplace.cnchost.com
Water filters.

Quantum Group, Inc.
11211 Sorento Valley Rd.
San Diego, CA 92121
858-457-3048
800-432-5599
www.qginc.com
Carbon-monoxide detectors.

Radiant Electric Heat, Inc.
3695 N. 126th St., Unit N
Brookfield, WI 53005
262-783-1282
800-774-4450
www.electricheat.com
Radiant heaters.

Radio Shack
Division of Tandy Corp.
Outlets in most major cities.
www.radioshack.com
Humidity meters.

Radon Control, Inc. (RCI)
567 Industrial Dr.
Carmel, IN 46032
317-846-7486
800-523-2084
www.radoncontrol.com
Radon-mitigation equipment.

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www.raydot.com
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800-4-RAYNOR
www.raynor.com
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www.rcdmastics.com
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RectorSeal Corp.
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713-263-8001
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www.rectorseal.com
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www.reflectixinc.com
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www.natresnet.org
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www.retrotec.com
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www.reversomatic.com
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800-321-4739
Radiant floor systems.

Wrisco Industries, Inc.
6075 West 115th St.
Alsip, IL 60803
708-385-7000
800-627-2646
www.wrisco.com
Screen porches.

Xypex Chemical Corp.
13731 Mayfield Pl.
Richmond, BC, Canada V6V 2G9
604-273-5265
800-961-4477
www.xypex.com
Concrete sealers.

Young Furniture
35 River Rd.
Bow, NH 03304
603-224-8830
www.youngfurnituremfg.com
Wood kitchen cabinets.

Yunker Plastics, Inc.
251 O'Connor Dr.
Elkhorn, WI 53121
262-743-1234
800-236-3328
www.yunkerplastics.com
Plastic sheeting.

Wm. Zinsser & Co.
173 Belmont Dr.
Somerset, NJ 08875
732-469-8100
www.zinsser.com
Shellac products.

Appendix II: Selected Bibliography

Books

American Iron and Steel Institute. *Residential Steel Framing Manual for Architects, Engineers, and Builders*, (Available from **American Iron and Steel Institute**).

Anachem, Inc. and Sandia National Laboratories. *Indoor Air Quality Handbook*. Albuquerque, NM: Sandia National Laboratories, September 1982. #SAND82-1773, UC-11.

Ashford, Nicholas and Claudia Miller. *Chemical Exposures: Low Levels, High Stakes*. New York: Van Nostrand Reinhold, 1991.

Baker, Paula, Erica Elliott, and John Banta. *Prescriptions for a Healthy House: A Practical Guide for Architects, Builders, and Homeowners*, Santa Fe, NM: InWord Press, 1998.

Barnett, Diana Lopez and William Browning. *A Primer on Sustainable Building*. Snowmass, CO: Rocky Mountain Institute, 1995.

Becker, Robert. *Cross Currents, The Perils of Electropollution*. Los Angeles: Jeremy Tarcher, 1990.

Becker, Robert and Gary Selden. *The Body Electric*. New York: Quill, 1985.

Beebe, Glenn. *Toxic Carpet III*. Cincinnati. OH: Glen Beebe, 1991. (Available from **Toxic Carpet Information Exchange**, $12.95 + $3.00 Shipping).

Bonneville Power Administration. *Builder's Field Guide to Energy Efficient Construction*. Portland, OR: Bonneville Power Administration, 1995. (Available from **Bonneville Power Administration**)

Bower, John. *Healthy House Building for the New Millennium: A design and construction guide*. Bloomington, IN: The Healthy House Institute, 2000.

Bower, John. *Understanding Ventilation: How to design, select, and install residential ventilation systems*. Bloomington, IN: The Healthy House Institute, 1995.

Bower, John and Lynn Marie Bower. *The Healthy House Answer Book: Answers to the 133 most commonly asked questions*. Bloomington, IN: The Healthy House Institute, 1997.

Bower, Lynn Marie. *Creating a Healthy Household: The ultimate guide for healthier, safer, less-toxic living*. Bloomington, IN: The Healthy House Institute, 2000.

