BUILDING ILLNESS IN THE WHITE-COLLAR WORKPLACE

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An increasing incidence of "building illness" is being noted among white-collar workers due to the high pollutant content of air in modern energy-efficient office buildings. These buildings are hermetically sealed, mechanically ventilated, and contain many materials that give off a variety of toxic fumes and aerosols. Severe outbreaks of illness have also been traced to ventilation problems in sealed hospital buildings. Similarly, tightly sealed and well insulated private homes present many sources of toxic pollutants to homemakers. Recent studies linking increases in the frequency and duration of respiratory illnesses with increasing pollution levels warn us that increases in indoor pollution levels should be avoided in the white-collar workplace, hospital, and private residence. Unfortunately, the cost of adequate ventilation of modern air-tight buildings is high. However, proper planning must be conducted to foresee and correct the impact of energy management policies on the livability and healthfulness of the indoor environment.

The comfortable view that the office worker and the homemaker are relatively free from exposure to occupational hazards is slowly changing under the impact of recent pioneering studies (1, 2). Nonetheless, it is still generally thought that white-collar environments are safe from the toxic fumes and dusts that pervade the air of industrial shops. Rapid changes in building and environmental service technology appear to have eliminated the relative advantage of the ambient environment of the white-collar workplace. The shift from natural to mechanical ventilation of buildings, new principles of design, and the use of new materials, products, and equipment have increased the level and variety of pollutants to which building inhabitants are now exposed.

In many ways, a modern office building is very much like a submarine standing on end. The quality of the ambient environment depends primarily on inside activities, materials, infiltration/exfiltration characteristics, and the ventilation procedures which clean and refresh the air. New modes of building construction and ventilation have had profound effects on the manner in which buildings generate, entrap or eliminate pollutants. This is because modern buildings (especially office buildings) are hermetically sealed, air-tight shells; their ventilation is interconnected through a mechanical ventilating, heating, and air conditioning system; and they contain materials (either as part of the building or as part of the furnishings and equipment) that give off a variety of toxic fumes and aerosols.

Generally, any outside pollutant finds its way indoors regardless of the structure or building. For instance, combustion byproducts from automobiles are drawn into the building through its ventilation system. (This includes tetraethyl-lead, for which almost the only source is automobile combustion.) Contaminants are also brought

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indoors on the clothing, hair, and skin of building inhabitants. Once inside, the elimination of pollutants depends on the building's exfiltration characteristics. Conditions in sealed buildings are such that some pollutants may be entrapped and concentrated indoors. Examples are dust residues from industrial carpet cleaning detergents, particles from asbestos or glass fiber insulation, off-gassing from various types of materials such as urea formaldehyde contained in composition board, carbon monoxide and hydrocarbons from plastics or oil paints, and fumes from photocopying or from smoking. Then there are a variety of life forms growing inside buildings, including molds, fungi, spores, bacteria, and algae. Many of them are lodged in and distributed through heating and air conditioning ducts. The fact that inhabitants may use various types of pesticides to combat indoor growth adds yet another factor to the toxic content of indoor pollution.

To this array of toxic materials, hospitals add specific residues of solvents containing benzene, anaesthetics or fumes from sterilizing equipment (all of which may have harmful health effects), and variable sources of infectious bacteria and viruses.

Private residences have also been affected by modern building materials. Many new products, such as formaldehyde-containing composition board, give off gases and residues. Entrapment of indoor pollutants is exacerbated by use of insulation and sealants to decrease the loss of heated (or cooled) air. The well insulated, sealed residence also entraps indoor-generated pollutants or pollutants drawn in from the outside. Some of the materials used to insulate a house may also contribute heavily to the exposure of occupants to dusts such as asbestos or to toxic off-gases such as formaldehyde. Similar off-gassing from special solar heating panels may add to that burden. The burden is especially heavy on homemakers, who ought to be recognized not only as practicing an occupation but as practicing one that exposes them to many hazards. Exposure to toxic fumes and dust generated in the well insulated home may place a severe burden on the homemaker's respiratory system. Many homemakers are especially affected by the widespread use of gas ranges, which are a primary source of toxic fumes in the home.

