BUILDING IN ALASKA

COOPERATIVE EXTENSION SERVICE, UNIVERSITY OF ALASKA, USDA & SEA GRANT COOPERATING

A-00956

March 1985

INDOOR AIR QUALITY

IS MY HOME HEALTHY FOR ME?

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3/85/RDS/454

INTRODUCTION

In the late 1970s and early 1980s, indoor air pollution became recognized as a problem associated with some tight, energy efficient building techniques. Homeowners need information about indoor air quality in order to understand the risks and the degree to which concerns are warranted. Research during the last few years has given us new information on the subject. This publication is designed to answer basic questions about indoor air quality, give sources of further help, information and perspectives on the problem.

Air pollution itself is an often misunderstood phenomenon. It has been associated with highly industrialized areas, and large urban populations where man-made sources of pollution are visibly evident. However, if conditions are bad for dispersion of pollutants, even a small, non-visible source can cause problems. Carbon monoxide alerts in Anchorage are an example.

Indoor air pollution can be the result of combustion in the home (stoves, furnaces, lamps), out-gassing from building products, or from natural sources, such as dust, pollen and radon gas. In this review, the subject of indoor air quality is specifically directed to the private housing sector. This sector is unregulated regarding air quality and has no easy access to information about air quality or how to insure the health of the occupants.

Here are some facts about indoor air pollution:

1. Do you have an indoor air quality problem? Several warning signs can alert you to possible air pollution in your home: a musty smell, stuffiness, noticeable lingering odors, severe moisture problems such as mold or heavy water condensation on walls and windows, frequent headaches, watery eyes, nausea or fatigue among occupants.

2. There are many control devices available such as fans, windows, air-to-air heat exchangers, pollutant filters, electronic air filters, fiber filters, charcoal filters and dehumidifiers. Each is designed for particular needs, budgets or pollutants. Some are more energy efficient than others.

3. The exchange of air from outdoors to indoors and back is vital in reducing air pollution in typical homes. A frequently asked question is, how much air exchange is adequate to assure acceptable indoor air quality? As is often the case with questions involving different people, different homes and construction types, it is difficult to respond to this question with a simple answer. The rate of air exchange required depends most on the volume of the living space, and the number and intensity of the pollutant sources.

4. Humidity, moisture and ensuing condensation problems on windows and cold spots can be indicators of an indoor air quality problem. Since reducing the humidity through ventilation in a building would also reduce the pollutant concentrations (by dilution and removal), relative humidity can serve as an indicator of air quality. Relative humidity is recommended to be between 30–50%. Higher relative humidity readings would indicate a need to reduce humidity, typically through ventilation. Pollutants are reduced and removed by ventilation as well. Ventilation is obviously an important factor for reducing both moisture and pollutant levels.

5. The Swedish Building Research Council recommends that new residential building structures be tightly sealed and weatherstripped to minimize air infiltration. In order to minimize indoor air quality problems, the Swedish Council also recommends that the building have an integral air ventilation system utilizing an air-to-air heat exchange to provide adequate fresh air without wasting energy.

   This contrasts with Alaskan energy conservation building practice where the house is typically well-sealed without consideration of appropriate levels of ventilation or air exchange. Condensation and air quality problems may result. There has been no residential base line indoor pollution data collected in Alaska that the authors are aware of.

   The house most likely to experience moisture problems in 1985 is a relatively new (4 years old or less) home, with high insulation levels, with a high integrity vapor barrier, with baseboard heat, and the furnace or boiler is located in the garage with no direct air linkage to the house. In such a home, no air for combustion is pulled into the house or moved out with the stack exhaust in combustion processes. During the winter, air stagnates in the house becoming more and more moist and polluted with time.

   Cursory research by the Alaska Department of Transportation and Public Facilities (DOTPF) Research Section on several homes in the Fairbanks area indicates that homes without mechanical ventilation systems generally had air exchange rates considerably lower than those reported in the literature for buildings elsewhere in the United States (Kailing, 1983).

