Environment and Power

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Bonneville Power Administration
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Issue Backgrounder: Energy Efficient New Homes & Indoor Air Pollutants

August 1989

Introduction

Across the nation, energy-efficient new homes are catching the attention of consumers, builders, utilities, and lenders. All stand to gain from the increased comfort, lasting value, and lower energy costs that these homes offer. The Bonneville Power Administration is also interested in these homes, not only because of their value to consumers, but because they offer the region an important and practical opportunity to conserve energy.

If a new home is not properly designed and maintained, however, the energy savings may be a mixed blessing. Some of these homes may have fewer air leaks than others. Because less air flows between indoors and outdoors, pollutants that are in that home may build up inside. Consequently, in all new homes one must plan ahead to control the flow of air and to avoid building materials that may emit pollutants.

This booklet discusses what indoor air pollution is and how it can affect your health. It describes how energy-efficient new homes can affect indoor air quality. It also describes features that can help ensure clean indoor air, and tells how to detect and control indoor pollutants commonly found in homes. Please refer to the references listed in this booklet for clarification of any technical statements. This booklet is not intended to be a technical reference manual on indoor air quality.

*Words in **italics** are defined in a glossary at the end of this booklet.*

Hidden in the shell of energy-efficient new homes are special features that hold in heat and keep out cold. But any new home may also have building materials that release pollutants into the home. Pollutants can also come from outside, and from everyday living. However, pollutant sources can be avoided and homes can be designed to carry pollutants to the outdoors.

Table of Content

Both the Super Good Cents and the Northwest Energy Code homes are built to model conservation standards of energy efficiency. All references in this booklet to Super Good Cents apply also to Northwest Energy Code homes.

WHAT IS INDOOR AIR POLLUTION?

Every home contains *pollutants* that can affect the quality of the indoor air. Some of the major pollutants are gases and particles generated when people use wood stoves and gas ranges, for example, or when they smoke. Some pollutants, such as *formaldehyde* and other organic chemicals, are emitted by certain building materials, home furnishings, cleaning agents and pesticides.

Pollutants in the outside air can also contribute to poor indoor air quality. For example, *carbon monoxide* and *nitrogen dioxide* from automobile and industrial emissions, as well as *radon* from underlying soil, can migrate indoors. In most cases, pollutants do not reach harmful levels. But in some homes, pollutants build up. As pollutant levels rise, they can increase the risk of harmful health effects for the home's occupants.

IS INDOOR AIR POLLUTION SOMETHING NEW?

Indoor air pollution has been with us ever since our ancestors first made their homes in caves. Smoke from fires, radon from the soil, and moisture from everyday living and the environment all could have been present. In recent years, researchers have become concerned and are giving indoor air pollutants a closer look.

Building tighter homes does not cause indoor pollution. But it can aggravate the problem in homes with existing *sources* of pollution. We are using more and more products that may be

The Model Conservation Standards and Energy-Efficient New Homes

Here in the Northwest, new building ***standards*** *are shaping the practices that go into making an energy-efficient home to suit our particular climates and needs. These standards, called the Model Conservation Standards, are presented in the* ***Northwest Conservation and Electric Power Plan.*** *They were written by the Northwest Power Planning Council , and presented in code format as the Northwest Energy Code.*

The standards are being implemented by utilities through BPA's Super Good Cents Program and by state and local building code departments through the Northwest Energy Code. The standards divide the Northwest into three climate zones. They offer a menu of cost-effective building measures matched to each zone. Builders and designers may pick and choose among energy saving options to meet the standards.

Individual homes can be as varied as the people who design and live in them and still meet the standards. But each is designed with extra features meant to keep the cold out and hold the heat in. From the outside, energy-efficient homes are easy to overlook because most of the improvements are under the skin, out of sight. But by looking closely, you can find some of the features, such as thermally improved windows and doors.

The biggest improvements are in the attic, under the floor and behind the walls. Here, you will find high levels of insulation and special building practices which ***tighten a house*** *by blocking routes taken by warm air to get outside. Heating or cooling ducts are well sealed and insulated.*

The features that block the escape of warm air and the entry of cold air also add the potential for increased ***concentrations*** *of indoor air pollutants. But with careful design and construction, sources of pollutants can be diverted, avoided, or sealed off; and mechanical* ***ventilation*** *is always installed to reduce further any pollutants that arise.*

In the Northwest, the energy saved in efficiently built new homes not only saves ratepayers money; it is a potential source of low-cost energy for the region. Energy conserving measures can easily be built into new homes. But they require much more cost and effort to add later. For this reason, every home built without energy-saving features is a lost opportunity for Northwest ratepayers.

sources of indoor pollutants. Some of these are built into the physical structure of our homes; others we bring inside.

HOW MUCH IS KNOWN ABOUT INDOOR AIR POLLUTION?

Researchers now know that pollutant levels in homes can sometimes exceed standards set to protect outdoor air quality. But pollutant levels in homes vary so widely that it is difficult to predict from general rules whether any one residence will have a pollution problem.

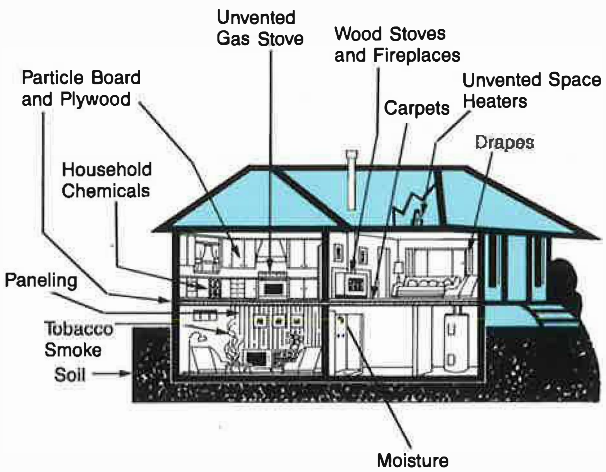
The Indoor Air Quality Puzzle

The quality of the air in our homes can be looked at as a puzzle with several interacting pieces. Some of the pieces remain stable, such as the volume of a house. Others we can control, such as the types and quantities of pollutants we bring into our house.

Specific information about many major pollutants is in the "Guide to Indoor Pollutants" which starts on page 9 in this booklet.

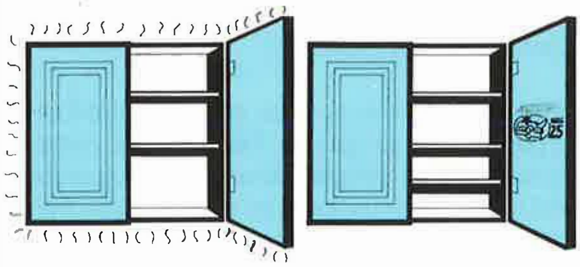
Sources of Indoor Pollution

Pollutants in homes can come from many sources, such as unvented combustion appliances, wood stoves, fireplaces and the soil under the house. Potential sources may be built into the structure of a house, or may be brought in as consumer products or furnishings. Yet other sources, such as radon, are outside the house and their pollutants *infiltrate* through cracks and other leaks. When designing a new home, plan to substitute for materials that are known sources of pollution and/or employ methods to block or divert pollution before it enters the house.



The Intensity of the Source Varies

Sources may emit pollutants at a high or low rate. Depending on the characteristics of the source, conditions that influence the *emission rate* include temperature, age, humidity, and installation and maintenance procedures. For example, products containing formaldehyde release much of their gas when they are new.



So, recently built kitchen cabinets made from particle board containing formaldehyde resins, emit higher levels of formaldehyde than cabinets several years old. High temperature and humidity will also increase the rate of *emissions*. If the cabinets were made of particle board designed to be *low-fuming,* less formaldehyde would be emitted than from otherwise comparable products.

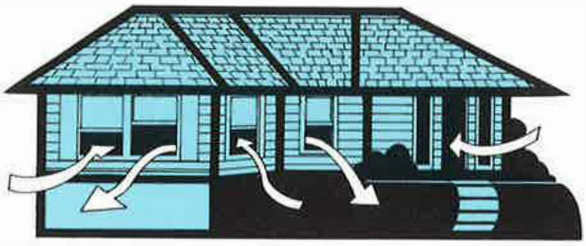
The Size of a Home Makes a Difference

Pollutants tend to be evenly distributed in a volume of air. Given a constant source, pollutants will be more concentrated in a small home and less concentrated in a large home.

If identical pollutant sources are placed in two houses, one large and one small, and all other conditions are equal, the pollutant level in the small house will be greater than that in the large house.

Removal Rates Vary

Typically, pollutants are removed from homes by natural air leakage. Other ways of removing pollutants include filtering and cleaning the air, replacing pollutant sources and mechanically ventilating the air. Given a constant source, the faster pollutants are removed, the lower overall concentrations will be.