Bower, Lynn Marie. *The Healthy Household: A complete guide for creating a healthy indoor environment*. Bloomington, IN: The Healthy House Institute, 1995.

David Brook and others, *Master Home Environmentalist Program Training Manual* (Seattle, WA: American Lung Association of Washington, July, 2000).

Breecher, Maury M. and Shirley Linde. *Healthy Homes in a Toxic World: Preventing, Identifying, and Eliminating Hidden Health Hazards in Your Home*. New York: John Wiley & Sons, 1992.

Brodeur, Paul. *Currents of Death: Power Lines, Computer Terminals, and the Attempt to Cover Up Their Threat to Your Health*. New York: Simon & Schuster, 1989.

Brodeur, Paul. *The Great Power-Line Cover-up: How the Utilities and the Government are Trying to Hide the Cancer Hazard Posed by Electromagnetic Fields*. Boston: Little, Brown, 1995.

Brodeur, Paul. *The Zapping of America: Microwaves, Their Deadly Risk, and the Cover-up*. New York: W.W. Norton & Co., 1977.

Canada Mortgage & Housing Corp. *Building Materials for the Hypersensitive*. Ottawa, ON, Canada: Canada Mortgage and Housing Corp., 1995, (Available from **CMHC**).

Canada Mortgage & Housing Corp. *Investigating, Diagnosing, & Treating Your Damp Basement*. Ottawa, ON, Canada: Canada Mortgage and Housing Corp., 1992, (Available from **CMHC**).

Canada Mortgage & Housing Corp. *Strategies for Healthful Residential Environments*. Ottawa, ON, Canada: Canada Mortgage and Housing Corp., June 1984, (Available from **CMHC**).

Canada Mortgage & Housing Corp. *Studies on Indoor Air Quality in Canadian Homes* (Three Volumes). Ottawa, ON, Canada: Canada Mortgage and Housing Corp., March 1985, (Available from **CMHC**).

Canada Mortgage & Housing Corp. *A Survey of Problem Homes of the Environmentally hypersensitive*. Ottawa, ON, Canada: Canada Mortgage and Housing Corp., May 1996, (Available from **CMHC**).

Carmody, John, Jeffrey Christian and Kenneth Labs. *Builder's Foundation Handbook*, #ORNL/CON-295, 1991, (Available from **NTIS**).

Corman, Rita. Air Pollution Primer, New York: American Lung Association, 1978.

Cone, James and Michael Hodgson, editors. *Occupational Medicine, State of the Art Reviews—Problem Buildings: Building-Associated Illness and the Sick Building Syndrome*. Philadelphia: Hanley & Belfus, October/December 1989.

Cullen, Mark, editor. *Occupational Medicine, State of the Art Reviews—Workers With Multiple Chemical Sensitivities*. Philadelphia: Hanley & Belfus, October/December 1987.

Curwell, S.R. and C.G. March. *Hazardous Building Materials: A Guide to the Selection of Alternatives*. London: E.&F.N. Spon, 1986.

Dadd, Debra Lynn. *Nontoxic and natural: How to avoid dangerous everyday products and buy or make safe ones*. Los Angeles: Jeremy Tarcher, 1984.

Davis, Andrew, and Paul Schaffman. *The Home Environmental Sourcebook: 50 environmental hazards to avoid when buying, selling, or maintaining your home.* New York: Henry Holt, 1996.

Demkin, Joseph, editor, *Environmental Resource Guide*. New York: John Wiley & Sons, published annually.

Dunford, Randall. *Your Health and the Indoor Environment: A complete guide to better* *health through control of the indoor atmosphere*. Dallas: NuDawn, 1991.

duPont, Peter and John Morrill. *Residential Indoor Air Quality & Energy Efficiency*. Washington: American Council for an Energy-Efficient Economy, 1989.

Environmental Protection Agency. *A Citizen's Guide to Radon*, #402-K92-001, May 1992, (Available from **EPA**).