   Airtight homes need to have adequate ventilation, and it should be planned along with the house.

6. Sweden has set standards for an adequate air change rate for maintaining indoor air quality. That rate is to change one-half of the air volume of the heated space per hour. For a standard home with dimensions of 24×48 feet with a daylight heated basement and eight-foot ceilings, the volume of air in the house is 18,432 cubic feet. Changing half the air each hour requires ventilating 9,216 cubic feet of air, which requires a fan that can move about 150 cubic feet per minute. This is a good "average" ventilation rate for a home.

7. Most older homes, especially those with poor vapor barriers, do not have indoor air pollution problems. Pollution potential is not a reason to avoid weatherizing old, leaky homes. Many older homes built in the 1950s and

1960s will leak air at the rate of three or more air changes per hour. Reducing the air changes from three to one per hour would cut infiltration by two-thirds and still provide enough air exchange for healthful indoor air quality. Consequently, weatherizing is generally a good idea in older homes, as long as the ventilation rate is at least one-half of the air volume of the home per hour.

8. Typically highest concentrations of pollutants occur in the winter when homes are kept tight for warmth. Many of the home pollutants are self-induced such as use of insecticides, paints and cleaning agents. Be aware of the potential build up of harmful pollutants, especially if there appears to be minimal ventilation. For example, don't use an oven cleaner, don't paint or don't weld in the basement on a cold day when you can't open the window for ventilation.

9. Mobile homes and prefabricated housing units are especially prone to indoor air pollution problems. They have lower mean air-exchange rates than conventional homes, are of smaller volume, use proportionally more materials containing volatile organic resins, and are more likely to use propane for cooking fuel (Spangler, et al.).

Research has identified a number of pollutants that appear to be the primary indoor air quality concerns to new, tightly constructed homes. A description of some of these pollutants are included in the following list of common pollutants. Much of this list and the discussion of the different pollutants are derived directly from a publication by the Bonneville Power Administration (1983).

THE COMMON INDOOR AIR POLLUTANTS

Radon

What It Is

Radon is an odorless, colorless, radioactive gas that is a decay product of radium. Radium is a naturally occurring trace element in the soil and rock which is present everywhere in the earth's crust. Concentrations vary widely.

Sources

Radon in homes may come from many sources. The main route of entry is from the soil and rock underlying the house. Radon migrates from the soil and rock through the cracks and openings in the walls and floors of the house. Radon may also enter through the use of well water.

Certain types of construction, such as earthen homes and solar heated structures with rock heat storage, may have high levels of radon because of the additional earth and rock used in such buildings.

Health Effects

The national average lifetime risk of incurring lung cancer from all causes is about four percent. Uranium miners, who have been exposed to very high concentrations of radon, have an increased incidence of lung cancer. Radon concentrations in homes are typically much lower than those found in uranium mines. Although estimates of radon-induced cancer at these lower levels are uncertain, radon is believed to cause about 5 to 20% of all lung cancers. About 80% of lung cancers are associated with tobacco smoking.

In Alaska's DOTPF study (1983), radon exposures were measured in all of the seven buildings tested, three of which were residential types of buildings. In only one was the exposure rate greater than the EPA recommended level of 4 picocuries/liter. The rate was 5.59 picocuries/liter. It was noted that this was a new home that had been recently sheetrocked and that this home also had the lowest average air exchange rate (0.08 air changes per hour). Thus, the house with the lowest average air exchange rate did have the highest radon exposure rate. This research was an extremely small sample however, and it is impossible to draw any definitive conclusions from this work, especially in areas outside of Fairbanks, which has a moderately high radiation level.

Canadian research specifically on tightly constructed homes (Dumont, 1984), reports the test results of 46 houses which were monitored for formaldehyde, nitrogen dioxide and radon. The radon exposure exceeded 4.0 pc/1 in 11 of the houses. This and other pollutant test results are reported under titled subsequent headings in the text.

