#4010

Indoor Air Pollutants

COMBUSTION PRODUCTS

FACTSHEET

WASHINGTON ENERGY EXTENSION SERVICE December 1987

The products of combustion from burning wood, coal, tobacco, oil, gas, or kerosene can enter the indoor environment. In many instances, combustion products from space or water heating systems are simply vented to the outdoors through a chimney flue. However, there is wide use of unvented heaters and stoves which do release a variety of potential contaminants. Potentially harmful combustion products include carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NOx), sulfur dioxide (SO_2), formaldehyde (HCHO), particulates, and benzo-(a)-pyrene (a carcinogen). In addition to the sources mentioned above, combustion products from automobile exhaust can enter the home from an attached garage.

Figure 1

MAJOR COMBUSTION PRODUCTS OF CONCERN
Carbon Monoxide (CO)
Nitrogen Oxides (NOx)
Respirable Suspended Particulates

Field studies of concentration of NOx, CO, and CO_2 in homes with unvented gas appliances and unvented kerosene heaters have been conducted. In homes with unvented gas appliances, elevated levels of CO and NOx have been measured. Kerosene heaters have been observed to contribute to high concentrations of CO_2 and NOx. There is not conclusive medical opinion on the health effects of relatively low-level long term exposure to these contaminants. At certain thresholds the nitrogen oxides are a respiratory irritant, and some studies have speculated on possible lung damage from long term exposure. At high levels CO and NOx inhibit the blood's ability to transport oxygen and can cause serious injury and death.

Figure 2

SOURCES OF HIGH EXPOSURES TO CO AND NOx
Auto exhaust from an attached garage
Faulty furnace
Improperly operated flame
Unvented combustion appliance in an enclosed space

Woodburning in a woodstove, furnace, or fireplace has also been implicated as a source for CO, NOx, particulates, and benzo-(a)-pyrene. While the actual field studies of wood burning residences have been quite limited, airtight and non-airtight woodstoves have been found to produce measurable amounts of pollutants in the home. Pollutants enter through leaks in the stove and chimney, during startup and reloading, during downdraft or plugged chimney conditions and through air exchange with polluted outdoor air.

Use of new technology stoves, improved to the installation and better operation can reduce both indoor and outdoor pollution from woodstoves.

Figure 3

% OF CARBOXYHEMOGLOBIN BLOOD CONCENTRATION (caused by CO in blood - more is worse)	
Non smokers in rural communities	.7%
Non smokers in urban communities	1%
"Passive" smokers	2-3%
Smokers	5-6%

More research has been done on tobacco smoke combustion. Indoor air pollutants from smoking include CO, benzo-(a)-pyrene, nicotine, and aldehydes. The concentrations of these pollutants obviously vary by the amount of smoking and the type of cigarette that is smoked. While the smoker is exposed to much greater levels of these pollutants, all building occupants are exposed to "passive smoke".

Respirable suspended particulates (RSP) are particles that are in the air and small enough to be inhaled into the lungs. They are comprised of many different compounds, some of which may be harmful. They can also transport carcinogenic agents such as radon and benzo-(a)-pyrene into the lungs. Respiratory illnesses may be aggravated by exposure to RSP.

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Control of indoor air pollution due to combustion products can be enhanced by assuring good combustion efficiency and proper venting of combustion gasses, avoiding unvented combustion appliances, and providing adequate ventilation.

Organic Compounds

The existence of numerous organic compounds in a vapor state or as particles in the indoor air of a home is quite typical. The home's furnishings and interior building materials emit organic vapors as they age and degrade. Carpets, wall coverings, pesticides, plastics, household cleaners and solvents are typical sources. In most cases, the concentration of these vapors is low enough that no health effects are observed. However, as with all indoor air pollutants, if the source of the pollutant is in sufficient quantity and its emission sufficiently high, health problems can occur.