Environmental Protection Agency. *Electric and Magnetic Fields From 60-Hertz Electric Power*, (Available from **EPA**).

Environmental Protection Agency. *The Inside Story, A Guide to Indoor Air Quality*, September 1993. #EPA/402-K-93-007, (Available from **EPA).**

Environmental Protection Agency. *EMF In Your Environment: Magnetic Field Measurements of Everyday Electrical Devices.* Washington, DC: EPA, December 1992. #402-R-008. (Available from **EPA**).

Environmental Protection Agency. *Radon-Resistant Residential New Construction*, #EPA/600/8-88/087, 1988, (Available from **EPA**).

Godish, Thad. *Indoor Air Pollution Control*. Chelsea, MI: Lewis Publishers, 1989.

Goldbeck, David. *The Smart Kitchen*, Woodstock, NY: Ceres Press, 1994.

Good, Clint. *Healthful Houses: How to design and build your own*. Bethesda, MD: Guaranty Press, 1988.

Golos, Natalie, Frances Golos Golbitz and Frances Spatz Leighton. *Coping with Your Allergies*. New York: Simon and Schuster, 1979.

Grant, Lucinda. The *Electrical Sensitivity Handbook: How electromagnetic fields (EMFs) are making people sick*. Prescott: Weldon Publishing, 1995.

Greenfield, Ellen. *House Dangerous: Indoor pollution in your home and office—and what you can do about it*. New York: Vintage Books, 1987.

Gulland, John. *The Fireplace in the House as a System.* Killaloe, ON Canada: Gulliand Associates, 1998, (Available from **Gulliand Associates**)

Harland, Edward. *Eco-Renovation: The ecological home improvement guide*. Post Mills, VT: Chelsea Green, 1994.

Harwood, Barbara. *The Healing House*, Carlsbad, CA: Hay House, 1997.

Howell, Charles and James Summerville, Eds., *Healthy Building for a Better Earth, The Proceedings of the First National Conference on Environmental Sensitivity in Construction*, 1991.

How to Read a Material Safety Data Sheet, San Diego, CA: American Lung Association of San Diego and Imperial Counties, 1988.

Hunter, Linda Mason. *The Healthy Home: An attic-to-basement guide to toxic-free living*. Emmaus, PA: Rodale Press, 1989.

Hyman, Jane Wegscheider. *The Light Book: How natural and artificial light affect our health, mood, and behavior*. Los Angeles: Jeremy Tarcher, 1990.

Interior Concerns Resource Guide. Mill Valley, CA: Interior Concerns Publications, Updated regularly. (Available from **Building Concerns**, $30.00).

Kadulski, Richard. *Heating Systems for Your New Home*. North Vancouver, BC, Canada: Drawing Room Graphic Services, Ltd.: 1998. (Available from **Drawing Room Graphic Services, Ltd.**, $23.49 Canadian).

Kadulski, Richard. *Residential Ventilation: Achieving Indoor air quality*. North Vancouver, BC, Canada: Drawing Room Graphics, Ltd.: 1988. (Available from **Drawing Room Graphic Services, Ltd.**, $23.49 Canadian).

Kundsin, Ruth, editor. *Architectural Design and Indoor Microbial Pollution*. New York: Oxford University Press, 1988.

Labs, Kenneth, et al. Building Foundation Design Handbook, #ORNL/Sub/86-72143/1, 1986. (Available from **NTIS**).

LeClair, Kim and David Rousseau. *Environmental by Design: A sourcebook of environmentally aware material choices*. Point Roberts, WA: Hartley & Marks, 1992.

Lischkoff, James K. and Joseph Lstiburek. *The Airtight House*. Ames IA: Iowa State University Research Foundation, 1985. (Available from **Iowa State University Research Foundation**, $12.95).

Loken, Steve. *Guide to Resource-Efficient Building Elements*. Missoula, MT: Center for Resourceful Building Technology, 1993 (Available from **Center for Resourceful Building Technology**, $25.00 + $3.00 S&H).