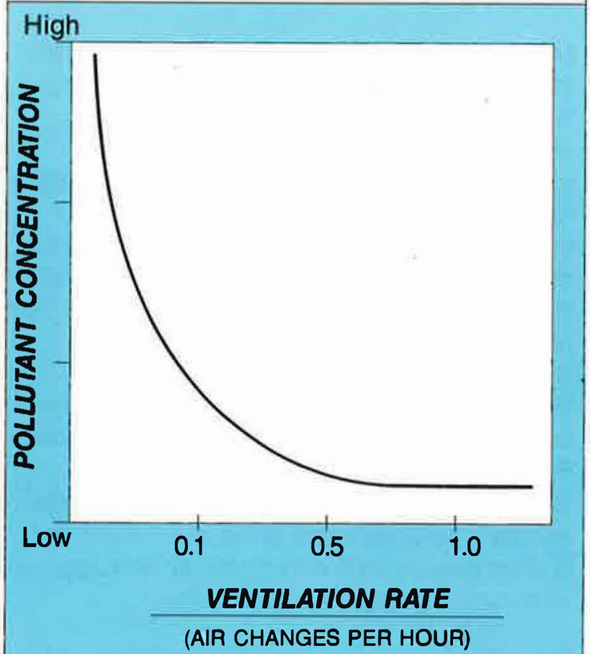
Air Change Rates Vary

Pollutant levels also depend on a residence's *air change rate*—the rate at which air inside the home is replaced by outside air. This rate is usually given as average *"air changes per hour."* The more tightly constructed a residence is, the lower its air change rate will be.

Indoor air pollutants and ventilation work together in such a way that when sources of pollution and other factors are constant, a decrease in ventilation leads to an increase in pollutant levels. This means that at lower ventilation rates, pollution levels will increase dramatically with even small drops in ventilation. This graph shows the general relationship between indoor pollutant concentrations and ventilation rates.

However, for pollutants that come from the outdoor sources, (e.g., radon, NO_2) lower air change rates may help limit the amount of pollution that comes into homes.

Ventilation and Indoor Air Quality



All things being equal, as ventilation rates decrease, pollutant levels rise.

The strength of pollution sources determines how effective ventilation will be at achieving acceptable pollutant levels. Ventilation can be low if sources of pollutants are weak. But when sources of pollutants are strong, ventilation alone may not be practical as a pollution control measure, and sources must be reduced.

Active Versus Passive Ventilation

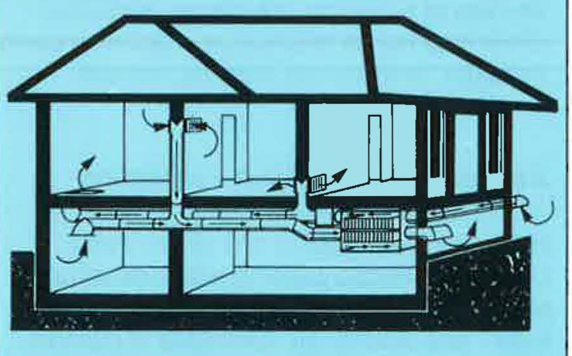
Indoor air is replaced in one of two ways. Current residential building practices usually rely on *passive ventilation* for the exchange of indoor and outdoor air. Examples of passive ventilation include operable windows and doors and air leaks through and around joints and cracks. Passive ventilation may be inadequate, however, because it depends on changing wind speed and temperature differences to circulate air. How residents act also makes a difference. When residents close up their home in winter the air change rate will be lower than during the summer when doors and windows are open. Wind speed, temperature, house leakiness, time of year and living patterns all affect how well passive ventilation works.

But homes should not rely on passive ventilation alone. All should be equipped with *active ventilation.* Active ventilation refers to fans and motors—mechanical devices—that give a steady level of controlled air flow. This active ventilation can be designed to recover heat from the outgoing air (known as "heat recovery") although "non-heat recovery" is also effective. Two common systems for ventilation are noted here.

Air-to-air heat exchangers. These active ventilation devices are widely used in Canada and Europe and are gaining popularity in this country. These devices increase a home's *air exchange* rate while capturing energy otherwise lost in the outgoing air. Air-to-air heat exchangers draw fresh air from outside the home and blow out stale indoor air. In winter, heat from the warm air leaving the home preheats the colder incoming air. This process recovers about 50 to 70 percent of the heat in the outgoing air.[1]

Air-to-air heat exchangers are most effective when installed as part of a central system while homes are being built. They can be tucked away in the top of a closet or in some other out-of-the-way but accessible spot. Smaller units also are mounted later in walls or window, but tend to be less efficient than the central units. This is because the central systems use

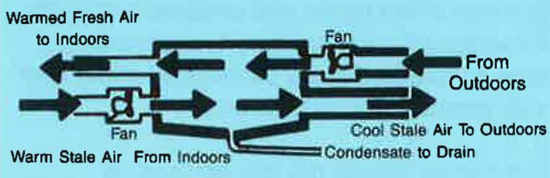
Mechanical Ventilation Systems



Mechanical ventilation maintains air exchange rates. Central systems are most effective, and are easiest to install when homes are being built.

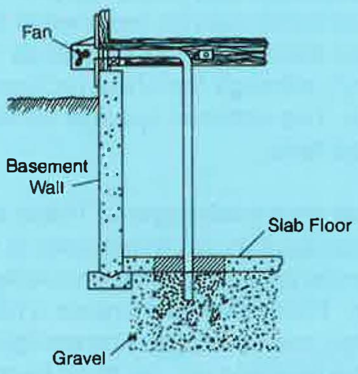
Air-to-Air Exchangers

Air-to-air heat exchangers are one type of mechanical ventilation system. In the core of these devices heat from outgoing stale air is transferred to incoming fresh air.



Subslab Ventilation Systems

Subslab ventilations systems can dilute or divert radon before it enters the home.



duct work that carries air throughout the house, and helps ventilate stagnant areas.

Exhaust-only ventilation. Another type of active ventilation is the exhaust-only ventilation system. This system uses fans to blow indoor air out of the house. Outside air replaces indoor air through specially designed air intake vents and other openings in the building shell. The vents control the amount of air intake and minimize any discomfort associated with cold air flowing into the house. These systems can be designed to capture the heat in out-going air, but often are not.

Exhaust-only can be sized to serve a whole house. Or smaller exhaust fans can provide spot ventilation. Familiar examples include bathroom fans and range hood exhausts. Spot ventilation works well when pollutants are localized and can be vented before they disperse throughout the house.

Ventilation systems working outside of a home's living area can also help control pollutants. Familiar examples of passive systems include vents in attics and crawlspaces to help control moisture. Where radon is a concern, active ventilation can divert or dilute radon before it enters the home. Active ventilation systems used to control radon include mechanical crawlspace ventilation, basement pressurization and sub-slab ventilation.

Dehumidifiers do not increase ventilation; they are mechanical devices that help control indoor air quality by removing unwanted extra moisture from the air. Central systems can be installed in heating systems. Or portable dehumidifiers, about the size of an end table, can be hidden away, or if properly finished, left out and blended with other furnishings.

For mechanical ventilation systems and dehumidifiers to remain effective, consumers need to learn and follow proper operating and care procedures. Talk to your builder and see your "Owner's Manual" for more information.

HOW "TIGHT" ARE ENERGY-EFFICIENT HOMES?

Measuring ventilation rates is difficult because the leakiness of houses varies tremendously. And different measurement methods give different results. Like other homes, energy-efficient homes can take many different shapes and incorporate many different features that may influence ventilation rates. Which route a builder takes will depend on many factors, such as cost, climate, consumer preference and local building codes.

Here in the Northwest options for building these homes are contained in the Model Conservation Standards which were developed by the Council. The Council's optional target for the tightest energy-efficient home is 0.1 ACH, but homes may be built with higher air leakage rates and still meet the standards.[2]

To control ventilation rates in very tight homes an air-to-air heat exchanger or other active ventilation system with heat recovery is required. Some researchers suggest that all homes should be equipped with mechanical ventilation.[3] *BPA* and the Council specify that mechanical ventilation systems be installed in all energy-efficient homes built under their programs.[4] These devices provide reliable rates of active ventilation and can bring ventilation rates up to typical levels of about 0.35 to 0.50 air changes per hour.

Even though mechanical ventilation can bring low ventilation rates up to typical levels, this is no guarantee of clean indoor air. Pollutant levels depend much more on the strength and quantity of pollutant sources found in the home, than on ventilation rates.[5]

ARE THERE STANDARDS FOR ACCEPTABLE POLLUTANT LEVELS?

Air quality standards define the concentrations of pollutants to which most people can be exposed for a given period of time without adverse health effects. Various agencies and organizations have standards or *guidelines* for indoor pollutant levels, but these mostly apply to the workplace or to public buildings. No air quality standards have been established that apply to all residences in the United States.

Prior to the Indoor Radon Abatement Act of 1988, the U.S. Environmental Protection Agency recommended that in homes exceeding an indoor radon level of 4.0 *pCi/l,* action should be taken to reduce exposure.[6] The act sets as a long-term goal indoor radon levels equal tc outdoor levels (0.2 pCi/l). However, this goal necessitates increased costs in the construction and operation of the home that may make it unattainable.

The higher the radon level, the sooner the action should be taken. See the "Guide To Indoor Pollutants" beginning on page 9 for more information about radon.