As long as ample ventilation ensures a constantly renewed fresh air supply, indoor pollution problems may not be severe enough to warrant special attention (although often this is not the case). However, as the amount of energy required to adequately ventilate buildings becomes increasingly expensive, suggested ventilation rates are being reduced (3, 4). When ventilation is reduced, the many pollutants generated and/or entrapped indoors become increasingly concentrated and are very likely sources for discomfort and illness. Landlords and developers readily reduce ventilation because the people most affected by the consequences of supplying less fresh air are relatively unorganized clerical and technical workers and women homemakers–large groups of affected individuals to be sure, but groups that lack political leverage. Yet so compelling have been the consequences of cutting down ventilation in sealed buildings, that the public health implications of indoor pollutant effects are being recognized. It is our purpose to document the primary data on sources and effects of indoor pollution. Only by understanding the sources of indoor pollution and their health effects can a reasonable architectural and ventilation design strategy be developed that will minimize the indoor burden of toxic substances and, with it, the risk of discomfort and illness to people who work inside.

BUILDING ILLNESS AS A RESPONSE TO SPECIFIC AGENTS

A number of investigations have found that recognizable symptom syndromes may occur in offices, homes, and hospitals in response to specific toxic dusts or fumes or viable organisms. The following are a few recent examples from office building studies:

Symptoms due to detergent residues. Dry detergent residue left in carpets after they were shampooed with undiluted carpet shampoo caused respiratory irritation among most employees in an office building and among all staff members and most children in a day care center (5). Symptoms included cough, dry throat, difficulty in breathing, nasal congestion, and headache. Eye irritation was also noted by day care center staff members. Symptoms persisted for many weeks until the carpets were wet extracted.

Symptoms due to fibrous glass dust from duct work. Fibrous glass dust entrained from unlined, matted fibrous glass ductwork which has sustained repeated water damage was determined to be responsible for an outbreak of itching, evanescent rash, and irritation of the eyes and respiratory system in a department store (6). Symptoms and dust resolved when filters were placed in ceiling louvers. (There are also a number of studies that report appreciable amounts of asbestos fibers in the atmosphere of offices without finding a direct relation between symptoms and these fiber densities (7). However, given the present knowledge about asbestos-related diseases, the observed fiber densities of 0.003 to 0.13 fibers/cc very likely represent a chronic disease hazard.)

Symptoms due to formaldehyde off-gassing from insulation. Formaldehyde, whether in the form of insulation or shelf or space dividers, has a tendency to "out-gas" or give off fumes as it deteriorates. In an air-tight building, even low levels of these fumes can cause a wide range of irritation to occupants. In one Los Angeles office building, workers complained of burning eyes, coughing, breathing difficulties, nausea, and dizziness (8). Measurements showed concentrations of 6 to 7 parts per million (ppm) of formaldehyde near the walls. Three ppm is considered the legal occupational threshold in the United States (9), although a lower standard of 1 ppm has been recommended (10); Consumer and Corporate Affairs Canada considers 0.1 ppm to be the maximum level allowed in homes insulated with urea formaldehyde foam insulation (UFFI).[1] (There are in fact a number of buildings with reported levels ranging from 0.04 ppm to 1.5 ppm of formaldehyde where investigators suspected symptoms to be related to off-gassing even at these lower levels (11).)

Symptoms due to photochemical smog formation. Photochemical smog is a complex of chemicals usually produced by the interaction under ultraviolet radiation of ozone and combustion byproducts. Buildings have been shown to contain all the airborne precursors of photochemical smog, including ultraviolet radiation (emitted from fluorescent lights, photocopy machines, and video display terminals), formaldehyde, hydrocarbon vapors, peroxyacetyl nitrate, benzilic monoalcylbenzenes (including toluene and styrene which combine with nitrate), and even trichloroethylene contained in white-out materials used by typists (12-14). In an experimental

[1]Severe outbreaks of health problems due to UFFI off-gassing followed the Canadian Government's dispensation of special grants to homeowners insulating their homes with urea formaldehyde foam. No epidemiological study has yet been initiated, however.

study conducted on occupants of an office building where excessive symptoms of eye irritation and headaches had been documented, Sterling and Sterling (15) demonstrated that when lighting and ventilation characteristics were varied so as to minimize levels of precursors of photochemical oxidants, symptoms were drastically reduced. When lighting and ventilation were returned to normal, excessive symptoms returned as well.