Ways to Reduce Radon Exposure

The best technique to reduce radon concentrations is to increase ventilation. Ventilation can be achieved in several ways. The simplest way is to open windows. You can avoid home-tightening measures such as weatherstripping, caulking or some storm windows. You can maintain your home's existing air exchange rate by installing a properly sized, air-to-air heat exchanger along with home-tightening measures and maintain energy conservation standards. (BPA, 1983).

Radon can also be controlled somewhat by carefully sealing the pathways in the basement and by isolating basement floor drains from the living space to keep local soil radon from getting into the house.

Formaldehyde

What It Is

Formaldehyde is a colorless, water-soluble gas. A low-cost chemical with excellent bonding characteristics, formaldehyde is a valuable component of glues used to manufacture plywood, particle board and textiles. It also is used to manufacture urea-formaldehyde foam insulation (UF foam), an insulation injected into sidewalls, primarily in the 1970s.

Sources

The primary sources of formaldehyde in residences are UF foam insulation, particle board, plywood, furniture, drapes and carpet. Less important sources are gas stoves, wood stoves and tobacco smoke.

Mobile homes tend to have higher concentrations of formaldehyde than other dwellings (without UF foam) because they 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.

As formaldehyde-containing materials age, they emit less formaldehyde, although the rate of decay is not well-defined. Temperature and humidity affect the rate at which formaldehyde is released from materials. It appears that half of the formaldehyde contained in most materials will be released in about four years.

Health Effects

Formaldehyde can cause irritation and respiratory disorders. For most people, the primary health problem associated with formaldehyde is irritation. Short-term, low exposures may cause burning of the eyes and irritation of the upper respiratory passages.

Irritation-related health problems usually stop as soon as exposure stops. About 10–20 percent of the population appears to be highly sensitive to formaldehyde. Chronic exposure can cause acute sensitization, even in people without a previous history of respiratory problems.

Canadian research on tightly constructed new homes (Dumont, 1984) indicates that 18 of 46 houses tested had formaldehyde levels above the ASHRAE limit of 0.1 part per million at 75 °F. Houses with higher formaldehyde concentrations tended to also have higher relative humidity. This is probably caused by two factors: (1) the houses with higher humidity probably had lower ventilation rates; and (2) formaldehyde off-gassing rate is known to increase with higher relative humidity.

Combustion Gases

What They Are

Carbon monoxide is a colorless, odorless, tasteless gas. It is a by-product of fuel burning. Nitrogen dioxide is a colorless, tasteless gas formed during combustion.

Sources

The major sources of carbon monoxide are kerosene space heaters, wood stoves, unvented gas stoves and ovens and garages attached to homes. Tobacco smoke is a less important source. The major sources of nitrogen dioxide are unvented gas stoves and ovens and kerosene space heaters. Several states have banned the residential use of kerosene heaters.

Carbon Monoxide

Health Effects

Both carbon monoxide and nitrogen dioxide interfere with the delivery of oxygen throughout the body and they can damage the lungs.

Very high concentrations of carbon monoxide (1,380 parts per million) are quickly fatal. Carbon monoxide poisoning from faulty oil and gas furnaces and attached garages is responsible for several deaths each year.

Exposure to about 90 ppm of carbon monoxide can cause mild headaches and dizziness. Exposure to about 25 ppm for 24 hours can hamper vision and brain functioning.

Exposure to more than 9 ppm of carbon monoxide for several hours may be hazardous to pregnant women (and especially to their fetuses), infants, and people who are anemic or have respiratory problems.

Health Standard

The Environmental Protection Agency (EPA) standard for maximum allowable level of carbon monoxide in outdoor air is 9 ppm for an eight-hour average exposure and 35 ppm for a one-hour average exposure. This standard has a safety margin designed to protect people with angina. 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.

