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# INDOOR AIR QUALITY

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Concern over the quality of outdoor air has been an active issue in recent years. People are concerned that the air they breathe is free from harmful contaminants. Most recently, attention has been focused on the quality of air in indoor environments. On average, people spend between 80-90% of their time indoors, each taking well over 10,000 breaths per day to provide the necessary oxygen for human metabolism. Given the amount of time spent indoors, maintaining safe indoor air quality should be a high priority.

Increased awareness about the merits of residential insulation and weatherization have motivated many to tighten the natural ventilation rate of their houses. The energy savings and increased comfort of "house tightening" are well documented. These conservation measures have been blamed, however, in media accounts for incidences of adverse health effects suffered by occupants. Beyond residential structures, press accounts of unhealthy air in schools and commercial buildings have received public attention.

Many people are now concerned about the effect of weatherization on their home's air quality. This factsheet will help place those concerns in perspective by discussing the interrelationship of home ventilation rates, sources of air contaminants, and the relative quality of the indoor air environment.

## WHAT IS AN UNSAFE AIR QUALITY LEVEL?

This is a crucial, but very difficult question to answer in a meaningful way. Air is contaminated when it has a higher than normal concentration of a particular pollutant. Air is never absolutely pure, so the question boils down to what is considered a "normal" or acceptable concentration of a pollutant. This is made even more complicated by the fact that each individual has different sensitivities to pollutant levels. What is an allergen or irritant for some will leave others seemingly unaffected.

Government standards have been set in the United States and many other countries for workplace exposure levels to some pollutant/toxic substances. Other countries have established

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guidelines or standards for home indoor air environments as well. As there are almost no regulatory standards for pollutant levels in United States residences (and no inexpensive way to know a wide range of pollutant concentrations), the question of maintaining a healthy indoor air environment requires an understanding of pollutants, where they come from and techniques for mitigating potential problems.

THE PROBLEM IN PERSPECTIVE

The single most important factor in indoor air quality is the pollutant source and its rate of emission. The greater the source in the indoor environment and the higher its rate of emission, the greater the potential for unhealthy air in the home. This combination of source and emmission can be thought of as a building loading factor. Most homes do not contain enough pollutants to create a bad indoor air environment. Where the load of pollutant sources is high, however, the reduction of natural ventilation by conservation measures could aggravate or intensify an air quality problem. Thus, while ventilation does, in almost all cases, reduce indoor air contaminants, the best method for protecting indoor air is to reduce or eliminate potential pollution sources.

COMMON HOUSEHOLD POLLUTANTS

Many of modern life's commonly accepted building materials and furnishings emit air pollutants. Particle board furniture, cabinets, flooring, oven cleaners, disinfectants, carpets, shampoos, insecticides, paints,and furniture strippers are just a scant few. The following discussion will highlight particular contaminants, their common sources, and accepted methods for reducing their presence in indoor air. Again, the existence of any one or more of the products in the home does not mean an air quality problem exists.

Formaldehyde

In 1983, production of formaldehyde in the United States was 5.7 billion pounds. The majority of this was used as an adhesive for particle board and plywood. Formaldehyde is also used in some upholstery, carpet and carpet glues, wallpaper, urea-formaldehyde insulation, paneling and is a by-product of combustion from gas stoves and cigarette smoking. Some of this material ends up in the home as shelving, cabinets, or structural members such as sheathing or sub-flooring.

Formaldehyde may vaporize from these products at room temperature. As indoor concentration levels increase, some occupants will begin to experience physical reactions. These reactions differ by individual sensitivities and other health related factors. (Chart 1 depicts concentration levels and individual thresholds). Common complaints are reported as headaches, dizziness, nausea, and other eye, respiratory, and skin irritations. As Chart 1 indicates, the wide range of sensitivity to formaldehyde makes it difficult to: 1) determine whether the indoor air is overly contaminated and, 2) 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 .1ppm (parts per million) for indoor levels.

Formaldehyde may continue to vaporize from its sources for an indefinite period of time. The rate of its emission is not constant, however, but is affected by a number of other factors. Wood products with urea formaldehyde resins outgas at a higher rate when new. Thus, over time, formaldehyde concentrations from these sources can be expected to decline. However, outgassing will continue from these sources over a number of years. Additionally, high temperature and humidity levels can triple or quadruple formaldehyde levels.