In regard to other pollutants, the *EPA* has established standards for some pollutants in the outdoor air. These standards are designed to "protect the public health . . . with an adequate margin of safety."[7] However, these standards cannot be readily applied to indoor air pollutant levels. People are exposed to indoor pollutants over longer periods of time. And outdoor standards do not always take into account the susceptibility of people who are very young, ill or elderly.[8]

The Occupational Safety and Health Administration regulates concentrations of pollutants in workplaces. However, the American Society of Heating, Refrigerating and Air Conditioning Engineer has recommended that for the general public, exposure should not exceed one-tenth of the industrial standards.[9]

The Department of Housing and Urban Development has set standards for levels of formaldehyde emission by products used in the manufactured housing industry (Federal Manufactured Home Construction and Safety Standards, 3280.308).

HOW DOES INDOOR AIR POLLUTION AFFECT OUR HEALTH?

Effects of High Pollutant Levels in Homes

Even brief exposure to high concentrations of certain pollutants—carbon monoxide, nitrogen oxides and formaldehyde, for example—can cause eye, nose, and throat irritation and respiratory problems. People may have headaches, dizziness or nausea. They may have trouble breathing or find they tire easily. Their symptoms vary, depending on their sensitivity to a particular pollutant and the level of exposure. Often these effects disappear when the source of the pollutant is removed. Even low concentrations of carbon monoxide can result in death.

Long-Term Effects of Low Pollutant Levels Uncertain

Scientists are concerned about the possible long-range effects of exposure to low levels of certain pollutants, but as yet there is very little information. Prolonged exposure to nitrogen dioxide and carbon monoxide may lead to chronic respiratory problems. People can develop chronic sensitivity to formaldehyde—an allergic reaction. Long-term exposure to tobacco, wood smoke, and radon may increase the risk of lung cancer.

However, uncertainties cloud the issue. As yet, very little is known about the effects of long-term exposure to low levels of pollutants found in homes. While studies are underway, research is still in its preliminary stages. The picture is further complicated by the fact that people are exposed to many pollutants, so it is difficult to isolate and analyze the effect of any one of them.

Most of what is known about the long-term health effects of pollutants comes from studies of workers exposed to high levels of pollutants on the job. These workers developed a range of medical problems, including respiratory diseases and cancer. But pollutant levels in the workplaces studied were many times higher than those found in homes. Also, researchers think that other factors in the working environment contributed to workers' illnesses. Further, workers—most of them adult males and many of them smokers—are not typical of the general population.

Until these uncertainties are resolved, scientists must be cautious. They assume that if pollutants can cause health problems at high exposure levels, there is a proportionate risk at low exposure levels.

WHAT CAN I DO ABOUT INDOOR AIR POLLUTION?

The quality of the air inside our homes is influenced by many variables. When these are left to chance it is very difficult to predict which homes might have high pollutant concentrations. But when attention is given to these variables by designers, builders and consumers, it is possible to construct and live in a home that is comfortable and healthy.

The best way to improve air quality is to not pollute it in the first place. Building materials and consumer products that are sources of pollutants should be avoided. When used, these materials should be sealed or isolated from the living area. Source removal or avoidance is usually a permanent, one time measure that requires no maintenance or operating costs.

BPA will continue to give Northwest consumers information about indoor air pollutants, energy efficiency, and improved building techniques in new homes.

In many cases, a less hazardous alternative can be found for many pollutants. For example, substitute low-fuming particle board for typical particle board to reduce formaldehyde levels.

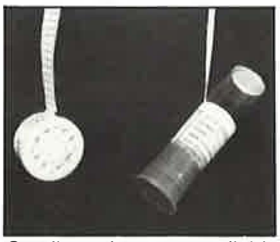
Ventilation and air cleaning can also help control indoor pollutants. Additional features such as radon control measures, exhaust fans or air-to-air heat exchangers let homeowners control levels of indoor pollution. Dehumidifiers can also be used in homes with moisture problems. Although these devices are more easily installed in new homes, they can also be added to existing buildings.

Once a home is built, consumers can avoid bringing in sources of pollutants. When the use of hazardous compounds is unavoidable, use the least toxic product available and follow the manufacturers' instructions carefully. If the directions call for a "well ventilated area" consider using the product outside or in an area detached from the house. Hazardous compounds should be stored outside the home. And to be safe, lock them up.

CAN I MEASURE POLLUTANT LEVELS IN MY HOME?

Techniques to measure pollutant concentrations in residences have been developed, but in many cases they involve complicated and expensive equipment, time and technical expertise.

Only a few relatively inexpensive, easy-to-use devices are available for your use at home. Monitors, small detectors that absorb pollutants, are available for formaldehyde, radon, nitrogen dioxide and carbon monoxide. These simple devices can be installed in your home, left for a period of time, and analyzed by a laboratory. The results tell you the average pollutant level during the monitoring period. You can then compare this level to existing standards, typical concentrations found in homes, and to levels known to cause health problems.



Small monitors are available to measure formaldehyde and radon levels in homes.

Free radon monitoring is available through Super Good Cents, Northwest Energy Code, and BPA weatherization programs. Check with your electric utility, local building code jurisdiction, or call your BPA area office for details. Phone numbers for contacting BPA's offices are in the back of this booklet.

GUIDE TO INDOOR POLLUTANTS

Overview of Indoor Air Pollutants, Potential Health Effects And Ways To

Pollutants	*Description*	*Health Effects*
Radon (See page 12)	*Odorless, colorless, radioactive gas, a decay product of radium which occurs naturally in the earth's crust.*	*Believed responsible for about 5 to 15 percent of all lung cancers.*
Formaldehyde (See page 15)	*Strong-smelling, colorless, water soluble gas, a component of some insulation and of glues used in making plywood, particle board and textiles.*	*Nose, throat and eye irritation, possibly nasal cancer.*
Combustion gases: Carbon Monoxide (See page 18)	*Colorless, odorless, tasteless gas from all fuel burning.*	*Lung ailments. Impaired vision and brain functioning. Can be fatal.*
Nitrogen Oxides (See page19)	*Nitrogen oxide is a colorless and odorless gas. Nitrogen dioxide has an odor at higher levels.*	*Lung damage. Lung disease after long exposure.*
Respirable Suspended Particulates (RSP) (See page 20)	*Particles in the air small enough to be inhaled*	*Nose, throat and eye irritation, lung cancer, emphysema, heart disease, bronchitis, respiratory infections.*
Household Chemicals (See page 21)	*Organic compounds found in household products.*	*Irritation of skin, eyes, nose and throat, effects on central nervous system and metabolic processes.*
Moisture (See page 22)	*Excessive humidity.*	*Contributes to growth of microorganisms. Acts as solvent for other pollutants.*

Reduce Exposure

Sources in Homes	To Reduce Exposure
Soil beneath home	• Ventilate crawlspaces—use a fan if needed. • Tightly seal floors. • Pour slabs to resist cracking and seal openings. • Depressurize the ground beneath the slab. • Install an active ventilation system. • Overpressurize basements.
Various materials, including particle board, plywood, furniture, drapes, and carpet.	• Use materials that are relatively low in formaldehyde. Examples are particle board which meet HUD standards and exterior grade plywood, which release less formaldehyde than interior grades. • Increase air exchange rates. • Install a dehumidifier.
Kerosene heaters, wood stoves unvented gas appliances, attached garages.	• Properly size and install wood stoves. • Install exhaust fan above gas stove. • Keep gas appliances properly adjusted. • Properly vent space heaters. • Provide outside air directly to wood stove and fireplace fireboxes. • Clean chimneys. • Do not let fires smolder. • Do not leave car idling in garage.
Kerosene heaters,unvented gas appliances.	• Install exhaust fans above gas stove. • Keep gas appliances properly adjusted. • Increase ventilation.
Tobacco smoke, wood smoke, unvented gas appliances, kerosene heaters, asbestos construction materials, house dust.	• Avoid smoking tobacco inside or smoke near open window. • Be sure wood stove door and flue do not leak. • Vent combustion appliances outdoors. • Change air filters regularly. • Increase ventilation. • Provide outside air directly to woodstove and fireplace firebox.
Synthetic materials, pesticides, aerosol sprays, cleaning agents, paints.	• Follow directions on labels for use. • Use chemicals only in well-ventilated areas. • Store chemicals in a garage or outdoor shed and keep locked up. • Substitute less hazardous products.
Breathing and perspiring, laundry, dishwashing, bathing, cooking, leaks, soil beneath home.	• Install ground cover. • Install exhaust fans in bathrooms, kitchens, and other moisture producing areas. • Vent moisture producing appliances such as dryers. • Install a dehumidifier or active ventilation system. • Provide proper water drainage around the home.

RADON

Radon is an odorless, colorless gas that comes from radium, a naturally occurring trace element in soil and rock. The amount of radon that escapes from the soil varies widely from location to location, depending on soil characteristics.

Sources

In the Pacific Northwest, most of the radon found in homes comes from the soil beneath them. Because it is a gas, pressure differences between the inside of a house and the outside can push radon through cracks and holes in foundations, walls and floors. It also diffuses, though more slowly, through concrete.

Well water may also contain radon, although it is considered a minor source in the Northwest. Unlike municipal water, well water is usually not exposed to the air before it is used indoors. When a faucet is turned on inside a home, radon in the water passes into the air. Natural gas is also considered a potential minor source.

To some extent, building supplies such as concrete, brick and other earthen materials may contain radon.