Most common organics are refined petroleum hydrocarbons which can be traced to sources such as cleaning fluids, paint thinners, solvents, drain cleaners, and window cleaners. Automobile emissions can be an outdoor source as well. Plastics emit polymer compounds such as vinyl chloride and other plasticizers. Home furnishings are also a major source of organic compounds.

Pesticides are found in indoor air environments as 90 percent of all homes are reported to use them. Numerous pesticide compounds are used including carbaryl, acephate, diazinon, and chlordane. (The use of chlordane was banned by the EPA in the mid 1970's except for termite control). Pesticides, once in the home, can remain as an air contaminant for a very long time.

The list of organic vapors contains many compounds - over 250 have been found in residential air environments. The ones mentioned above are just some of the more common compounds. Some of these agents are known to be toxic while others are simply irritants. Very little is known about the effects of these compounds on the health of building occupants or the synergistic health effects of combinations of them. More research in this area is underway.

Of course, the limitation or removal of sources is the most effective way to reduce organic compound concentrations. Increased ventilation will also lower the contaminants' concentration in the air. It should be kept in mind, however, that the mere presence of organic vapors in the air does not indicate that human health will be affected or that mitigation strategies are warranted.

Written By Mike Nuess and Stan Price.

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FS-1803 (11/87)

Indoor Air Pollutant
FORMALDEHYDE

FACTSHEET

WASHINGTON ENERGY EXTENSION SERVICE December 1987

Formaldehyde is a highly reactive chemical that is emitted in gaseous form from a number of sources in the home. In 1987, production of formaldehyde in the United States was 5.9 billion pounds. The industrial uses of formaldehyde are numerous and there is currently no economically available substitute. It is used in urea formaldehyde (UF) adhesive for particle board, hardwood plywood, and medium density fiberboard. Formaldehyde is also used in some upholstery, carpet and carpet glues, wallpaper, urea-formaldehyde foam insulation, and paneling. In addition, formaldehyde is a by-product of combustion from gas and woodburning stoves as well as cigarette smoking.

A major source of formaldehyde in the home is building materials. Formaldehyde gas emissions from these materials result from the release of unreacted formaldehyde in the glue mixture that bonds these materials together. Formaldehyde gas emissions also result when water vapor reacts with the cured UF resin, breaking down the urea formaldehyde bond and releasing additional formaldehyde. The warm and humid conditions necessary for this breakdown can occur frequently in some homes.

As indoor concentrations of formaldehyde levels increase, some occupants will begin to experience physical reactions. These reactions differ by individual sensitivities and other health related factors. Common complaints are reported as headaches, dizziness, nausea, and other eye, respiratory, and skin irritations. People vary widely in sensitivity to formaldehyde. It has been estimated that between 10-20 percent of the U.S. population may be susceptible to formaldehyde at very low concentrations. The wide range of sensitivity to formaldehyde makes it difficult to:

- o Determine whether the indoor air is overly contaminated; and
- o Assign the presence of physical symptoms to formaldehyde exposure.

Environmental experts disagree on what is a "safe" formaldehyde level for the general population (those that do not have extreme sensitivities). The National Indoor Environmental Institute, ASHRAE, and the American National Standards Institute recommend a limit of 0.1ppm (parts per million) for indoor levels.

Formaldehyde will vaporize from its sources for an indefinite period of time. The rate of its emission is not constant and a 50 percent fluctuation in daily concentrations of formaldehyde is not uncommon. Wood products with UF resins outgas at a higher rate when new. Thus, over time, formaldehyde concentrations from these sources can be expected to decline, though outgassing will continue for a number of years. Additionally, high temperature and humidity levels can triple or quadruple formaldehyde levels.

The lower the source strength, the lower the indoor concentrations will be. Becoming aware of the composition of home furnishings such as kitchen counters, cabinets, bookshelves and coffee tables, in order to avoid excessive use of formaldehyde emitting materials is a good beginning.

