Chapter X

INDOOR AIR QUALITY

Chapter X.—INDOOR AIR QUALITY

TABLE

FIGURE

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Energy conservation measures that decrease air exchange rates in buildings may increase problems associated with indoor air quality. Without appropriate control measures, a “tighter” house may allow a significant buildup of air pollutants — carbon monoxide, nitrogen dioxide, hydrocarbons, respirable particulate, and others–that are generated within the structure. An increase in indoor concentrations of these pollutants may have a serious effect on the comfort and health of the occupants.

INDOOR AIR QUALITY

The air pollution control effort in the United States has generally considered the pollutant concentrations of outdoor air as the appropriate measure for population exposure. Exceptions to this emphasis have been the attention given the industrial workplace environment and building codes for office and public buildings, which require minimum ventilation rates. The indoor residential environment, to the extent that it has been considered, has generally been assumed to shelter the occupants from exposure to higher pollutant concentrations found outdoors.

It is now clear that indoor levels of several important air pollutants can be as high as or higher than outdoor levels. (See table 74.) Consider the results of a few recent research projects:

- Several studies have shown that household gas stoves can cause high indoor concentrations of carbon monoxide, nitrogen oxides, and fine particulates. Lawrence Berkeley Laboratory' and other sources have shown that nitrogen oxide emissions from such stoves are sufficiently high to cause kitchen concentrations to exceed the range of recommended 1-hour national ambient air quality standards (NAAQS). Some studies have also indicated that carbon monoxide levels may be raised to levels above the short-term ambient standards, but results have been extremely variable from study to study.
- Danish scientists have found high levels (up to nearly twice the legal occupational exposure limit) of formaldehyde in homes that have substantial quantities of particle board in their structure.[2] Similarly high levels of formaldehyde concentrations have been found in mobile homes in the United States.
- Several studies have shown that smoking seriously affects the indoor environment. The particulate from cigarette smoking are in the respirable size range; nicotine is the second largest component of the smoke.[3] Moderate smoking (a pack a day) can cause particulate concentrations to exceed the 24-hour ambient air quality standard.[4]

Internal sources of pollution include gas stoves, a variety of building construction materials including wallboard, paint, and insulation, cigarette smoking, aerosol spray, cleaning and cooking products, and products used for hobbies and crafts. Even the concrete and stone in the floors and walls of homes add quantities of radon “daughters” (a fission

[1]Craig D. Hollowell and C. W Traynor, *Combustion-Generated Indoor Air Pollution* (Lawrence Berkeley Laboratory, April 1978) Report LBL-7832

[2]I Andersen, “Formaldehyde in the Indoor Environmental-Health Implications and the Setting of Standards,” *International Indoor Climate Symposium* (Copenhagen, Aug. 30- Sept. 1, 1978).

[3]W C. Hinde and M. S. First, 1975, “Concentrations of Nicotine and Tobacco Smoke in Public places,” *New England Journal of Medicine,* 292:844-5.

[4]For example, see S. J. Peakale and G. De Oliverira, 1975, “The Simultaneous Analysis of Carbon Monoxide and Suspended Particulate Matter Produced by Cigarette Smoki rig,” *Environment/ Research,* 9:99-114.

product of radon)—potential causes of lung cancer—to the indoor environment. Table 74 provides a brief summary of the sources, effects, and exposure levels of the important air pollutants found in significant quantities in indoor air.

Table 74.—Characteristics of Some Indoor Air Pollutants

Pollutant	Major sources	Impacts	Exposure indoors
Sulfur dioxide (SO_2)	Outside air	Risk of acute and long-term respiratory problems in conjunction with particulate	Usually somewhat lower than outdoors
Carbon monoxide (CO). .	Outside air (autos), gas stoves, smoking, infiltration from garage	Headache, dizziness at lower concentrations; nausea, vomiting, asphyxiation, death at higher concentrations	Can be high from indoor sources; much outdoor concentration is passed indoors
Nitrogen dioxide (NO_2). .	Outside air, gas stoves, oil **or** gas furnaces **(when** imperfectly vented)	Risk of acute respiratory problems, possible long-term respiratory problems, possible increased mortality from cardiovascular disease and cancer	Can be very high, especially when gas stove is operating
Photochemical oxidants	Outside air	Eye irritation, respiratory discomfort; long-term problems not well-understood	Lower than outdoor concentration
Total suspended particulate (including trace elements).	Outside air and resuspension from physical activity; smoking, asbestos insulation, gas stoves, etc.	Risk of short-term pulmonary effects; some toxic components can have severe and varied effects	Can be very high, especially from smoking; particles in respirable size range dominate
Hydrocarbons.	Outside air, smoking, pesticides, spray can propellants (fluorocarbons), cleaning solvents, building materials, etc.	Risk of a variety of severe acute and long-term effects	Can be high, also can have continuous low-level concentrations
Radon & radon daughters	Cement, stone, bricks, etc.	Enhanced risk of lung cancer, other cancers	May be significant
Bacteria & spores.	Coughing, sneezing	Spread of respiratory illness	Higher than outdoors