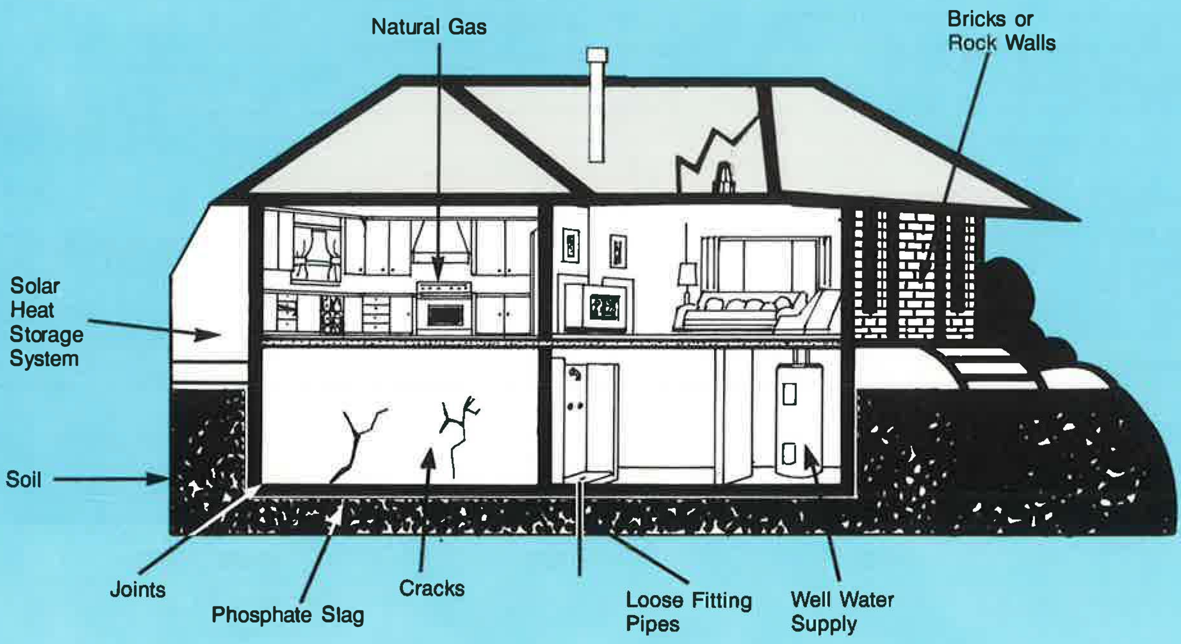
Measurement and Standards

Radon does not remain a gas for very long. It quickly breaks down, or decays, into several elements. Two elements, or *"progeny",* generate potentially damaging radiation, called *"alpha radiation",* as they, in turn, decay. Concentrations of radon and its progeny are usually expressed in "picoCuries per liter", or pCi/l. The "Curie" (named after Pierre and Marie Curie, the discoverers of radium) is a measurement of radiation. (A picoCurie is one-trillionth of a Curie). A measurement of 1 pCi/l would indicate the presence of one picoCurie of radioactive material in one liter of air.

To date, there has been no *standard* set for indoor radon for all residential housing throughout the United States. Various organizations have proposed a range of *guidelines.* As shown in the table, BPA has set 5 pCi/l as an action level for homes participating in its conservation programs, and the EPA had historically set 4 pCi/l as a recommended action level for all homes. Occupational standards are included for comparison.

SOURCES AND PATHWAYS OF RADON IN HOMES

Soil is the primary source of radon in homes, although building materials and other sources can contribute. Cracks and holes allow radon gas to leak into the home.



RADON GUIDELINES

Organization	Recommended Maximum Radon Level	Comments
U.S. Mine Safety & Health Administration	*16 pCi/l*	*Regulation for Miners.*
National Council on Radiation, Protection, and Measurement	*8 pCi/l*	*Recommended Action Level for General Population.*
Bonneville Power Administration	*5 pCi/l*	*Action Level for Residential Conservation Programs.*
Environmental Protection Agency	*4 pCi/l*	*Recommended Action Level for Residences.*

Health Effects

If *radon progeny* are inhaled, they can become lodged in the lung. As they decay, alpha radiation may damage lung tissue. Prolonged exposure to radon increases the risk of lung cancer.

Concern about the health effects of radon emerged from studies of uranium miners working for many years in high levels of radon. These miners developed lung cancer at a higher rate than does the general population.

Researchers are cautious about generalizing about risks to the entire population on the basis of these findings. The miners studied were generally exposed to levels almost 100 times higher than that found in the average home.[10] Nor do these miners, mostly adult males and cigarette smokers, represent a typical cross section of the general population. Also, since the men worked where there are many airborne particles, it is possible that the *combined* effects of dust inhalation, smoking and radon exposure led to the higher incidence of lung cancer, rather than just exposure to radon alone. In their analyses, scientists have attempted to correct for differences between miners and the general population, but much uncertainty remains.

Faced with uncertainties, the scientific community is conservative, preferring to overestimate rather than underestimate health risks. Estimates range from about 5 percent to 15 percent of all lung cancers are due to radon.[11] The Surgeon General attributes about 85 percent of all lung cancers to smoking.[12]

For a nonsmoker, the risk of lung cancer from exposure to 1 pCi/l of radon for life is roughly equivalent to the risk of a fatal accident from driving a car about six miles per day over your lifetime.[13]

Radon Levels in Homes

The amount of radon that reaches the living space of a home depends partly on the home's characteristics. If there is a ventilated crawl space between the ground and the living area, some of the radon will escape outdoors through the vent holes. If the home's foundation or basement is flush with the ground, radon will pass readily through cracks and holes in the foundation and enter the living space.

Natural air change rates are important as well. Radon will be diluted more quickly from a house with 1.0 air change per hour than from a house with 0.5 air changes per hour. Also, with higher air change rates, radon may have greater potential for entering the home from the soil.

To investigate radon levels in Pacific Northwest new residences, BPA monitored radon concentrations in 688 homes as part of the Residential Standards Demonstration Program. A subset of the homes were also intensely studied by a group of scientists. Both studies concluded that geographic location is more important in determining radon concentrations than use or nonuse of energy-efficient features.[14] The

RSDP study found a mean radon level of about 1 pCi/l for both energy-efficient and current practice homes.[15]

BPA is also monitoring radon levels in existing homes as part of the Residential Weatherization Program. The average concentration from measurements taken in about 31,889 homes is 1.26 pCi/l; 3.5 percent of homes exceed 5 pCi/l.[16]

In general, the higher levels were found in some homes in eastern Washington, northern Idaho, and western Montana. However, geography is not a reliable predictor of radon levels, since radon pockets are extremely localized. Neighboring houses can have very different levels.

Radon Monitors

Radon can only be detected through monitoring, but devices are commercially available. These lightweight plastic monitors, about the size of a wristwatch, are installed in a home for several months and then mailed to a laboratory for analysis. Alpha radiation from radon progeny leave tiny "tracks" in a piece of treated plastic inside the monitor. When the monitor is processed, these tracks can be seen under a microscope and then analyzed to

A small radon monitor can be hung inside a home, then analyzed by a laboratory to measure radon concentrations.

determine the average level of concentration. More information about these monitors is available from BPA's local area offices (See Page 24 for area office telephone numbers).

Reducing Radon Exposure

The best radon control for a given home depends on individual construction techniques, style and radon concentration. Control measures work by deflecting or blocking radon's entry into the house, or removing radon after it has entered. Following is a list of radon control measures.

A well-ventilated crawl space allows radon to escape outdoors, rather than enter a home.

- **Design and build your home with plenty of foundation vents.** New homes with crawl spaces should have plenty of these vents to dilute and flush radon gas before it enters the home. Do not block these vents once they are in. Fans may be used to boost air flow through crawlspaces.

- **Build an airtight, insulated partition.** If the home is built with a partial basement and a partial crawlspace, build an airtight barrier between the two and ventilate the crawlspace.

Carefully poured and sealed concrete slabs help block the entry of radon into the home.

- **Ventilate the area beneath the slab.** Sub-slab ventilation works in homes built over slabs or basements by exhausting air from, or pushing air into the gravel beneath the slab or floor. The air flow helps divert radon gas before it enters the home.

- **Overpressurize basements.** Using mechanical ventilation to pull air from a heated upper floor and pushing it into the basement, creates more pressure in the basement than that in the surrounding soil. This can offset the pressure that draws radon from the soil into the house.

- **Tightly seal cracks and openings.** Reducing air leaks in the floor over crawlspaces helps block radon's entry into the home. When pouring concrete walls and floors, take care to avoid cracks. A common place for a crack when pouring concrete is at the joint where the floor and wall meet. Also seal plumbing and utility penetrations through the slab. If cracks or holes do appear later, seal them with caulking, epoxy or other sealants. Sealing materials may deteriorate over time and new cracks can appear; periodic checking and maintenance are required. Sealing may result in only moderate reductions by itself, but it is necessary for other measures, such as sub-slab depressurization or overpressurization, and crawlspace ventilation to work effectively.

- **install an air-to-air heat exchanger.** By pulling in a stable rate of outside air, air-to-air heat exchangers vent and dilute indoor concentrations of radon. These devices by themself, are not likely to yield sufficient reductions of radon levels in homes with very high concentrations. It is important that you properly maintain and operate these devices. See your "Owner's Manual" or talk to your builder for more information. If your new home is not equipped with an air-to-air heat exchanger, one can be added. Some *retrofit* units are not as effective as central, whole-house units which are installed in new construction. These units must be properly sized. Two or more retrofit units may be needed for a large house.