FORMALDEHYDE CONCENTRATIONS	
Typical Outdoor Range	.01 - .03 ppm
Typical Indoor Range	.01 - 2 ppm
ASHRAE & ANSI maximum exposure guideline	.1 ppm

Figure 1. Formaldehyde Concentrations

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For example, softwood plywoods, waferboard, and oriented strand board don't emit formaldehyde because the glues are based on phenol formaldehyde resins which have a different chemical nature when cured. Secondly, one can use building materials that are rated for low formaldehyde emissions. Recently, advanced UF adhesives have resulted in large reductions in formaldehyde emissions from wood products. Certain building codes (such as the Model Conservation Standards of the Northwest Power Planning Council) now specify a maximum permissible formaldehyde emission rate. the Department of Housing and Urban Development has set a standard for formaldehyde emissions in manufactured housing of less than .2ppm for plywood and .3ppm for particle board, and many products are stamped to indicate compliance with the HUD standards. The HUD standards are designed to provide an ambient level of .4ppm or less in manufactured housing.

Loose fill insulation such as cellulose or mineral fibers can be used in place of urea-formaldehyde foam insulation (UFFI). However when properly installed, UFFI presents no threat to health, and has been used safely in Europe for over 30 years. Failure to observe stringent mixing and installation requirements led to the UFFI related formaldehyde problems in the U.S. and in 1982 the Consumer Product Safety Commission banned UFFI insulation in homes. However this ban was overturned by a federal court in 1983 and it is no longer banned. If you have UFFI insulation in your home it is possible to test formaldehyde concentration levels with relatively inexpensive passive monitors. Most UFFI installations are now more than five years old, so emission rates have dropped significantly below initial levels.

Where formaldehyde-based wood products are used in significant quantity, and removal is impractical, the application of a sealing coating can reduce emissions.

SEALING FORMALDEHYDE EMITTING SURFACES

PAINTS	COVERINGS
Polyurethane (most effective)	Vinyl
Epoxy (less effective)	Metal Foil
Latex (even less effective)	Kraft Paper

Figure 2. Sealing Formaldehyde Emitting Surfaces

The provision of adequate ventilation is essential in every home because it is impossible to eliminate all pollutant sources (for example people!). Efforts to both assure proper ventilation and maintain lower humidity levels can help reduce formaldehyde levels. However, ventilation alone will be impractical in many cases because of the strength of the formaldehyde source. One way to increase ventilation without paying as great an energy penalty is with heat recovery ventilation (See the WEES factsheets on ventilation).

If source removal, source reduction, and reasonable levels of ventilation are insufficient, you can reduce formaldehyde levels through use of an air recirculation system that removes formaldehyde from the air with a potassium permanganate and elumine filter. Common air purification systems using charcoal filters and/or electrostatic precipitation are not effective at removing formaldehyde from the air. In extreme cases, such as mobile homes built with large amounts of formaldehyde emitting wood products, fumigation with ammonia may be possible.

If you would like to measure your home for formaldehyde, you can do so with passive monitors that are exposed in the home for about a week and then returned to a laboratory for analysis. The cost is roughly $25-$50. You can obtain more information about monitoring for formaldehyde from WEES or your local health department.

Written by Mike Nuess and Stan Price.

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Indoor Air Pollutant
MOISTURE

FACTSHEET

WASHINGTON ENERGY EXTENSION SERVICE — December 1987

Water vapor is not typically viewed as an indoor air contaminant, but it does have an effect on comfort level and it also influences the emission rate of some other pollutants, formaldehyde for example. In addition, condensation that occurs on building surfaces can sponsor the growth of fungi and microbial contamination.

The comfort range of residential relative humidity levels is typically between 30 percent to 60 percent. Very low humidity levels can cause upper respiratory irritation while high levels increase the probability of condensation and fungal growth. The sources of moisture in the indoor air environment are numerous and varied. (See the WEES factsheet "Reducing Moisture Problems".)