Lowering the indoor concentration of formaldehyde starts with avoiding the use or removing the sources from the home. The lower the source strength, the lower the indoor concentrations will be. Being aware of the composition of home furnishings, such as kitchen counters, cabinets, bookshelves and coffee tables, to avoid excessive use of particle board is a start. Being aware of building materials and potential alternatives can also make a difference. Loose fill insulation such as cellulose or mineral fibers can be used in place of urea-formaldehyde foam insulation (UFFI). Exterior grade plywood uses a lower emitting phenol-formaldehyde resin than does interior grade plywood. Wood product manufacturers are now producing particle board that is "low emitting". Specifying this product upon purchase can help to avoid possible air quality problems. Care should be taken that the low emitting material has a manufacturers guarantee of less than .1ppm emission rating. This may require contacting the particle board manufacturer.

Where formaldehyde-based wood products are used in significant quantity , applying a sealing coating may help reduce emissions. Vapor barrier points can be used for this. Formaldehyde from sources such as upholstery must be removed from the home to have an effect on concentration levels. Urea formaldehyde foam insulation presents a unique problem in that it is difficult and expensive to remove. There is a commercially available ammonia treatment which when applied to the UFFI causes a reaction which reduces formaldehyde emissions. This procedure has not, to date, had wide spread application, however.

A final strategy for lowering formaldehyde concentrations is to increase ventilation and lower humidity levels. One way to increase ventilation without paying an energy penalty is with an air-to-air heat exchanger. An air-to-air heat exchanger is a fan powered appliance which reclaims from 50-80% of the heat from exhausted room air for fresh outdoor air. The WEES factsheet, "Air to Air Heat Exchangers", describes these appliances in depth. The air-to-air heat exchanger is not an air purification or filtration appliance. Common air purification systems using charcoal filters are not effective at removing formaldehyde from the air.

<u>Radon</u>

Radon is a radioactive gas created by the decay of radium. Radium is common in soil, rocks, and other mineral deposits. Radon is therefore constantly emitted into the atmosphere and can be found in ground or well water. When radon finds its way into the indoor environment it has a small volume of air in which to mix. Thus, concentrations levels can increase.

The source of radon in houses is typically not building materials, but instead the soil around the home or in the crawlspace. Well water can also contain radon. Typical points of entry into the home for radon emanating from the soil are: cracks in masonry slabs or foundation walls; service penetrations and floor drains; and through direct diffusion. Concentration of radon in the home is usually measure in picocuries per liter (pCi/L). There has not been large scale testing of average concentrations in houses, but current estimates are 1-2 pCi/L during the winter months.

The radioactive by-products of radon attach to dust particles and are deposited into the lung when a person breathes. If these particles remain in the lung, medical research indicates that they can, over a long period of time, cause tissue damage or lung cancer. The specter of a colorless odorless gas, emanating from the soil, causing potential lung cancer seems frightening. However, the problem must be kept in perspective. In most homes, the radon level is so low that the probability of negative health effects is very minimal. Higher radon concentrations in houses correlates with high radon levels in the soil. Generally, Washington does not have the type of geologic formations that are high in radon. The Environmental Protection Agency (EPA) has established a guideline for maximum indoor concentration of 4 pCi/L. Only through a laboratory analysis can radon concentrations be determined, however. Small collection devices are currently available for measuring radon levels. These detectors are simply exposed to indoor air (or well water) for 2-6 months and then sent to a laboratory for analysis.

Where radon levels are high, it is best to seal the house from the radon source and/or provide additional ventilation. These steps might include a polyethylene vapor barrier over crawlspace soil and additional crawlspace ventilation, sealing cracks in basement walls or floor slabs, and, in the case of well water, providing aeration. Again, an air-to-air heat exchanger can be employed to provide additional ventilation. Another technique used in areas with high radon levels in the soil is sub-slab ventilation. This removes radon concentration before it enters the home.

Particulates

The indoor air contains a significant number of solid particles (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 re-suspended when the air is disturbed by house cleaning or by other activity. The air can also contain harmful microbes and heavy metals, though the latter are typically a problem from ingestion rather than inhalation.