Concentrations Found in Homes

The greatest concentrations of carbon monoxide occur when combustion air is restricted, as in a smoldering wood fire. Typical average indoor concentrations of carbon monoxide vary between .5 and 5 ppm. Cooking over a gas stove typically increases carbon monoxide levels by 5 to 10 ppm. An improperly adjusted gas stove can emit carbon monoxide at more than 30 times the rate of a well-tuned stove. If your stove is not adjusted properly, it is likely to have a yellow-tipped rather than a blue-tipped flame.

Convective-type kerosene heaters tested by the Consumers Union, a nonprofit organization, produced an average concentration of 5 ppm. The radiant-type kerosene heaters in these tests produced an average concentration of 13 ppm. Concentrations of carbon monoxide from this type of heater can be significant even at higher than average air exchange rates.

Nitrogen Dioxide

Health Effects

Like carbon monoxide, nitrogen dioxide reduces the body's ability to absorb and distribute oxygen. This produces effects similar to carbon monoxide. Nitrogen dioxide can increase the stress placed on the cardiovascular system. Nevertheless, nitrogen dioxide does not reach lethal levels in homes.

Nitrogen dioxide can cause short-term and long-term damage to the lungs. It impairs the lung's ability to cleanse itself. Long-term exposure may contribute to the development of various lung diseases. The effect of short-term exposure to high concentrations is unclear. Low concentrations of nitrogen dioxide, less than 0.53 ppm, do not appear to cause chronic respiratory diseases.

Concentrations Found in Homes

Nitrogen dioxide concentrations equal to or greater than EPA's standard for outdoor air are fairly common in kitchens with unvented gas stoves or ovens. Nitrogen dioxide and carbon monoxide tend to spread evenly throughout a home. In about an hour after a gas stove or oven is turned off, the level of these pollutants is likely to be similar throughout the house.

Indoor hourly concentrations of nitrogen dioxide appear to vary between .05 ppm and .5 ppm. Typical weekly indoor concentrations range from 0.2 to .1 ppm. The upper levels in both of these ranges are associated with unvented gas appliances. Short-term peaks of .7 ppm have been measured.

Ways to Reduce Carbon Monoxide and Nitrogen Dioxide Exposure

An exhaust fan above a gas stove can remove about 70 percent of the pollutants produced while cooking. Opening two opposite windows to provide cross-ventilation also can effectively reduce pollutant levels.

Installing an air-to-air heat exchanger would also help to remove these pollutants.

Have fireplace flues and chimneys cleaned frequently. Make sure wood stoves are properly ventilated. Do not let fires smolder.

Combustion Particles

What They Are

Respirable suspended particulates (RSP) are very small particles which may become lodged in the lungs. Benzo-(a)-pyrene (BaP) is a tarry, organic particle which comes from incomplete combustion.

Sources

Tobacco smoke is usually the largest indoor source of RSP. Wood and tobacco smoke are the major indoor sources of BaP. Wood smoke is also a source of RSP. Unvented gas appliances and kerosene space heaters are less important sources of both RSP and BaP.

Respirable Suspended Particulates

Health Effects

Lung cancer, emphysema, and heart disease are well-established risks of cigarette smoking. Sidestream smoke, which is inhaled by nonsmokers, can also cause various health problems.

Short-term exposure to sidestream smoke can cause irritation to the eyes, nose and throat. It can also cause respiratory infections and can aggravate the condition of people with allergies or with heart or lung disease.

Benzo-(a)-pyrene

Health Effects

The best evidence that BaP can cause lung cancer comes from studies of workers who have been regularly exposed to BaP.

In addition to the studies of workers, several researchers have found a relationship between levels of BaP in outdoor air and lung cancer rates. Higher rates of lung cancer were found in cities where BaP levels were high.

BaP is an important component of cigarette smoke. Some of the risk of developing lung cancer from smoking may come from the toxicity of BaP.