SOME SOURCES OF MOISTURE IN THE HOME		
human occupants	house plants	unvented space heaters
cooling	pets	gas ranges
dishwashing	laundry activities	unvented clothes dryers
bathing	fish tanks	crawl space or basement floors and walls

Figure 1. Moisture Sources

If either moisture source control or ventilation is inadequate, house humidity levels can increase and cause moisture related problems. Warm humid house air can condense on cooler building surfaces, especially windows. Damp walls and decaying wood members can host a variety of fungi which will become airborne with any air currents. These fungal inhalants can cause allergic reaction in some individuals. Bacteria and viruses also thrive in moist house air. The presence of these microbes is not in any way unique to this type of environment. Microbial contamination is consistent with every type of environment except specially designed "clean rooms" used for medical or specialized manufacturing tasks. Under conditions of high humidity, water vapor can react with the cured urea formaldehyde resins in particle board, plywood, etc. and cause an increase in formaldehyde gas emissions.

By controlling the sources of moisture and utilizing localized ventilation in the kitchen and bathroom, most homes can keep humidity levels reasonable. In the coastal areas of the Northwest, however, a combination of high winter outdoor humidity in relation to moderated winter temperatures, makes the task of controlling moisture problems more difficult. Additional mitigation strategies include the air-to-air heat exchanger (if the model does not pass water vapor across the exchange medium) and dehumidifiers. It should be noted that dehumidifiers can only lower relative humidity to a low of 50-60 percent.

Written by Mike Nuess and Stan Price.

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Indoor Air Pollutant
PARTICLES

FACTSHEET

WASHINGTON ENERGY EXTENSION SERVICE

December 1987

Indoor air contains a significant number of particles (both solid and liquid ones) as aerosols in varying sizes and of various composition. Both organic and inorganic agents are found in the air, including pollens, spores, asbestos fibers, insect debris, food remnants, and pet dander. When the air is still, this material tends to settle, only to be resuspended when the air is disturbed by house cleaning or other activity. The air can also contain harmful microbes and heavy metals, though the latter are typically a problem from ingestion rather than inhalation.

Particle size is a significant determinant of the effect particulates have on building occupants. While the total suspended particulate count (referred to as TSP) is important, the upper and lower respiratory system generally screens larger particles from the lung. However, those particles of 10 microns or less (a micron is one millionth of a meter), also known as respirable suspended particles (RSP), can enter the blood or lymph tissue and cause a host of respiratory problems. For those individuals allergic to respirable particles, the reaction can cover a range of clinical syndromes from allergic rhinitis to bronchial asthma.

Other than house dust, tobacco smoke is probably the single greatest contributor to particle concentration in the home. A burning cigarette not only emits respirable particles, but a host of other contaminants including aldehydes and benzo-(a)-pyrene. The health effects impacting the smoker and those exposed to the smoke are well documented.

Other combustion devices such as wood or coal stoves and fireplaces also contribute to particulate concentration in the air. Airtight and non-airtight stoves both produce measurable amounts of particles in the home. When inhaled, these particles can carry other wood smoke contaminants such as aldehydes and benzo-a-pyrene into the lungs. Urban neighborhoods with a high level of woodburning often experience poor air quality in the winter. When outdoor air is laden with smoke particles, it can enter the home through natural or mechanical air exchange and pollute the indoor air.

Microbial air contaminants can range from bacteria and viruses to fungi and spores. Indoor air can contain a multitude of these bacterial or viral agents, primarily introduced by human activity ranging from sneezing to the shedding of skin scales. Many of these agents thrive on moist house dust and can be inhaled by occupants. Normal body defense mechanisms screen most of these microbial agents before they enter the lungs.

Other microbials in the form of fungi from damp surfaces or rotting wood can concentrate and cause allergic reactions in sensitive individuals. Seemingly innocent activity such as walking across a carpet, shaking out bed covers, or dusting can cause suspension of fungal spores and house dust.