Although all these methods are expected to help reduce radon concentrations in a home, little scientific evidence is available on their overall effectiveness. In preliminary research sponsored by BPA, these methods are found effective. The EPA recommends similar measures.[17] BPA and other organizations have worked to map the distribution of radon. This information makes it possible to predict concentrations in given locations in a general sense. However monitoring is still recommended.

Particle board and plywood used in cabinets release formaldehyde, but "low-fuming" products are available.

FORMALDEHYDE

Formaldehyde is a colorless, water-soluble gas. A low-cost chemical with excellent bonding characteristics, formaldehyde is found in urea-resins used to manufacture plywood, particle board, and textiles. Formaldehyde is also a component of *ureaformaldehyde foam* (UF foam) *insulation* injected into sidewalls, primarily in the early 1970s. UF foam is rarely used by today's building industry.

Sources

UF foam insulation, particle board, plywood, fiberboard, furniture, drapes and carpeting are the primary sources of formaldehyde. Some formaldehyde is also produced during

The U.S. Department of Housing and Urban Development has established standards for the amount of formaldehyde released from plywood and particle board to be used in mobile homes.

combustion, though gas stoves, wood stoves and tobacco smoke are minor sources.

Mobile homes generally have higher levels of formaldehyde than other dwellings because they have a small living area, a low air-change rate, and are usually constructed with more particle board and plywood. Many of the complaints about irritating effects of formaldehyde have come from residents of mobile homes.[18]

Measurement and Standards

Formaldehyde measurements are often given as *parts per million* (Ppm). A measurement of 1 Ppm would indicate the presence of one unit of formaldehyde in a million units of air.

The U.S. Department of Housing and Urban Development has set emission standards for particle board at 0.3 Ppm, and interior plywood at 0.2 Ppm to meet a target of 0.4 Ppm in mobile homes.[19] But no standard has been established for formaldehyde levels in all residences.

ASHRAE has recommended 0.1 Ppm as the maximum level for continuous indoor exposure.

The National Academy of Sciences has concluded that exposures to about 0.25 Ppm would not be irritating to a large majority of the healthy adults in the United States.

Health Effects

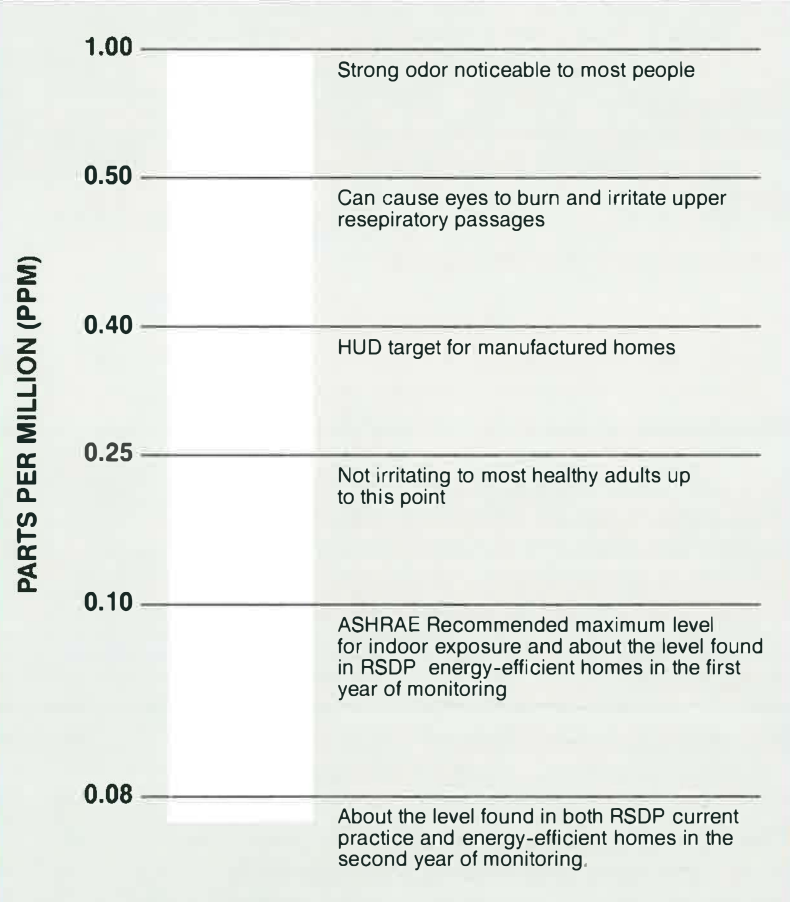
Formaldehyde is highly irritating to skin, eyes, mucous membranes and the respiratory tract. Short-term, low exposure may cause eye, nose and throat irritation.[20] These health problems usually stop as soon as exposure stops.

Individual sensitivity to formaldehyde varies. About 10 to 20 percent of the population appears to be highly sensitive to formaldehyde at low levels.[21] Some people report mild eye, nose and throat irritation at concentrations less than 0.5 Ppm, while others note these symptoms at concentrations as low as 0.25 Ppm.[22] Low concentrations can also cause asthmatic symptoms in some susceptible people, and chronic exposure can make people more sensitive to formaldehyde.[23]

Exposure to 1 to 2 Ppm may cause headaches, nausea, coughing, constriction in the chest, a feeling of pressure in the head and rapid heartbeat.[24] Over a long period of time, exposure to formaldehyde may cause changes in the respiratory system.[25]

Studies have shown that formaldehyde can produce nasal cancer in animals. To date, however, there is no direct evidence that formaldehyde causes cancer in humans. Nevertheless, to minimize potential health risks, the Federal Panel on Formaldehyde, and several federal agencies, have concluded that formaldehyde should be considered a *carcinogen* until information to the contrary is available.[26]

Formaldehyde Concentrations



Source: Gupta et al., "Formaldehyde in Indoor Air: Sources and Toxicity," Environment International

Formaldehyde Levels in Homes

Because of the range of products available containing formaldehyde, it is impossible to predict what level of formaldehyde would be found in a given residence. On-site measurements would be necessary. However, limited measurements indicate a range of formaldehyde concentrations likely to be found in homes (shown in the chart).

If a home has a high level of formaldehyde, the occupants are likely to be aware of it. Most people notice the strong odor of formaldehyde at about 1Ppm. Some people can smell formaldehyde at much lower concentrations.

Products meeting HUD standards for mobile-home construction are stamped or tagged, and can be used in all new homes.

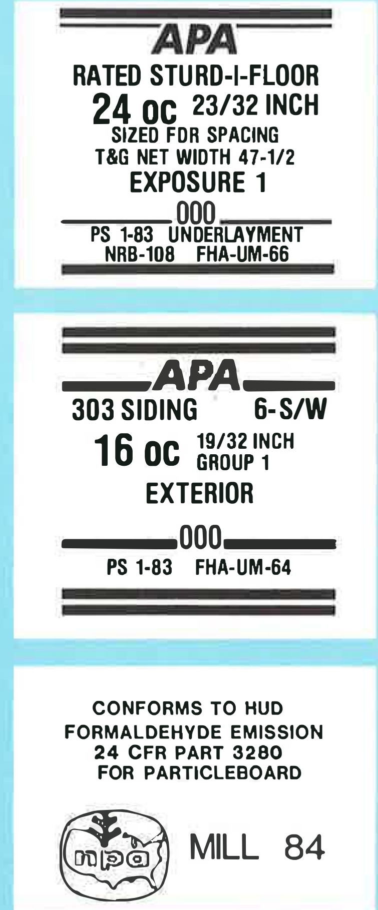
The rate at which formaldehyde is released from materials varies. As products containing formaldehyde age and cure, they emit less formaldehyde. Though the rate is not well defined, it appears that half of the formaldehyde contained in most materials is released in two to five years.[27] Formaldehyde levels also increase with higher temperatures and humidity. Relatively high levels of formaldehyde are likely to be found in new homes, where materials have not had time to release much gas.

BPA measured formaldehyde levels in about 876 Northwest homes over a 2-year period as part of the RSDP.[28] In the first year of measurements, researchers found that energy-efficient homes had a slightly higher formaldehyde level than current practice homes, 0.102Ppm versus 0.083 Ppm. In the second year, both home types had very similar levels, 0.076 Ppm in energy-efficient homes and 0.084 Ppm in current practice homes. These findings indicate that dwelling age is a primary factor in determining formaldehyde concentrations.

Monitors

An inexpensive easy-to-use formaldehyde monitor is available for consumers. This small measuring device is placed in a room for about a week, and then mailed to a laboratory for analysis. A list of businesses that sell these monitors is available from BPA's local area offices (See Page 24 for area office telephone numbers).

Formaldehyde levels in homes can be measured with a small monitor.



Consumers can look for stamps like these to find particle board and plywood that is "low-fuming" or made with non-urea resins.

Reducing Formaldehyde Exposure

The easiest way to reduce formaldehyde levels is to avoid products made with urea-formaldehyde resins or to use products made with low concentrations of these resins.