Particulate size is a significant determinant in the effect they 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

## Chart 1.

| POLLUTANT | SOURCES | HEALTH EFFECTS | INDOOR AIR STANDARDS (MAXIMUM LEVELS) | MITIGATION |
|---|---|---|---|---|
| **FORMALDEHYDE** - a gas produced by industry for use in urea-formaldehyde bonded wood products. | Particle board, plywood paneling, gas stoves, urea-formaldehyde foam insulation, ceiling tile, draperies, furniture, clothing, carpets, unvented heaters, upholstery, human activities, and smoking. | Suspected carcinogenic (nasal cancer), linked to respiratory problems, headaches, dizziness, depression, insomnia, eye irritation, and fatigue.<br><br>EFFECTS — CONCENTRATION (ppm)<br>Neurophysiological Effects .05 - 1.5<br>Odor Threshold .05 - 1.0<br>Eye Irritation .01 - 2.0<br>Upper Airway Irritation .10 -25.0<br>Lower Airway & Pulmonary Effects 5.0 - 30.0<br>Pulmonary Edema, Inflamation, Pneumonia 50.0 -100.0<br>Death 100+ | - 0.10 ppm recommended by ASHRAE, ANSI, and by most environmentalists<br>- Also Dutch and West German Standards | - Sealing coatings (vapor barrier paints)<br>- Remove Source<br>- Increased Ventilation |
| **RADON** - an inert, radioactive gas; a decay product of uranium which is present as traces in all soil. Radon is invisible, odorless, and tasteless. Measurement is in pico curies per liter of air*.<br><br>* 1 pCi of Radon has 0.037 disintegrations occurring each second. | released directly into the home from masonry (concrete, brick, stove, gypsum board) and indirectly from surrounding soil into well water, crawl spaces and through crack and gape in floor slabs, loose fitting piping, and drainage systems into basements. | - Radon progeny attach themselves to particles and may become lodged in the lungs. Further decay then causes tissue damage and can cause the development of lung cancer.<br>- EPA estimates suggest the following rough comparison of the lifetime exposure to a given Radon level and the risk of lung cancer associated with cigarette smoking:<br>1 pCi/L/day = 1 cigarette/day<br>- EPA estimates 10,000 annual lung cancer deaths attributable to indoor Radon. Other estimates by scientists give a range of 2,000 - 20,000.<br>- Effects are usually felt after 15-20 years of exposure. | - EPA indoor air standard: 4pCi/L maximum<br>- Average winter level in U.S. homes: 1 - 2 pCi/L | - Seal the house from the Radon source<br>- Increase ventilation |
| **PARTICULATES** - Respirable Suspended Particles (RSP) are particles less than about 10 microns in diameter. RSP tend to be carried to and lodge in the deepest part of the lungs. **Suspended particulate matter often includes:** house dust, fungi, bacteria, pollens, spores and viruses, asbestos fibers, heavy metals, mineral wool, glass fibers and Benzo-(a)-Pyrene (a combustion by-product). | Tobacco smoke (80 mg/cigarette), Wood stoves (9.4 mg/hr.), Coal stoves, fireplaces, wind born dust, house dusting and other activities, people, pets, floor and ceiling tile, roofing and duct insulation (asbestos), damp surfaces (fungi), auto exhaust (heavy metals). | - Eye and nose irritation.<br>- Allergic inflammation nasal mucous membranes<br>- Transmission of Illnesses<br>- Lung Cancer (Asbestos, Benzo-(a)-Pyrene)<br>- Acts synergistically with other pollutants (i.e. carrier of Radon progeny) | - .5 mg/m$^3$ recommended by ASHRAE | - Remove source (except asbestos)<br>- Lower humidity level (fungal growth)<br>- Seal leaks in wood stove pipes<br>- Air filtration, electrostatic precipitators |