Heavy metals can also be found as part of the TSP in the indoor environment. These metals, such as lead, cadmium, zinc and mercury typically infiltrate from outside sources such as automobile exhaust. Little is currently known on their effects at respirable levels found in homes, which are typically quite low.

Asbestos deserves special mention. For many years, asbestos was a common component of many building materials. The mere presence of material containing asbestos does not constitute a hazard. However if these materials are broken or crumble, they become "friable" and the asbestos fibers can enter the air and be breathed into the lung. Asbestos exposure has been shown to cause cancer of the lung as well as cancers of other organs. Asbestos related diseases generally appear 15 to 35 years after first exposure. It is not known how much asbestos exposure is necessary to cause disease, and no safe level of exposure has been established. The risk from asbestos exposure is significantly compounded by smoking.

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Figure 1. Asbestos Sources

SOME SOURCES OF ASBESTOS IN THE HOME	
Patching Compounds	Siding
Textured Paints	Furnace Body and Duct Insulation
Roofing	Hot Water Pipe Insulation

When materials containing asbestos fibers are found in the home, it is generally recommended that they not be disturbed by attempting to remove the material. Small repairs to damaged asbestos can be made with certain tapes and paints applied to seal the material and prevent crumbling. If, however, remodeling or another activity is contemplated that will necessitate its removal, appropriate safeguards should be taken. Though it is legal for a homeowner to remove asbestos, the homeowner must notify the local air pollution control authority before removing asbestos. Professional assistance is highly recommended, and professional asbestos removal contractors must be certified by the State Department of Labor and Industries.

A number of strategies can be employed to reduce particulate concentration in the home. The most obvious tactic is to reduce or eliminate tobacco smoke from the indoor environment. Fungal growth can be slowed by reducing excess humidity levels of the indoor air. In homes with woodstoves, use of new, highly efficient woodstoves can reduce the generation of smoke particles; and proper installation and careful operation can reduce the escape of wood smoke into the home. On poor air quality days, curtailment of woodstove use is an effective means of reducing indoor and outdoor particulate levels.

Particulate removal can be accomplished by using air filtration, electrostatic precipitators, and air ionizers. Filters, like those common in furnace systems, are typically a coarsely woven fiber that traps only the largest of particles. They are not particularly effective at reduction of RSP (10 microns and smaller). However, other filter types that screen very small particles are available. HEPA (High-Efficiency Particulate Air) filters remove very tiny particles with extremely high efficiency (99.5 percent efficiency for 0.3 micron particles). Each filter type will be rated by the size particle it traps, its resistance to air flow, and its service life. Recently, a new type of filter has come on the market which has a permanent negative charge in its fibers. These fibers attract particles as they pass through the filter and therefore are very effective.

Electrostatic precipitators work in much the same way by attracting particles to charged collection plates. The plates are removable and can be washed with soap and water. Electrostatic precipitators are available for installation in the duct of a forced air furnace or as portable units for independent operation. Though some units may produce a small amount of ozone, many include charcoal filters which effectively remove the ozone before it enters the room air.

Air ionizers or negative ion generators emit negative ions which charge airborne particulates. This negative charge makes the particulates attach to room surfaces which have a lower electrical potential. This is, however, not as desirable as removing the particle since the possibility of resuspension is always there. Air ionizers have been the subject of much debate and criticism due to questionable advertising claims for effectiveness and health benefits.

The existence of particles indoors should be kept in perspective. It should be stressed that the above mentioned devices do not remove gaseous contaminants such as formaldehyde from the air. Also, no measure of meticulous house cleaning can significantly reduce particle concentration. Their presence in the air is a natural and unavoidable situation. In cases where concentrations are high, individual sensitivities affected, or synergistic effects suspected (e.g. particulates in conjunction with other contaminants), a mitigation strategy is warranted.