- **Use "low-fuming" formaldehyde products.** Particle board and plywood manufactured to produce less formaldehyde gas can substantially reduce levels in new homes. Many manufacturers are making low-fuming particle board and plywood to meet *HUD's* standards for mobile homes. These products are becoming widely available and are stamped for easy identification.

- **Use building materials that do not contain urea resins.** Products made with exterior glues containing "phenol" resins release less formaldehyde than products made with interior grade glues containing "urea" resins. Manufacturers belonging to the American Plywood Association stamp interior type products made with exterior glues with an "Exposure 1" classification. Exterior type products are stamped "Exterior." Natural wood can also be used as a substitute.

- **Increase air exchange rates.** This may also reduce formaldehyde levels. However, the amount of formaldehyde in the air has a bearing on the amount of formaldehyde released from sources.[29] Emission rates tend to decrease as room concentrations increase, until a balance point is met. When air exchange rates are increased, outside air will dilute and flush indoor levels of formaldehyde. But part of the benefit will be lost because pollutant sources may emit more formaldehyde until a new balance point is met. Although increased ventilation does help to lower concentrations, exactly how much it helps is still being studied.[30]

- **Seal sources of formaldehyde.** Where you have access and the decor of your home allows, it may be possible to seal some sources of formaldehyde using vinyl sheet flooring, paints, shellac, varnishes or lacquer. But the coating must be continuous and remain intact to be effective.

- **Install a dehumidifier.** Formaldehyde levels may be controlled by lowering indoor humidity levels.[31]

COMBUSTION GASES: CARBON MONOXIDE and NITROGEN OXIDES

Carbon monoxide is a colorless, odorless gas. It is a product of incomplete combustion when natural gas, oil, wood, coal, tobacco and other materials are burned. Carbon monoxide increases when there is an inadequate supply of combustion air, as is often found in improperly maintained woodstoves, gas stoves, oil stoves and furnaces.

The nitrogen oxides, nitrogen oxide and nitrogen dioxide, are gases formed during combustion.

An unvented gas stove is a major source of carbon monoxide and nitrogen oxides.

Sources

Unvented kerosene space heaters, wood stoves, gas stoves and tobacco smoke are major sources of carbon monoxide. Faulty furnaces and exhaust fumes from garages attached to homes are less common sources, but they can contribute significant amounts of carbon monoxide to indoor air.[32]

The major sources of nitrogen oxide and nitrogen dioxide are unvented gas stoves and kerosene space heaters. High outdoor levels of nitrogen dioxide, found in highly industrialized areas, can also affect indoor levels.[33]

Measurement and Standards

Carbon monoxide measurements are often given in parts per million. A measurement of 1 Ppm would indicate the presence of one unit of carbon monoxide in a million units of air.

No federal or state standards exist for carbon monoxide in residences. Japan, the only country with a standard for carbon monoxide in nonoccupational indoor environments, has set a limit of 10 Ppm for continuous exposure. The EPA standard for maximum allowable level of carbon monoxide in outdoor air is 9 Ppm exposure averaged over eight hours, and 35 Ppm for a 1-hour average exposure. This standard has a safety margin built in to protect people with angina.[34] These people have inadequate blood and oxygen flow to the heart, so they are especially sensitive to any interference with the body's ability to absorb or distribute oxygen.

Oxides of nitrogen are often measured as parts per million. A measurement of 1 Ppm would indicate the presence of one unit of nitrogen oxide or dioxide in 1 million units of air.

No indoor standard has been set for nitrogen oxide or nitrogen dioxide. EPA's standard for maximum allowable concentration of nitrogen dioxide in outdoor air is 0.05 Ppm (averaged over a year).

Health Effects

Carbon monoxide interferes with the delivery of oxygen throughout the body.[35] Mild oxygen deficiencies can affect vision and brain function. Exposure to concentrations of carbon monoxide 10 to 20 times greater than that generally found in homes can cause headaches and irregular heart beat.[36] Higher concentrations can cause nausea, weakness, confusion and death. Carbon monoxide poisoning from faulty oil and gas furnaces and from cars left running in attached garages cause several deaths each year.[37]

Oxides of nitrogen can cause changes in the respiratory system. Healthy people are generally not affected at levels of 1.5Ppm or below. But sensitive individuals can experience respiratory tract irritations at 0.5Ppm. Children and persons with asthma, chronic bronchitis and other respiratory disorders appear to be the most sensitive.

Prolonged exposure to high levels of nitrogen dioxide (about 50 Ppm) can cause lung damage and chronic lung disease.[38] But the scientific community is not yet in agreement that prolonged exposure to low levels of nitrogen oxide and nitrogen dioxide can cause chronic respiratory illnesses.[39] Information on chronic nitrogen dioxide poisoning is extremely scarce because: (1) symptoms do not appear until a critical concentration is reached; (2) respiratory damage develops slowly; and (3) it is difficult to isolate the effects of nitrogen dioxide from those of associated pollutants.[40] Research on the health effects of exposure to low levels of nitrogen dioxide is continuing.

Carbon Monoxide Levels in Homes

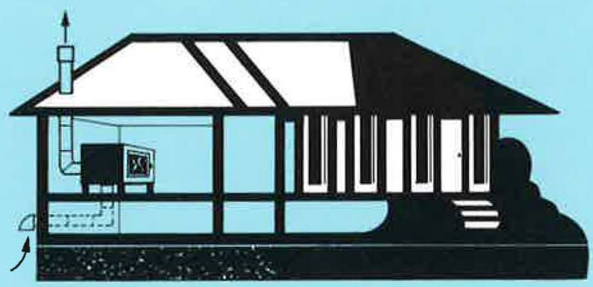
The average carbon monoxide concentration in homes typically varies between 0.5 and 5 Ppm.[41] Cooking over a gas stove can add 5 to 10 Ppm to the existing level.[42] Concentrations of 22 Ppm and 39 Ppm have been measured for poorly adjusted gas stoves.[43]

Unvented gas or kerosene heaters can emit high levels of carbon monoxide. In laboratory tests, a convective kerosene heater produced carbon monoxide levels of 50 Ppm after 45 minutes, even though the laboratory air change rate was twice that found in a typical house.[44] Several states have banned residential use of kerosene heaters.

Nitrogen Oxides Levels Found in Homes

Short-term nitrogen dioxide concentrations equaling or surpassing EPA's standard for outdoor annual average concentrations (0.05 Ppm) are fairly common in kitchens where natural gas is used for cooking.[45] Measurements indicate that typical levels in kitchens with gas stoves range from 0.025 Ppm to 0.08 Ppm.[46] Concentrations in homes without gas appliances would be the same as the outdoor level.[47] In the Pacific Northwest, the typical outdoor level of nitrogen dioxide is 0.03 Ppm, though levels vary with location.[48] (Nitrogen dioxide in the outdoor air comes mainly from motor vehicle and industrial emissions). In a study of electrically heated Northwest homes, indoor levels of nitrogen dioxide were all less than outdoor levels.[49]

Unvented space heaters are major sources of nitrogen dioxide. In laboratory tests, nitrogen dioxide concentration from a convective kerosene space heater reached 1 Ppm after 45 minutes—about 20 times the EPA standard for average annual concentrations in outdoor air.[50]



Monitors

Passive monitors are available for both nitrogen dioxide and carbon monoxide.

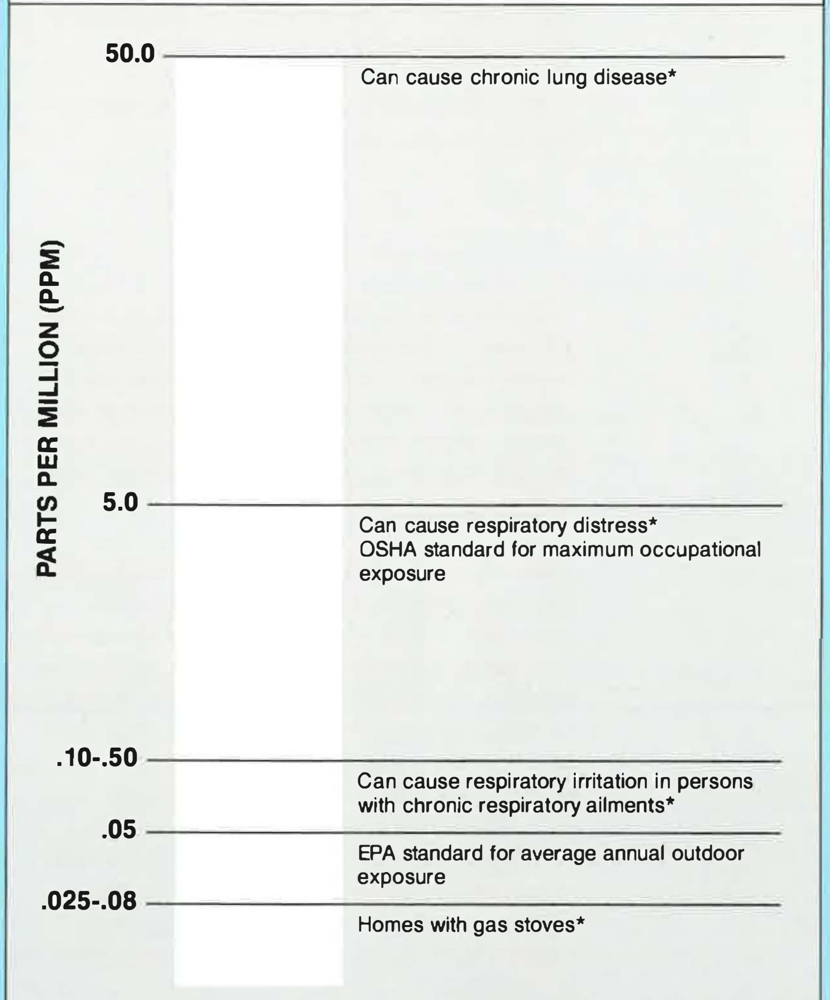
Reducing Exposure to Combustion Gases

- **Choose a properly sized woodstove to heat your home.** Oversized stoves burn more fuel, produce more pollutants, and will overheat your home. Energy efficient homes require very little heating and may not need a woodstove.