Lstiburek, Joseph. *Builder's Guide: Cold Climates*. (Available from **Building Science Corp.**, $43.00).

Lstiburek, Joseph. *Builder's Guide for Hot-Dry/Mixed-Dry (Cooling) Climates* (Available from **Building Science Corp.**, $43.00).

Lstiburek, Joseph. *Builder's Guide for Hot-Humid (Cooling) Climates* (Available from **Building Science Corp.**, $43.00).

Lstiburek, Joseph. *Builder's Guide for Mixed (Heating and Cooling) Climates* (Available from **Building Science Corp.**, $43.00).

Lstiburek, Joseph. *Exemplary Home Builder's Field Guide*. (Available from **Advanced Energy** $45.00).

Lstiburek, Joseph and John Carmody. *Moisture Control Handbook: Principles and practices for residential and small commercial buildings.* New York: Van Nostrand Reinhold, 1993.

Marinelli, Janet and Paul Bierman-Lytle. *Your Natural Home: The Complete sourcebook and design manual for creating a healthy beautiful, and environmentally sensitive house*. Boston: Little, Brown & Co., 1995.

May, Jeffrey C. *My House Is Killing Me*. Baltimore, MD: Johns Hopkins Press, 2001.

Miller, Norma L., editor. *The Healthy School Handbook: Conquering the Sick Building Syndrome and Other Environmental Hazards in and Around Your School*. Washington, DC: National Education Association Professional Library, 1995.

Nisson, J.D. Ned, and Gautam Dutt. *The Superinsulated Home Book*, New York: John Wiley and Sons, 1985.

Ogren, Thomas. *Allergy-Free Gardening*, Berkeley, CA: Ten Speed Press, 2000.

Olkowski, William, Sheila Daar, and Helga Olkowski. *Common-Sense Pest Control: Least-toxic solutions for your home, garden, pets and community*. Newton, CT: Taunton Press, 1991.

Pearson, David. *The Natural House Book: Creating a healthy, harmonious, and ecologically-sound home environment*. New York: Simon and Schuster, 1989.

Pearson, David. *The New Natural House Book*, New York: Fireside, 1998.

Pearson, David. *The Natural House Catalog: Everything you need to create an environmentally friendly home*. New York: Simon and Schuster, 1996.

Pinsky, Mark. *The EMF Book: What you should know about electromagnetic fields, electromagnetic radiation, and your health*. New York: Warner Books, 1995.

Pfeiffer, Guy O. and Casimir M. Nikel. *The Household Environment and Chronic Illness*. Springfield, IL: Charles C. Thomas Publisher, 1980.

Randolph, Theron. *Human Ecology and Susceptibility to the Chemical Environment*. Springfield IL: Charles C. Thomas Publisher, 1962.

Riley, Karl. *Tracing EMFs in Building Wiring and Grounding*. Tucson: Magnetic Sciences International, 1995. (Available from **Magnetic Sciences International**, $30.00).

Rousseau, David and William Rea. Your Home, *Your Health and Well-Being: What you can do to design or renovate your house or apartment to be free of outdoor and indoor pollution*. Berkeley, CA: Ten Speed Press, 1988.

Rousseau, David and James Wasley. *Healthy by Design*, Point Roberts, WA: Hartley & Marks, 1997.

Rossol, Monona. T*he Artists Complete Health and safety Guide*. New York: Allworth Press, 1990.

Schoemaker, Joyce and Charity Vitale. *Healthy Homes, Healthy Kids: Protecting your children from everyday environmental hazards*. Washington: Island Press, 1991.

Small, Bruce. *Indoor Air Pollution and Housing Technology*. Ottawa, ON, Canada: Canada Mortgage and Housing Corp., 1983, (Available from **CMHC**).

Stein, Dan. *Dan's Practical Guide to Least Toxic Home Pest Control*. Eugene, OR: Hulogisi, 1991.

Sugarman, Ellen. *Warning: The Electricity Around You May Be Hazardous to Your Health*. New York: Fireside, 1992.