ENERGY CONSERVATION EFFECTS ON INDOOR AIR QUALITY

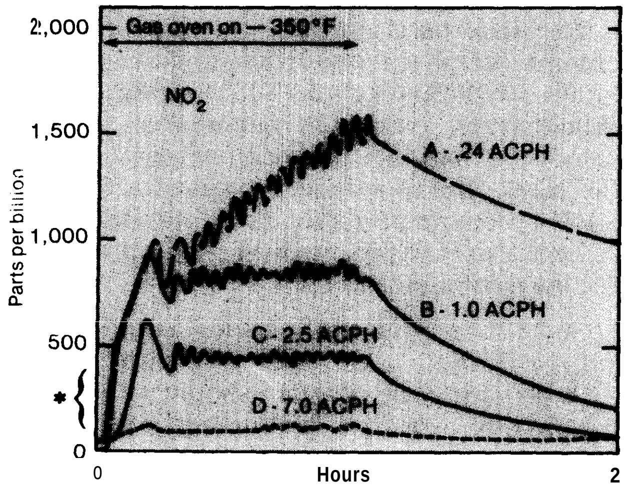
A principal strategy for conserving energy in homes is to lower the rates of air exchange from infiltration and exfiltration, as this air exchange is a major heat loss mechanism (and a major source of cooling loss in hot weather) in buildings. Lowering air exchange rates is accomplished by sealing the structure, e.g., by weatherstripping, caulking, sealing cracks, and tight construction.

Lowering the air exchange rates in a structure also slows the diffusion of indoor-generated air pollutants to the outside. In other words, the pollutants tend to be trapped inside the structure. Many of the studies of indoor air quality show a clear and strong inverse relationship between pollutant levels and air exchange rates. For instance, figure 21 demonstrates a very strong inverse relationship between air exchange rates and nitrogen dioxide concentrations in the presence of an operating gas oven.[5]

Many of the indoor air quality problems were discovered only when air exchange rates were drastically reduced and the pollution effects became obvious to the building's inhabitants. These effects tend to be odor and mois-

[5]Hollowell and Traynor, op cit.

Figure 21.—Nitrogen Dioxide Concentrations in a 27m³ Experimental Room at Various Air Exchange Rates



NOTE: Gas oven operated for 1 -hour at 350° F.

*Range of recommended 1 hr. air quality standard.

ACPH = air change per hour.

ture buildup rather than health problems, as the former are more commonly associated with the housing environment. Problems of this nature are not uncommon in Scandinavia, where recently built housing is far tighter than average new homes in the United States. Such difficulties could seriously impair the credibility of energy conservation programs in the same way that problems of flammable cellulose insulation have recently discouraged buyers,

Promotion of energy conservation measures for buildings may exacerbate an existing indoor air quality problem whose present dimensions are largely unknown. Thus, it is crucial that the conservation effort be closely coupled with a program to expand our understanding of indoor air quality as well as with measures to protect the indoor environment.

EXPANDING OUR UNDERSTANDING OF INDOOR AIR QUALITY

The Federal research effort on indoor air quality has been limited to a few small, piecemeal contracts. The total Federal effort appears to have been on the order of $1 million yearly for the past several years. The Department of Energy (DOE) has funded most of its small effort through Lawrence Berkeley Laboratory in California; the Environmental Protection Agency's (EPA) major effort was with Geomet, Inc., in Gaithersburg, Md. Neither of these series of studies can be characterized as a comprehensive, systematic effort to increase our knowledge about the sources, characteristics, and effects of indoor air pollution.

This low level of effort is particularly difficult to understand because both DOE and EPA have ample evidence to demonstrate that the current system of air pollution monitoring based on central measurement stations is often **not** measuring true exposure. Besides the obvious problem of indoor air pollution, the exposure measurement problems that arise from nonuniform pollution distribution, commuting activities, and other factors severely **limit the credibility of central-station-based exposure** estimates.

As a result of these errors in measurement:

- The current enforcement of air quality standards based on central station pollution monitors may not be adequately protecting the public.
- The emission control strategies designed to support these standards may be either too lenient, too strict, or else simply badly skewed.
- Epidemiological studies of pollutant health effects suffer from severe errors in measurement of population exposure.

Thus the lack of understanding of indoor air quality is part of a larger problem of determining total environmental exposure to air pollution. Any Government program designed to improve our understanding of the indoor environment should take care to integrate this research with research into the total exposure problem.

In the past few years, a number of excellent personal air pollution monitoring instruments have been developed for selected air pollutants. If monitors were available for a wider range of indoor and outdoor air pollutants, field studies could use them to measure real exposures of a representative sample of the urban population. The relationship between existing air pollution monitors and actual exposures might be better understood, with the following benefits:

- A more accurate, uniform, and meaningful measure of air quality than is possible with today's data. This would provide a more realistic measure of the success of present control strategies.
- Identification of critical portions of the population –by occupation, location, or other factors — that require special attention, especially during episodes of extremely high pollution concentrations.
- Development and validation of models capable of predicting pollution exposure to other than ambient pollutant concentrations.
- Exposure data that is necessary to conduct credible statistical studies of the health effects of low levels of pollution.