- **Supply outside combustion air directly to the firebox in woodstoves and fireplaces.** BPA requires this in its programs and recommends it in local building codes.

- **Have fireplace flues and chimneys inspected and cleaned frequently.**

Nitrogen Dioxide Concentrations



*Electric Power Research Institute, *Manual on Indoor Air Quality*

- **Make sure that wood stoves are installed correctly with tight fitting doors and stovepipes that have no cracks or leaks.**

- **Install and use tight fitting glass doors on fireplaces.**

- **Do not let fires smolder.**

- **Avoid opening and closing woodstove doors.**

- **Make sure that all household combustion appliances are vented to the outside.**

- **When using combustion appliances, provide cross-ventilation by opening two opposite windows.**

- **Install an active ventilation system.**

- **Avoid sealing a crawl space where an oil or gas heater is vented.**

- **Make sure that gas appliances are properly adjusted and leak-free.** If your stove is not properly adjusted, it is likely to have a yellow-tipped rather than a blue-tipped flame. Call your gas company for assistance.

- **Do not leave your car engine running inside an attached garage.**

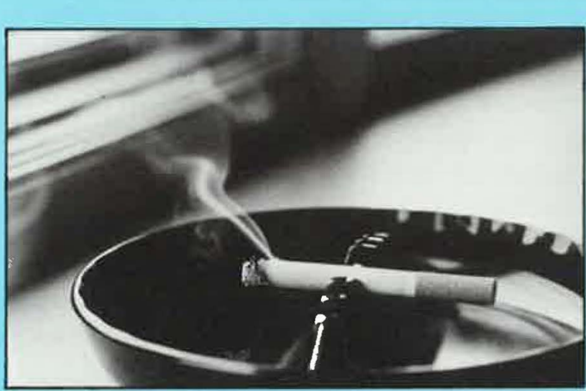
RESPIRABLE SUSPENDED PARTICULATES (RSP)

Respirable suspended particulates (RSP) are particles or fibers in the air which are small enough to be inhaled. These particles can lodge in the lungs and irritate or damage lung tissue. Many different particulates are found in homes, including soap powders, pollen, lint and dust.

Asbestos is a mineral fiber used mostly before the mid-1970s in a variety of construction materials. While chronic exposure to asbestos has led to respiratory diseases and cancer in workers, exposure to asbestos in the home only occurs when asbestos material are disturbed and the fibers are released into the air. In new homes exposure to asbestos is unlikely. The U.S. Environmental Protection Agency, the Consumer Product Safety Commission, and manufacturers have taken steps to reduce exposure. In the mid-1970s these groups prohibited or voluntarily stopped using asbestos in the following products: sprayed on insulation, fire protection, soundproofing, pipe coverings that easily crumble, artificial logs, patching compounds and hand-held hair dryers.

Sources

Tobacco smoking is a source of most respirable suspended particles in homes. Wood smoke, unvented gas appliances and kerosene space heaters also produce RSP.



Tobacco smoke is usually the largest indoor source of respirable suspended particulates, including benzo-(a)-pyrene, a suspected carcinogen.

Woodstoves and fireplaces are likely to emit pollutants under the following conditions: improper stove installation such as insufficient stack height, poor flue fittings or leaky doors. This can also occur when the fire is being stoked or fuel is being added, during accidents (such as when a log rolls out of the fireplace), when the fire is allowed to smolder, or when negative indoor air pressure (for example, from an exhaust fan) results in backdrafting.

Measurement and Standards

RSP measurements are given as micrograms (one-millionth of a gram) per cubic meter (ug/m^3). As yet there is no standard for respirable suspended particulates, although the EPA has an outdoor standard for total suspended particulates (TSP). TSP includes larger particles as well as RSP. Since larger particles appear to be filtered out by the nasal passages rather than becoming lodged in the lungs, they are not believed to pose a serious health problem.

The EPA's standard for the maximum allowable level of total suspended particulates in outdoor air is 75 ug/m^3. Japan has set an indoor (nonoccupational) standard for TSP of 150 ug/m^3.

Health Effects

Particulates are composed of many compounds which at elevated levels can irritate eyes and mucous membranes. Dust is an irritant and can also carry gases or other substances into the lungs. Respiratory illnesses, especially chronic illnesses like bronchitis and emphysema, are linked to exposure to particulates.[51]

Cigarette smoking is believed to cause lung cancer, emphysema and heart disease. According to recent studies, tobacco smoke can affect the health of nonsmokers. In a room where cigarettes are smoked, sidestream smoke inhaled by nonsmokers can irritate the eyes, nose and throat, even when there is "adequate" ventilation.[52] Sidestream smoke can also cause respiratory infections and can aggravate the condition of people with allergies or with heart or lung disease.[53] Studies have linked respiratory illness in children with parental smoking.[54]

Some researchers are beginning to link exposure to sidestream cigarette smoke with an increase risk of lung cancer, but no reasonable estimates of health effects are now possible.

RSP Levels Found in Homes

Concentrations of RSP in homes where there are no smokers are likely to be about the same as outdoor levels, 20 ug/m^3.[55] Monthly concentrations of RSP in a home with one smoker have been measured at about 40 ug/m^3.[56] In the same study, with two or more smokers, an average monthly concentration of RSP was measured at 75 ug/m^3, equal to the EPA outdoor standard for all particulates.

Reducing RSP Exposure

- **If you smoke, smoke near an open window.**

- **Choose a properly sized woodstove to heat your home.** Oversized stoves burn more fuel, produce more pollutants, and will overheat your home. Energy efficient homes require very little heating and may not need a woodstove.

- **Supply outside combustion air directly to the firebox in woodstoves and fireplaces.** BPA requires this in its programs and recommends it be required by local building codes.

- **Have fireplace flues and chimneys inspected and cleaned frequently.**

- **Make sure that wood stoves are installed correctly with tight fitting doors and stovepipes that have no cracks or leaks.**

- **Install and use tight fitting glass fireplace doors.**

- **Do not let fires smolder.**

- **Avoid opening and closing woodstove doors.**

- **Vent all combustion appliances to the outdoors.**

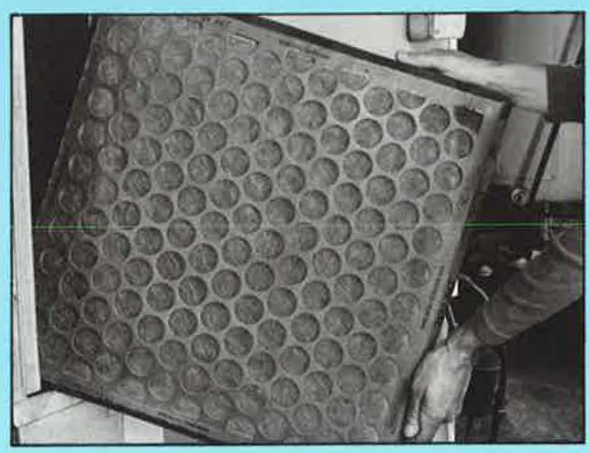
- **Burn seasoned, dry wood.**

- **Increase ventilation by opening windows or installing active ventilation.**

- **Change filters regularly on forced-air heating or cooling systems.**

- **Ask friends not to smoke in your home.**

- **Use a particulate filter or air cleaner.**



Change furnace filters regularly to reduce particulates in the air.

HOUSEHOLD CHEMICALS

Many of the chemicals used in household cleaners, pesticides and material contain toxic substances. These chemicals are often referred to as "organic compounds" because they have a carbon base.

Sources

Household chemicals are as varied as consumers habits, hobbies and furnishings. Synthetic materials used in carpeting, wall coverings, linoleum fabrics, rubber and plastic emit organic compounds as they age and deteriorate. Adhesives, cleaning agents, paints, personal hygiene products and waxes contain solvents that evaporate into the air. Pesticides, insecticides and herbicides contain a variety of toxic chemicals. Aerosol sprays contain propellant gases, such as propane, butane and nitrous oxide. Finally, natural gas, tobacco, wood and other materials emit organic gases and particles during combustion.

Read product labels and follow instructions. Labels have important information about possible hazards.

Health Effects

Household chemicals contain such a wide variety of organic compounds that health effects are difficult to assess.[57]. Each compound has different effects, and when products are combined, they may interact and produce still other health effects. Some compounds are irritants, others cause cancer. Some affect the central nervous system, some interfere with metabolic processes.[58]

Concentration Found in Homes

Concentrations of specific organic compounds in homes are generally well below occupational exposure levels established by *OSHA*.[59] However, OSHA standards were designed for an industrial setting where workers are exposed to high levels of single compounds. In homes, people are likely to be exposed to several compounds at low concentrations at the same time. As yet researchers know very little about the combined effects of organic compounds or the effects of exposure to low levels over long periods of time.