Written by Mike Nuess and Stan Price.

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Indoor Air Pollutant
RADON

FACTSHEET

WASHINGTON ENERGY EXTENSION SERVICE

November 1987

Radon is an inert, radioactive gas created by the decay of radium, a naturally occurring metallic element found in varying concentrations in all soils. Radon is constantly emitted from the soil to the atmosphere where it rapidly becomes very diluted. When radon finds its way into the indoor environment it has a small volume of air in which to mix, and concentration levels can increase. An atom of radon has a half-life of about four days (one half-life is the time required for one half of a given amount of radioactive material to decay into other elements). The decay of radon is followed by four rapid decays that take place in about an hour, forming in each case a new atom. These four atoms are often called radon progeny or radon daughters.

While radon is chemically inert (will not combine with or react to other elements or molecules), the daughters are not. They often either attach to suspended particulates which are breathed into the lung, or are drawn directly into the lung and attach to the lung itself. Each radioactive decay emits radiation that can damage lung tissue. The only known health effect of radon is lung cancer. Radon is currently considered by the Environmental Protection Agency to be the second leading cause of lung cancer, causing roughly 5-10 percent of all lung cancers. Radon is also the largest single source of radiation exposure to the U.S. population.

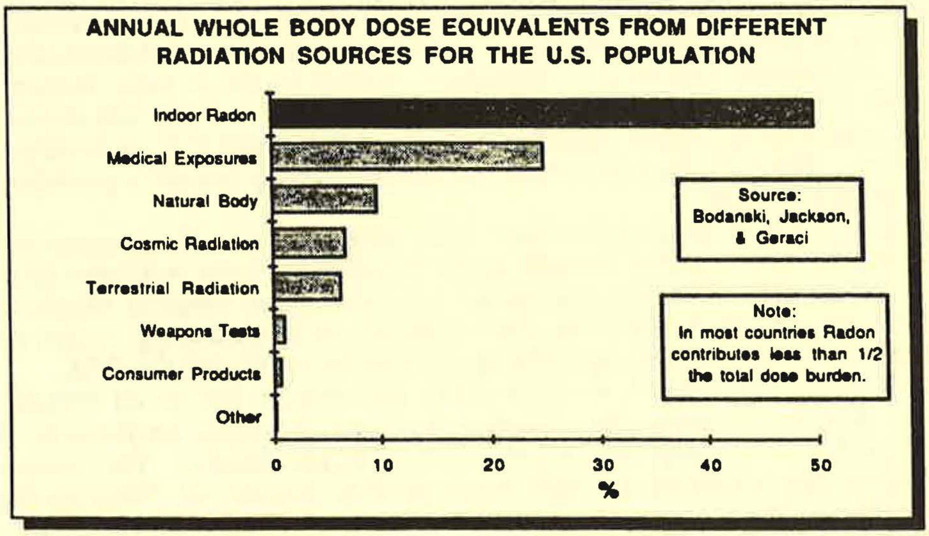

Figure 1. Radon Contribution To Total Radiation Dose Burden

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Sources of radon include soil gas, ground water, and earth or rock based building materials. The significant source of radon in Washington houses has typically not been building materials or water, but instead the soil around and under the home. Typical points of entry for radon emanating from the soil are:

- o Cracks in masonry slabs or foundation walls,
- o Electrical, gas, and plumbing service penetrations,
- o Floor drains and sump pits,
- o Top of concrete block walls,
- o Exposed earth, and
- o Joints between basement floor and wall.