Diseases from viable organisms located in duct systems, cooling towers or humidification chambers. Outbreaks of legionellosis (Legionnaire's disease) have been linked to viruses from air ventilation systems. Legionellosis has been isolated from cooling towers and evaporative condensors. Drifting of clouds of infected droplets originating in these devices results in the introduction of organisms into buildings, often through the air intakes of the air handling system (16). Another virus, thermophilic actinomycetes, contaminating the recirculated water in air conditioning and ducted air heating systems of domestic cold mist vaporizers, has been shown to be responsible for hypersensitivity pneumonitis in some subjects (17-20). Humidifier fever, a variant of the above syndrome, has been described in offices, factories, and operating theatres (21, 22). Biological contamination of humidifier systems is again thought to be the cause. The main causal organism may be an ameba, Naegleria Gruberi. Recent Centers for Disease Control studies indicate that amebae (Acanthameba) are also common contaminants of air conditioning systems, including those without humidification (23).

Special Problems in Hospitals and Laboratories

Workers in hospitals and laboratories may be exposed to very special air contaminant problems. The National Institute for Occupational Safety and Health (NIOSH) monitored the exposure of nurses and anesthesiologists to nitrous oxide, ethane, and halothane in the operating and recovery rooms of five Colorado hospitals between 1977 and 1980 (24-29). In all cases the investigators concluded that a health hazard existed due to excessive levels of waste anesthetic gases. These levels were presumably caused by a combination of: (a) inadequate venting of the scavenging system; (b) contamination of the air supply by recirculated air; (c) difficulty in administering gas to some patients; (d) improperly fitted face masks; and (e) the technique of administration by the anesthesiologist. Between 40 and 50 percent of operating room and recovery room personnel suffered from acute symptoms, including fatigue, headache, dizziness/lightheadedness, nausea, drowsiness, cough, and skin irritation (27).

Excessive exposure of hospital staff to chemicals used in the sterilization of surgical equipment has often been suspected. One investigation of ethylene oxide determined that at the nurses breathing zones contaminant levels did not constitute a health hazard; however, the investigator commented on the potential for overexposure when the ethylene oxide sterilizer is first opened, and workers were advised not to place their heads inside or breath vapors from the sterilization unit just after the sterilization procedure (29).

In an industrial hygiene study of a surgical daycare center, complaints of drowsiness, headaches, lethargy, and swelling and irritation of the eyes were found to be reduced after use of the organic germicides isopropyl alcohol, glutaraldehyde, and parachlorophenol was reduced (30). The investigators also noted that these same organic compounds may further contribute to formation of other highly irritating organics in the air through reaction with ozone, nitrogen oxides, and other urban air pollutants in a mechanism similar to the formation of photochemical "smog."

In addition to exposure to toxic chemicals, hospital workers face the added danger of exposure to airborne organisms circulated through the ventilation system. Since its discovery in 1976, Legionnaire's disease has turned up in hospitals around the world and in many cases has been traced either to contamination of the water supply, cooling tower or humidification system.

Proper ventilation of laboratories where toxic chemicals and organisms are used is crucial to the health of the general population adjacent to the laboratory as well as the laboratory workers. Improper installation, operation or design of laboratory exhaust may be responsible for insufficient removal of toxic substances from research laboratories (31). An additional problem when laboratories are contained within or near other buildings is contamination of the fresh air supply with laboratory exhaust. This can have disastrous consequences, as in the case of an outbreak of smallpox caused by improper venting of a research laboratory (31). Other examples, which include NIOSH investigations at Oregon State and Amherst Universities, have demonstrated the potential for laboratory exhaust to be reintrained into the general ventilation system (32, 33).

More recently, an investigation of a Canadian Government research center concluded that fume hoods designed to harmlessly remove exhaust from laboratories were feeding laboratory exhaust back into the building's ventilation system (34).

Special Pollution Problems in Private Residences

The ambient environment in private residences has always had the potential to be hazardous to occupant health. This is primarily due to the needs of cooking and air and hot-water heating. Pollutants due to cooking and heating have been exacerbated by the recent increase in fuel costs which has led to tight sealing of the private residence. At the same time, mechanical ventilation devices for residences, which to some extent can control air quality in industrial or office environments, are lacking. Many forms of insulation materials, especially urea formaldehyde-containing insulation, contribute heavily to toxic gases in the home. Formaldehyde also off-gasses from composition board. Chlorophenols, which are used to treat lumber, are also off-gassed.