Reducing Exposure to Household Chemicals

- **Before using household chemicals, read the label carefully.** Products usually carry warning and instructions for use aimed at reducing exposure.

- **Use chemicals only in well-ventilated areas.** Consider using them only outdoors or in an area detached from the house or equipped with an exhaust fan.

- **Store household chemicals in a well-ventilated outdoor space, such as a detached garage or outdoor shed.** Gases and vapors can leak from containers. For safety, keep these materials locked up.

- **Substitute less hazardous products for household chemicals.** For instance, use a liquid or dry form of a product rather than aerosol sprays. Ventilate or clear a room to control odors rather than use a room deodorant.

Household chemicals contain many toxic substances. Use these products only in well-ventilated areas, and store them outside in a garage or shed. If possible, lock them up for safety.

MOISTURE

Moisture, a product of every day life, is usually not considered a pollutant. However, when it becomes excessive it may lead to structural and health effects.

Sources

Moisture in homes comes from many sources. Usually these are within the home and come from typical household activities. The following table describes several common sources and the amount of moisture a typical family of four will produce in a day.[60]

Typical Daily Moisture Generated By a Family of Four	
Sources	***Pints of Water Generated Per Day***
Breathing and Perspiring	12
Dishwashing	1
Showers/Baths	2
Cooking	4
Laundering	5
TOTAL	***24 Pints Per Day***

Other activities that can dramatically increase the amount of moisture in your home include installing an indoor sauna, spa, or hot tub, keeping many plants, or drying laundry on indoor lines or in an unvented dryer.

Moisture can also enter the home from outside. As much as 20 gallons of water per day will evaporate from moist soil under a 1,400 square foot crawl space.[61] How much of this moisture enters your home depends on the measures taken to block its entry. Other sources include leaks in ceilings and walls.

Measurement and Standards

Moisture in the air is often measured as relative humidity (RH). The amount of moisture air can hold depends on its temperature. Cooler air cannot hold as much water vapor as warmer air. When air holds all of the moisture that it can at a given temperature, it becomes saturated, and has a relative humidity of 100 percent. Since warm air can hold more water vapor than cool air, the relative humidity of the air increases as its temperature decreases. If the air cools to the point where it becomes saturated, part of the moisture is given up as condensation.

Relative humidity levels from 30 percent to 60 percent are important to maintaining a comfortable indoor environment.[62]

Health Effects

The health effects of high moisture levels are not clearly understood. Moisture-related micro-organisms such as spores, mold, mildew, mites, bacteria and viruses may multiply in high-humidity[63] or high moisture.

Moisture also affects health by acting as a solvent for other pollutants.[64] For example, products made with urea-formaldehyde resins will emit higher levels of formaldehyde gas as relative humidity increases.

Reducing Exposure

The best ways to prevent excessive moisture are accomplished when a home is being designed and built:

- **Install a 6-mil black polyethylene ground cover in the crawl space.**
- **Ensure adequate ventilation in the attic crawl space.**
- **Add ducts to carry moisture outside from clothes dryers and other moisture-producing appliances.**
- **Use fans (spot ventilation) in kitchens, bathrooms and other moisture-producing areas.**
- **Place proper drainage in crawl spaces and in the ground adjacent to the house.**
- **Install a dehumidifier, air-to-air heat exchanger or other active ventilation system.**

Most of these methods are included in the Council's and BPA's requirements for energy-efficient homes meeting the Model Conservation Standards.

Preventive measures, such as placing ground covers over exposed soil in crawl spaces, help block the movement of moisture into the home.

BONNEVILLE'S INVOLVEMENT WITH INDOOR AIR QUALITY

BPA was among the first federal agencies to become concerned with the issue of air quality in homes. Before embarking on programs to improve the energy efficiency of new and existing homes, BPA reviewed the scientific research available on indoor pollutants.

To help fill the information gaps, BPA sponsored original studies on the effect of house-tightening measures on air change rates and pollutant levels, and ways of controlling indoor pollutants.

One result of this work was an *Environmental Impact Statement* in which the costs, benefits and risks of weatherizing existing electrically heated homes in the Northwest were analyzed. The EIS was completed in the fall of 1984. BPA's analysis showed that pollutant levels in homes are generally low, though levels in any one home are difficult to predict. BPA concluded that when consumers are well informed about indoor pollutants and the problems they can cause, consumers can best determine if indoor air pollution is acceptable in their own homes.

BPA recently completed the final EIS on the effects of building new energy-efficient homes. This document was geared toward increasing the flexibility of builders and homebuyers in choosing pollutant control methods for use in BPA's new energy-efficient homes programs. Public distribution of the EIS occurred in August 1988.

New information will continue to be provided as it becomes available. If you have questions about BPA's research efforts, use the phone numbers listed below.

FOR MORE INFORMATION

If you have any questions on the information presented in this booklet, contact your nearest BPA Area or District Office or BPA's Public Involvement Office, P.O. Box 12999, Portland, Oregon 97212.

Phone: Public Involvement Office
(503) 230-3478 in Portland

toll-free (800) 547-8429 in Oregon outside Portland

toll-free (800) 547-6048 in other Western states

BPA Area and District Offices:

Portland	(503) 230-3490
Eugene	(503) 345-0311
Seattle	(206) 442-4130
Spokane	(509) 456-2518
Missoula	(406) 329-3860
Wenachee	(509) 662-4377
Walla Walla	(509) 552-6226
Idaho Falls	(208) 523-2706
Boise	(208) 334-9138

GLOSSARY

ACH: Air changes per hour.

Active ventilation: The movement of air into and out of a building, using mechanical devices.

Air change rate: Amount of air that flows into or out of a building in a specified amount of time.

Air exchange: The total movement of air into and out of a building by passive (natural) and active (mechanical) ventilation.

Alpha radiation: Particles emitted by radon progeny that may cause lung cancer.

ASHRAE: Abbreviation for "American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc."

Benzo-(a)-Pyrene (BaP): A tarry, organic material that is a by-product of incomplete combustion. BaP has been shown to induce cancer in animals.

BPA: Bonneville Power Administration

Carbon Monoxide: A colorless, odorless gas that comes from incomplete combustion.

Carcinogen: A substance thought to be capable of causing cancer.

Concentration: Amount of a pollutant in a given volume of air.

Contaminant: Substance in the air that is not normally present or that is present in greater-than-normal concentration.

Diffusion: Spontaneous scattering of particles and molecules throughout the air from areas of high concentration to areas of low concentration.

Emission: A discharge of pollutants into the atmosphere.

Emission rate: Amount of a *contaminant* released into the air by a source in a specified amount of time.

Environmental Impact Statement: A document prepared by a federal agency assessing the environmental effects of its proposals for legislation and/or other major actions significantly affecting the quality of the human environment. Environmental Impact Statements are used as tools for decisionmaking and are required by the National Environmental Policy Act of 1969.

EPA: U.S. Environmental Protection Agency.

Formaldehyde: An organic chemical widely used to bond material. Formaldehyde-based glues and binders are widely used in plywood, particle board, and furniture, for example.

Guidelines: Criteria recommended by government agencies, professional organizations, or other groups. Guidelines are not legally binding.

House Tightening: The process of sealing cracks, joints and other nonintentional paths by which outside air may enter a residence.

HUD: U.S. Department of Housing and Urban Development.

Infiltration: Unintentional air leakage into, and for our purposes here, out of a structure through and around cracks, holes and joints. Air leakage out of a structure is often called exfiltration.

Low-fuming: Products made with formaldehyde resins designed to release less amounts of formaldehyde gas than otherwise comparable products.

Nitrogen Dioxide: A gas formed during combustion.

NWEC: Northwest Energy Code.

OSHA: Occupational Safety and Health Administration.

Passive ventilation: The movement of air through and around cracks and joints and windows and doors.

Pollutant: Contaminant present in a concentration high enough to cause adverse effects to health or environment.

ppm: Abbreviation for "parts per million," a unit of concentration. When applied to air pollutants, ppm refers to units of a pollutant per million units of air.

Radon: A natural occurring colorless, radioactive gas formed by the disintegration of radium.

Radon Progeny: Products of the radioactive decay of radon. The decay of radon leaves a charged metal atom that can attach to dust. Both attached and unattached particles can by inhaled and can lodge in the lung. The alpha radiation emitted by the radon progeny can damage lung tissue.

Respirable Suspended Particles (RSP): Particles less than 3.5 microns in diameter. When inhaled, RSP tend to be carried into the deepest part of the lung.

RSDP: The Residential Standards Demonstration Program. A Bonneville program to demonstrate and study energy efficient building practices, costs, and environmental effects.

Source: Object or process that releases contaminants into the air.

Standards: Criteria enacted by statute or regulation and are legally binding.

Urea-Formaldehyde Foam Insulation: A form of insulation blown into walls of homes, primarily during the 1970s.

Ventilation: The movement of air into and out of a building.

Whole-House Ventilation: An active ventilation system designed to move air into and out of an entire residence.

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