Various experts estimate the cost of developing a personal monitor for a particular pollutant at $250,000. ' A 1975 workshop' at Brookhaven National Laboratory recommended a national development program at the level of $1.5 million per year for **5** years. Such a program probably would suffice to produce the prototype personal monitors needed for the most important pollutants.

Given the existence of personal monitors for industrial applications, the first step of any such development program should be a rigorous quality assurance testing and evaluation of the existing technology to determine its applicability to exposure assessment studies. As monitors for critical pollutants become available, they can be deployed to provide the assessments described above. These assessments, if conducted with careful attention to discovering the socioeconomic and physical characteristics that govern the variation of pollution exposure within an area, should provide the understanding of indoor air quality that is currently lacking.

PROTECTING THE INDOOR ENVIRONMENT

There are three basic approaches to protecting the indoor air environment:

1. maintenance of an adequate level of air change,
2. air purification, and
3. reduction of indoor sources of air pollution.

Air Change

Because energy conservation involves deliberately reducing air infiltration and exfiltration — natural air exchange—the maintenance of a satisfactory level of indoor air quality involves artificially inducing an air exchange with some mechanism to recapture the heat in the exhaust air. In Europe, and particularly in Sweden, it is not uncommon to provide a heat-recovering system as part of the home ventilating system. An advantage of such controlled air change is that air removal points can be located near the major sources of moisture, odor, and pollutants. For example, the kitchen can be ventilated at a higher rate than the remainder of the home. Also, development of inexpensive monitoring equipment will allow the rate of air change to be varied according to the (air quality) need. However, the

'Lance Wallace, "Personal Monitors," in vol. IVa (Environmental Monitoring Supplement) of Analytical Studies for the U S Environmental Protection Agency, National Academy of Sciences, Washington, D. C., November 1977

'M. G. Morgan and S. Morris, "Individual Air Pollution Monitors An Assessment of National Research Needs," report of a workshop held at Brookhaven National Laboratory, July 8-10, 1975, Energy Research and Development Administration, January 1976.

critical factor in avoiding the loss of the conservation benefits of reducing natural infiltration is still the exhaust air heat recovery. A number of devices in varying stages of development are capable of extracting this heat and transferring it to the incoming air. These include heat pumps, heat pipes, interpenetrating ducting, heat wheels, and runaround systems (see volume 11, p. 548, for a description of how these systems work). The interpenetrating ducting systems, which are heat exchangers with the incoming and exhaust air streams in parallel but opposite directions, are presently available, can be extremely efficient, and are the simplest of the systems; they appear to be the most feasible systems for residential use.

Air Purification

Air purification is an alternative or a complement to air change as a method of assuring good indoor air quality. Ventilation with heat recovery may be inadequate to maintain adequate air quality if the outside air is polluted. Without air purification devices to screen the incoming air, the ventilation system can compromise the building's "sheltering" effect in protecting its occupants from outside pollution.

Indoor air pollutants vary sufficiently to require a variety of devices to ensure thorough control. The pollutant categories that require different methods of control are moisture, particulates, and airborne chemicals and odors. Moisture can be controlled by dehumidification equipment in the heating season and air-conditioning in the cooling season. Particulate control is accomplished in most homes with forced-air heating and cooling by inserting a filter in the ducts. These filters are not efficient collectors of finer respirable particulate. Electrostatic precipitators can be added to allow control of a greater range of particle sizes; this equipment is available today.

Reduced infiltration rates will most affect the need for control of airborne chemicals and odors. Aside from ventilation, the control technology categories are:

1. **Absorption** by dissolving the pollutants in liquids. Spray washing, which can also capture particulate and provide a dehumidifying function, is often used in large buildings.
2. Adsorption of the odors and chemicals on a solid, usually activated carbon. This method should have the greatest residential application.
3. Chemical reaction by oxidation to an inert, odorless state. The oxidizing chemical can be added to the water in a spray washer or to the activated charcoal in an adsorption filter for a combined effect.

Much work remains to be done on all these technologies.

Pollution Source Reduction

Much indoor air pollution occurs because of (or is increased by) poor maintenance or improper manufacturing techniques. For example, levels of formaldehyde emissions from wallboard depend on proper curing of the material. Carbon monoxide emissions from gas stoves can be increased by several orders of magnitude by improper burner adjustment or maintenance. Defects in the venting of gas and oil furnaces can and often do contribute to indoor air pollution. Many of the chemicals used **in cleaning and** in hobby work are extravagantly and/or improperly used, and their contribution to degrading of indoor air quality could be substantially reduced through increased awareness of their adverse effects. It seems likely that many chemicals in use in the home environment are inappropriate except under carefully controlled conditions and should be controlled; however, no analysis of the appropriateness of such controls was conducted during this study.

A strategy for pollution source reduction should clearly include an added emphasis on combustion equipment maintenance and design, as well as far greater Government attention to the composition of common household chemicals and their packaging and labeling, plus the pollution-causing properties of materials used inside the home.