Many residences, in North America and Europe especially, use natural gas as a cooking fuel. Indoor combustion of natural gas is a source of emissions of such toxic gases as carbon monoxide and nitrogen oxides. This may become exceedingly hazardous in the indoor atmosphere of well sealed and insulated private homes.

Levels of gaseous air pollutants (CO, NO, NO_2, and aldehydes) and respirable particles are sharply elevated in indoor environments where gas appliances are used. Average concentrations of carbon monoxide in kitchens have been found to routinely exceed the Environmental Protection Agency's occupational ambient air quality guideline of a maximum of 35 ppm carbon monoxide during cooking with gas ranges (35, 36). Average (not peak) carbon monoxide levels in kitchens during meal preparation may approximate 40 ppm.

Asphyxiation is a well known consequence of a combination of gas applicance use and inadequate ventilation. Goldsmith (39) estimated that approximately 100,000 deaths due to carbon monoxide poisoning occur yearly in the United States. Low levels of emissions of oxides of nitrogen from gas range cookers have been associated with respiratory symptoms in children (38-41). In energy-efficient buildings where infiltration is reduced, the impact of indoor-generated pollutants on indoor air quality may have more serious ramifications than in conventional buildings.

To cooking must be added the practice, frequent especially among poorer families, of using the gas range for supplementary heat. A study by Consolidated Edison of New York lends itself to estimates that as many as 55 percent of their customers may use the gas range for supplemental heating. These figures agree with a study by Sterling and Kobayashi (36) which found that in 50 percent of a sample of New York apartments in poor neighborhoods the gas range was used as a supplementary heater. High carbon monoxide and nitrous dioxide values were found in these homes. There is a possibility that the learning ability of children in these homes may be impaired early in life from exposure to high levels of carbon monoxide.

The application of new energy-conserving technology, untested for consumer safety, to homes may also create serious health hazards. The Colorado Department of Health investigated complaints of headache, nausea, vomiting, and skin and eye irritation on sunny days received from occupants of homes with installed solar panels consisting of polyester-fiberglass glazings coated with acrylic, isocyanurate insulation, and silicone sealant (42). The investigation consisted of field inspection of installations and interviews with occupants. The investigators concluded that the solar panels appear to have a persistent off-gassing problem. Nearly all of the households interviewed perceived an odor, and about half may have had symptoms related to an unknown exposure to chemicals which might off-gas from the fiberglass glazing or other components.

DISEASE IN RESPONSE TO GENERAL POLLUTION

Does the level of air pollution as currently encountered in buildings cause disease? This question has been difficult to answer because populations exposed to low doses of many air pollutants may not respond in a uniform way, nor do measurements of building environments usually show excessively high levels of specific toxic agents. True, there is evidence that points to general air pollution levels as a source of illnesses. For instance, there is a much higher lung cancer rate in urban than rural settings, especially in industrialized urban centers. But people live quite different lives in cities than in rural areas, and while the higher general air pollution levels in cities may be suspect, they are not necessarily demonstrated to be the cause of increased lung cancer or other mortality in urban communities. A more precise correlation between disease and general pollution has been established by relating changes in frequency and duration of morbidity in a community to its fluctuating air pollution levels.

Hospital Morbidity in Response to General Air Pollution

An approach to determining the effect on the health of a community by prevailing levels of pollutants is through the study of acute effects possibly induced by small changes in air pollution levels. Such acute effects can be measured on an ordinarily healthy population group, temporarily at a low level of resistance, by observing ordinarily healthy individuals who seek health services or are hospitalized for different diseases. Such individuals may be considered at low levels of resistance to environmental insults. The question for investigation is whether or not air pollution at prevailing levels of concentration presents enough (additional) stress to contribute to the incidence and severity or range of diseases. It was only when air pollution network measurement and hospitalized patient records were made machine readable that air pollution effects on an adequate number of hospital patients could be studied.

Studies by Sterling et al. (43-45) used American Blue Cross-Blue Shield data from nine hospitals, each with more than 100 beds and less than five miles from a pollution measurement station (without obstructing mountain ranges between the hospital and the air pollution station). Air pollution levels were obtained for a period of 223 successive days. Hospital data were obtained from approximately 30,000 patients.

As not all diseases may be expected to be similarly affected by pollutant levels, diseases were grouped into those that were "relevant," such as allergic disorders or acute upper respiratory infections, and those "not relevant," such as elective surgery.