Ways to reduce BaP and RSP Exposure

Indoor exposure to these pollutants can effectively be reduced by not smoking tobacco. Smoking near an open window may help reduce these pollutants.

Wood stoves should be properly installed with a tight-fitting stove pipe that has no cracks or leaks.

Combustion appliances should be vented to the outdoors. Increasing ventilation by opening windows or by installing an air-to-air heat exchanger will reduce RSP and BaP levels.

WHAT ARE THE ACCEPTABLE INDOOR POLLUTANT LEVELS?

The most widely accepted guidelines for safe levels of these substances in indoor air is contained in the document **Ventilation for Acceptable Air Quality,** published by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) and U.S. Environmental Protection Agency (EPA). Values for acceptable levels are given in Table 1.

Table 1
Guidelines for Generally Acceptable Levels of Selected Air Contaminants

Contaminant	Level	Reference
Formaldehyde	0.12 mg/m3 0.1 ppm at 25 °C	ASHRAE 62-1981
Radon	4 pCi/1	U.S. EPA
Radon daughters	0.01 working levels	ASHRAE 62-1981
Nitrogen Dioxide	100 ug/m3 50 ppb at 25 °C	U.S. EPA

How does a person recognize or detect specific air quality problems? If you need to pursue the identification of a specific pollutant, there are technologies available for doing so. A partial listing of those available is given below for each pollutant.

RADON: A badge containing a filmstrip which is exposed by radon decay particles is worn for a period of time. The source for these is:

Terradex Corporation
460 N. Widget Lane
Walnut Creek, CA 94598
(415) 938-2545

NITROGEN DIOXIDE: This is measured by a device called a diffusion tube sampler which can also be used for sampling all nitrogen oxides. The system is available from:

Air Quality Resources, Incorporated
2800 7th Street
Berkeley, CA 94710
(415) 644-2097

FORMALDEHYDE: The same company listed for nitrogen dioxide sampling makes a diffusion tube sampler for formaldehyde sampling. This system was used by Canadian researchers in their work in determining the formaldehyde content in homes containing urea-formaldehyde foam insulation (UFFI).

3M Corporation has a model 3720 monitor for formaldehyde monitoring. The cost is approximately $35–$45.

3M, Occupational Health & Safety Division
3M Center
Building 2207W02
St. Paul, MN 55144
(612) 733-8029 (for information: Nick Susuki)

DuPont Corporation has a formaldehyde sensor system available, but it is less adapted to individual homeowner use. In February of 1984, it comes in boxes of 10 badges for $250. No sales of amounts less than 10, and if you get DuPont to analyze the badge after exposure, it costs an additional $22 per badge. Also, it has a six-month refrigerated shelf life, and the boxes are dated. For more information:

DuPont Corporation
Instrument Systems
P.O. Box 10
Kennett Square, PA 19348
(215) 444-4035

CARBON MONOXIDE: A diffusion-style personal carbon monoxide monitor that uses an electrochemical cell is available from:

Energetics Science Division
Becton Pickinson and Company
Six Skyline Drive
New York, NY 10532
(914) 592-3010

A noncommercial model of a diffusion tube sampler for carbon monoxide is maintained at the following address. Call or write for information:

John Girman
Building 90, Room 3058
Lawrence Berkeley Lab
Berkeley, CA 94720
(415) 486-4668

Generally, high humidity is a first indicator of poor air quality. Improving ventilation with more vents or an air-to-air heat exchanger to ventilate the building is a pragmatic solution. Both these options are covered in other Cooperative Extension Service publications. Please write to us, or call your local Cooperative Extension Service for further information and updates.

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This publication was prepared with the support of the U.S. Department of Energy Grant No. DE-FG51-80CS69081. However, any opinions, findings, conclusions, or recommendations herein are those of the author and do not necessarily reflect the views of DOE or the State of Alaska.

Funding for printing provided by the Division of Community Development of the Department of Community and Regional Affairs.