Figure 2. Soil Gas Transfer

SOIL GAS TRANSFER INTO THE HOME
is primarily a
PRESSURE DRIVEN FLOW

ACTUAL RADON CONCENTRATION DEPENDS ON

- Radium Content of Soil
- Soil Permeability
- Indoor-Outdoor Temperature Difference
- Wind Speed
- House Ventilation Rate
- Leakage Distribution
- Construction Details
- Occupant Activities
- Rainfall and Barometric Pressure

Concentration of radon in the home is usually measured in picocuries per liter (pCi/L). One pCi/L is 2.2 radioactive decays per liter of air per minute (roughly 2 decays/quart/minute). The average level of radon in U.S. homes is about one pCi/L. The Bonneville Power Administration has measured more than 10,000 weatherized homes in Washington. Radon levels in these homes ranged from less than one pCi/L to 92 pCi/L. About 1.6 percent of those homes had radon levels above 5 pCi/L.

Though no standards for radon exposure have been set in the U.S., a number of agencies have established guidelines. The U.S. Environmental Protection Agency has set a guideline of no more than 4 pCi/L annual average exposure.

Though certain areas of Washington have more tested homes with elevated levels of radon than other areas, it is not possible to predict whether or not a particular home will have elevated radon levels until that home is tested. The EPA has established a Radon/Radon Progeny Measurement Proficiency Program that allows vendors to demonstrate their competence at measuring indoor radon levels. You may obtain the proficiency report listing qualifying vendors by contacting the EPA.

There are a number of ways to measure radon that require the use of expensive equipment by trained technicians. It is also possible for a homeowner to purchase passive monitors from a number of private vendors in the U.S. The cost ranges from $12 to $30 per monitor. The monitors are exposed in the home for an appropriate length of time and under specified conditions. They are then returned to the vendor for laboratory analysis. It is important to realize that radon levels in the home will vary significantly on both a daily and seasonal basis, so one must have an understanding of those factors that could affect the radon levels in order to monitor properly. The EPA has developed protocols for proper monitoring for each radon measurement method.

Once the home occupants' average annual exposure to radon has been measured, a decision can be made as to what kind of action is appropriate. A number of methods are available to mitigate radon levels in the home. Mitigation efforts have in some cases succeeded in reducing radon levels by more than 99 percent. Costs typically range from a few hundred to $2,000 to $3,000.

Each home is unique and the particular mitigation strategy will depend upon many factors including:

- o The type of home,
- o The condition of the home,
- o The radon source,
- o The percentage of radon reduction necessary,
- o The lifestyle of the occupants.

Basically there are two approaches to mitigating radon. The first is source control. It is seldom practical to eliminate the radon source but it is usually most practical to reduce the source strength by preventing radon's entry into the home. When elevated radon levels are due to a soil gas source, source control measures seek to:

- o Divert the flow of soil gas so it cannot enter the home; and
- o Seal openings, such as cracks and joints, between the home and the soil.

The second approach is ventilation. Generally ventilation cannot achieve reductions as significant as source control, but ventilation can often complement source control measures. Also, ventilation can be a good choice when smaller reductions are necessary. The following table lists a number of measures that can be used either individually or in different combinations to reduce radon from a soil gas source.

Table 1. Mitigation Strategies

MITIGATING RADON FROM A SOIL GAS SOURCE	
SOURCE CONTROL Keep It Out	VENTILATION Dilute It Once It's In
CRAWLSPACE VENTILATION	NATURAL VENTILATION
	SPOT VENTILATION
COVERING EXPOSED EARTH	FORCED VENTILATION
SEALING CRACKS AND HOLES	HEAT RECOVERY VENTILATION
BLOCK WALL VENTILATION	
SUB SLAB SUCTION	
SUB SLAB PRESSURIZATION	
EXTERIOR SUB SURFACE SUCTION	
DRAIN TILE VENTILATION	
SUMP PUMP VENTILATION	
COMBUSTION AIR SUPPLY	
BASEMENT PRESSURIZATION	

Potential elevated levels of radon in a new home can be much more cost-effectively controlled by installation of certain preventive and anticipatory measures during the construction of a new home. There is some risk because no homesite can currently be tested before the home is built, but if a home is to be built in an area where radon has become suspect, the small extra investment may well be good insurance.

Written by Mike Nuess

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