Tile Council of America. *Handbook for Ceramic Tile Installation*, updated annually (Available from **Tile Council of America**).

Turiel, Isaac. *Indoor Air Quality and Human Health*. Stanford, CA: Stanford University Press, 1985.

U.S. Congress, Office of Technology Assessment, *Biological Effects of Power Frequency Electric and Magnetic Fields—Background Paper.* Washington, DC: U.S. Government Printing Office, May 1989. #OTA-BP-E-53.

U.S. Department of Energy. *Indoor Air Quality Environmental Information Handbook: Building System Characteristics*. Washington, DC: U.S. Department of Energy, January 1987. #DOE/EV/10450-H1.

U.S. Department of Energy. *Indoor Air Quality Environmental Information Handbook: Combustion Sources, 1989 Update*. Washington, DC: U.S. Department of Energy, June 1990. #DOE/EH/79079-H1.

U.S. Department of Energy. *Indoor Air Quality Environmental Information Handbook: Radon*. Washington, DC: U.S. Department of Energy, January 1986. #DOE/PE/72013-2.

U.S. Department of Health and Human Services. *NIOSH Pocket Guide to Chemical Hazards*. Washington, DC: U.S. Government Printing Office, June 1994.

Venolia, Carol. *Healing Environments: Your guide to indoor well-being*. Berkeley, CA: Celestial Arts, 1988.

Zamm, Alfred Z. *Why Your House May Endanger Your Health*. New York: Simon and Schuster, 1980.

Videos

Banta, John. Current Switch, How to identify & reduce or eliminate electromagnetic pollution in the home. VHS videotape. (Available from **Less EMF, Inc.**, $29.95 + $4.50 S&H)

Bower, John and Lynn Marie Bower. The Healthy House: Designing, building, and furnishing a non-toxic home. Bloomington, IN: The Healthy House Institute, 2000. A 13-episode series on 5 VHS videotapes.

Bower, John. Your House, Your Health: A Non-toxic Building Guide. Bloomington, IN: The Healthy House Institute, 1993. VHS videotape.

Kormos, Robin. Healthy Homes Video, Interviews with Paul Bierman-Lytle and Sherry Rogers, MD. VHS videotape. (Available from Robin Kormos, 149 Avenue A, NY, NY 10009, 212-460-8921, $17.95 + $3.00 S&H).

Periodicals

Building Concerns Newsletter, "Information on Sustainable Design, Building, and Development." **Building Concerns**, Bimonthly subscription $35.00.

Energy Design Update, "The Monthly Newsletter on Energy-Efficient Housing." **Cutter Information Corp.**, Monthly subscription $337.00.

Environmental Building News, "A newsletter on environmentally responsible design and construction." **Environmental Building News**, Monthly subscription $67.00.

Environmental Design & Construction, "A magazine for successful building—economically and environmentally," **Environmental Design & Construction**, bimonthly subscription, free to qualified individuals.

IEQ Strategies, "Practical Advice for the Control of Indoor Environmental Quality." **Cutter Information Corp.**, Monthly subscription $317.00.

Indoor Air, "International Journal of Indoor Air Quality and Climate." **Munksgaard International Publishers Ltd.**, Quarterly subscription. Published in Denmark.

Indoor Air Bulletin, "Technology, research and news for indoor environmental quality." **Indoor Air Information Service**, Monthly subscription $195.00.

Indoor Environment Business, "Solutions and Strategies for Success in Managing Indoor Environments." **IAQ Publications, Inc.** Monthly subscription $275.00.

Indoor Environment Connections, "The newspaper for the IAQ marketplace." **Indoor Environment Communications.**, Monthly subscription $75.00.

Inside IAQ, "EPA's Indoor Air Quality Research Update." **Indoor Environment Management Branch**, Semi-annual subscription.

Solplan Review, "The independent journal of energy conservation, building science & construction practice." **Drawing Room Graphic Services Ltd.**, Bimonthly subscription $48.15 Canadian ($52.00 U.S.).