| POLLUTANT | SOURCES | HEALTH EFFECTS | INDOOR AIR STANDARDS (MAXIMUM LEVELS) | MITIGATION |
|---|---|---|---|---|
| **COMBUSTION BY-PRODUCTS**<br>ALDEHYDES (see FORMALDEHYDE)<br>BENZO-(A)-PYRENE<br>NICOTINE (see PARTICULATE)<br>RESPIRABLE PARTICLES<br>ORGANIC COMPOUNDS | | | | |
| **SULFUR DIOXIDE** ($SO_2$) - heavy, colorless, suffocating gas. | - Burning wood, coal, tobacco oil, gas or kerosene<br>- Unvented heaters and stoves<br>- Automobile exhaust from an attached garage | - highly irritating to skin, eyes and mucous membrane.<br>1 ppm (construction of upper airways occurs)<br>19 ppm (eye and throat irritation occurs) | 0.5 ppm recommended by ASHRAE | - Use electric appliances<br>- Install pilotless appliances<br>- Spot Ventilate<br>- Separate garage from house |
| **CARBON DIOXIDE** ($CO_2$) - colorless, odorless, gas. Common to 0.3% of ambient air. | (see SULFUR DIOXIDE) | - Asphyxiant causes headaches 18g/$m^3$<br>- At higher concentrations (dizziness, shortness of breath, drowsiness)<br>- Long-term effects of low levels not presently known | 2450 ppm recommended by ASHRAE (4400 mg/$m^3$) | (see SULFUR DIOXIDE) |
| **CARBON MONOXIDE** (CO) - colorless, odorless, highly poisonous gas. | (see SULFUR DIOXIDE) | LEVEL — EFFECTS<br>17ppm, 24 hours — Impairment of visual acuity and brain functioning.<br>26 - 52ppm, 24 hrs. — Irregular heart functioning and headaches.<br>525ppm, 1 hour — Headache, nausea and mental confusion.<br>1480ppm, 1 hour — Death | 5 ppm recommended by ASHRAE | (see SULFUR DIOXIDE) |
| **NITROGEN DIOXIDE** ($NO_2$) - a poisonous reddish brown gas. | (see SULFUR DIOXIDE) | - highly toxic, can cause lung damage<br>0.16 - .21ppm (physiological damage may occur)<br>34.0ppm (lowest observed concentration causing pulmonary problems) | 0.5 ppm recommended by ASHRAE | (see SULFUR DIOXIDE) |
| **NITRIC OXIDE** (NO) - colorless gas | (see SULFUR DIOXIDE) | - Highly irritating to skin, eyes, and mucous membrane.<br>57 - 170ppm (cause immediate irritation of nose and throat; coughing and burning in the throat and chest. | 2.5 ppm recommended by ASHRAE | (see SULFUR DIOXIDE) |

one millionth of a meter), also known as respirable suspended particulates (RSP), can enter the blood or lymph tissue and cause a host of respiratory problems. For those individuals allergic to the respirable particles, the reaction can cover a range of clinical syndromes from allergic rhinitis to bronchial asthma.

Tobacco smoke is probably the single greatest contributor to particulate concentration in the home outside of house dust. A burning cigarette not only emits respirable particles, but a host of other contaminants including aldehydes and benzo-(a)-pyrene. The health effects to 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 (other combustion by-products will be discussed later).

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 respired 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 waling 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.

In the area of particulate contamination, asbestos deserves special mention. For many years, asbestos was a common component of many building materials including floor and ceiling tile,roofing, and duct insulation. In many instances the mere presence of this material does not constitute a hazard. However, if these materials are broken or crumble,asbestos fibers become airborne and can be inhaled. It is now known that these fibers remain in the lung and lymph tissue and can, over an extended period of years, lead to cancer of the lung. Furthermore, the risk from asbestos exposure is compounded by smoking.

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. If, however, remodeling plans or other activity is contemplated that necessitates its removal, appropriate safeguards should be taken. Professional assistance in asbestos removal or contacting the local public health office is recommended.

To reduce particulate concentration in the home, a number of strategies can be employed. Most obvious is to reduce or eliminate tobacco smoke from the indoor environment. Fungal growth can be affected by reducing the humidity level of the indoor air (more on that later).

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 reducing RSP (10 microns and smaller). Other filter types that screen very small particles are available, however. 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 to the fibers. These fibers attract particles as they pass through the filter and therefore act as a very effective screen.

Electrostatic precipitators work in much the same way by attracting particles to charged collection plates. These precipitators are available for installation in the duct of a forced air furnace or as portable units for independent operation. These electrostatic precipitators have the advantage of removable plates that can be washed with soap and water as opposed to filters which need periodic replacement. 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 susceptible to attaching to room surfaces which have a lower electrical potential. This is, however, not as desirable as removing the particulate since the possibility for resuspension is always there. Air ionizers have been the subject of much debate and criticism due to some dealers' questionable advertising claims for effectiveness and health benefits.

It should be stressed that the above mentioned devices do not remove gaseous contaminants from the air. (They are effective however, at reducing radon progeny which are attached to airborne particles.) The existence of particulates in the indoor environment should be kept in perspective as well. No measure of meticulous house cleaning can significantly affect particulate 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.

<u>Moisture</u>

Water vapor is not typically viewed as an air contaminant, but it does have an effect on comfort level and also influences the emission rate of pollutants like formaldehyde. In addition, condensation that occurs on building surfaces can, beyond the problem of structural deterioration,sponsor the growth of fungi and promote microbial contamination.

Residential relative humidity levels are typically listed in a comfort range of between 30-60%. 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. A partial list includes human occupants, kitchen and bath functions, house plants, laundry facilities,fish tanks, unvented combustion from space heaters or gas stoves, and diffusion from crawl space or basement areas. The WEES factsheet "Reducing Moisture Problems" contains a comprehensive discussion on sources and control.

If adequate ventilation or source control is not exercised, house humidity levels can increase and cause moisture related problems. Warm humid house air can condense on cooler building surface. 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, however, as microbial contamination is consistent with every type of environment except specially designed "clean rooms" used for medical or specialized manufacturing tasks.

By controlling the sources of moisture and providing localized ventilation in the kitchen and bath 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 moderate winter temperatures, makes the task of checking moisture problems 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%.

Combustion By-Products

The products of combustion from burning wood,coal,tobacco, oil, gas, or kerosene can enter the indoor environment. In many instances, combustion by-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. Combustion by-products include carbon monoxide (CO), carbon dioxide ($CO_2$), water vapor ($H_2O$), nitric oxide (NO), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), and formaldehyde (HCHO). Wood and coal can also produce benzo-(a)-pyrene which is a carcinogen. In addition to the sources mentioned above, combustion products from automobile exhaust can enter the home from an attached garage.

Field studies of concentrations of NO, $NO_2$, 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, $NO_2$, and NO have been measured. Kerosene heaters have been observed to contribute to high concentrations of $CO_2$, $NO_2$, and NO. There is no conclusive medical opinion on the health effects of relatively low-level but 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.

Wood burning in a woodstove, furnace, or fireplace has also been implicated as a source for CO, $SO_2$ and nitrogen oxides (in addition to particulates and benzo-(a)-pyrene). The actual field studies of wood burning residences have been quite limited however.

More research has been done on tobacco smoke combustion (discussed earlier as a contributor to particulate concentration). 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".

<u>Organic Compounds</u>
The existence of numerous organic compounds in a vapor state or as particulates in the 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. (Organic particulates such as fungi and bacterial agents have been previously discussed). 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 thinner, solvents, drain cleaner, and window cleaner. Automobile emissions can be an outdoor source as well. Polymer compounds such as vinyl chloride and other plasticizers can also be found in indoor air. Home furnishings are a major source.

Pesticides are also found in indoor air environments as 90% 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 very long time.

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

Of course, the removal or limitation of sources is the most effective way to reduce organic compound concentrations. Increased ventilation will also lower the contaminants' presence 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.

HOME VENTILATION

This factsheet has recommended that reducing "building loading" or the elimination of pollutant sources is the best strategy to minimize indoor air pollutants. A second strategy of increased ventilation is recommended in cases where problems or potential problems exist.

All houses have a "natural ventilation" rate referred to as infiltration. Outside air enters (and indoor air exits) from cracks and gaps in the building construction. The amount of infiltration that occurs depends on the quality of construction, the presence of weatherization materials, wind speed and direction, and occupant lifestyle. Different classifications of residential structures, such as mobile homes, also make a difference. Estimating the amount of air exchange in a residence is, therefore, nothing more than an expression of a broad range that fits "typical" houses, but is not necessarily accurate to any one case.

The air exchange rate expressed in air change per hour (ACH) indicates the volume of house air that is replaced by outdoor air in one hour. Homes that are older than five years have typical rates of .5 to 1.5 ACH. Newer homes have lower rates typically from .3 to .75 ACH. Having ACH rates of 2 to 3 is certainly possible in houses that are poorly maintained and/or lack appropriate weatherization materials. On the other hand, special construction techniques can also be utilized to lower natural ventilation rates to below .1 ACH.

By taking weatherization steps such as caulking and weatherstripping, the traditional home's ACH can be reduced, which saves energy and increases comfort. The question here is whether such activity endangers indoor air quality. It is impossible to make a blanket statement on this question because individual houses vary greatly. However, it is clear that a large amount of pollutant sources in the home is a much better indicator of possible air quality problems than are natural ventilation rates. Attention to this building loading factor is, then, the most important factor. In those cases where loading is high, the decrease of natural ventilation could aggravate or heighten an air quality problem.

In those houses that are built with special infiltration control techniques, it is most appropriate to provide efficient mechanical ventilation as with an air to air heat exchanger. It is probably wise, however, to still pay close attention to building loading factors. Additionally, those homes with very low natural ventilation must take particular caution with combustion devices to insure that sufficient air is provided for complete combustion and chimney draft.

IDENTIFICATION AND TESTING

As might be expected, the identification of air quality problems is normally difficult. The number of sources for pollutants is high and individual sensitivities vary. Potential health effects will also vary widely and can, in some cases, by subtle or delayed. Obviously, a medical doctor should be consulted for any health related problems.

The analysis of air quality in the home can be done in a variety of ways. The easiest is to fully air a building and carefully observe where problems or odors occur. If specific pollutants are suspected, the least expensive method of analysis is a passive sampling device. The devices are designed as badges or buttons and provide concentration information on a specific pollutant. In some, the badge will change color to indicate excessive levels and in others the device must be analyzed in a laboratory. This approach of passive samplers, while inexpensive, has obvious limitations.

A more sophisticated, but expensive approach is to obtain laboratory analysis of indoor air samples. This can be done in a variety of way. Pollutant concentrations can be measured as an "instantaneous sample", that is, the air quality at one point in time or a sample that is gathered over a longer time period of hours or days. A most expensive approach, typical of research projects, is a continuous monitoring of air quality.

When choosing a method of analysis, remember that pollutant concentrations will change according to temperature, humidity, ventilation, and other factors. Some air quality laboratories also provide consulting services in addition to air quality measurements. If an air quality problem is suspected, it is important to work with professionals who have experience with the wide range of indoor pollutants and have the necessary instruments for detecting their presence.

## SUGGESTED READING

* Bonneville Power Administration. Indoor Air Quality and Building Energy-Efficient Homes. BPA Office of Conservation. 1984.

  Good overview on the entire range of pollutants with information on existing standards.

* Lawrence Berkeley Laboratory. Manual on Indoor Air Quality. Electric Power Research Institute. 1984.

  Written by R.C. Diamond and D.T. Grimsrud, this is a detailed work, but understandable for the non-technical reader.

* Meyer, Beat. Indoor Air Quality. Addison-Wesley Publishing. 1983.

  Comprehensive and technical work on air quality. Even though it is very detailed, it is so well written that anyone can benefit from the information. Should be standard reference for any air qualtiy specialist.

* Sachs, Harvey. "Clearing the Air", Rodale's New Shelter. Rodale Press. September 1984.

  Sachs is one of the premier names in indoor air quality. He gives nice overview of the issues in this article.

* Spengler, John and Ken Sexton. "Indoor Air Pollution: A Public Health Perspective". Science. July 1983.

  Landmark article on indoor air quality from a public health perspective.

This factsheet was written by Stan Price. Chart prepared by George Anderson. The author wishes to thank the following individuals for their assistance: Karol Stevens, Dr. Beat Meyer, Dr. Harvey Sachs, Brad Prezant, Dr. Richard Knights, and the WEES staff.