Results of the analysis were uniform and convincing. Frequency of admission and duration of hospitalization for relevant diseases were significantly correlated with fluctuations in pollution levels. Associations were most pronounced with levels of particles, which are by far the best measure of general pollution, and with SO_2, a measure related to "dirty" fuels.

In a recent survey of environmental and health complaints of office workers in six buildings, Sterling et al. (46) noted a higher incidence of both health and environmental complaints among workers in sealed buildings than among workers in buildings with operable windows. As indoor pollutant levels are generally higher than those outdoors or in well ventilated, windowed structures, this again is probably a reflection on the increase of symptoms to conditions of increased general pollution.

DISCUSSION

Buildings are complex environments which entrap and concentrate as well as generate agents that cause discomfort and often disease. Architects and ventilation engineers have been primarily concerned in the past with regulating heat and humidity and some of the byproducts of human activities such as odors. Clearly we have entered a period in which building designers and engineers need to expand their horizons and incorporate design features in their plans that will minimize the large varieties of general pollutants that may dominate a building's atmosphere, especially those that are related to specific diseases.

Where a specific source for a building illness has been identified, it can be avoided. When high levels of urea formaldehyde are a problem, the building designer would be wise to avoid formaldehyde-containing composition board. Where industrial detergents due to shampooing of carpets are a problem, they can be exchanged for other types of cleaning methods or carpets can be avoided entirely. Where Legionnaire's disease threatens, periodic thorough cleaning of filters, cooling towers, and humidification chambers may be effective. However, getting rid of specific sources, while helpful, does not actually solve the underlying problem of "building illness."

Many fumes are generated inside from off-gassing of wall and floor coverings, furniture, and paints. Numerous ready sources (e.g. photocopying equipment) of various toxic chemicals are distributed throughout buildings. Many different types of dusts and fibers may come through ventilation ducts or be brought in by individuals. Biological life can adapt itself to all conditions. This includes the inside of buildings, especially the ventilation system, and also various surfaces.

Studies linking increases in respiratory illness frequency and duration with increases in pollution levels warn that any increase in indoor pollution ought to be avoided in the white-collar workplace, hospital, and private residence. Our demonstration of the possible formation of photochemical smog indoors and the relief of eye irritation following increased ventilation indicates that the one major cure for problems of modern sealed buildings may be a high rate of ventilation. The same conclusions emerge from the demonstration of an association between building ventilation characteristics and the frequency of building-related complaints. Unfortunately, the cost of vigorous ventilation of modern sealed buildings is high, and it may well be that the so-called "energy-conserving" building, as presently designed and ventilated, will end up being not so energy conserving at all.

That the modern office building may not be energy conserving is not the greatest concern of the people who work in it. Their concern is the environment to which they are subjected. It needs to be recognized that the environment in an office may be as toxic as the environment in an industrial shop. However, it is not necessary to add this risk to office work. Adequate ventilation can remove much of the harmful pollution.[2]

Unfortunately, modern office buildings are not easily ventilated—a fact that needs to be faced by employers and employees alike. It is likely that heavy subsidies will be required to convert the highly polluted modern sealed building into a well ventilated structure suitable for the employment of human workers.

The hospital has always been a difficult place to keep free from airborne hazards both to patients and staff. The modern sealed building makes matters increasingly difficult because the ventilation system itself becomes a breeding ground and distribution system for toxic viruses and bacteria. Here, perhaps more than in the modern office building, new architecture and ventilation practices need to be evolved.

Health risks to individuals in their own homes are rarely recognized, especially those to full-time homemakers. For instance, the Canadian Government encouraged homeowners to insulate their homes with urea formaldehyde foam to save on fuel use. The resultant gassing of a large number of Canadian homes with toxic fumes has created a major emergency for many of the people who own these buildings as well as

[2] Studies by the National Institute for Occupational Safety and Health, the Centers for Disease Control, and other agencies appear to show that only where office and technical workers are organized are they able to compel the attention of employers and health agencies to needed changes. Instrumental in focusing attention on the health problems of office workers have been the organizations of women workers such as the Coalition of Labor Union Women, the Women's Occupational Health Resource Center, Working Women (U.S.), and the British Society on Social Responsibility (47).

for the government that encouraged and even subsidized the fatal insulation errors. Both the United States and Canadian Governments have held high hopes for the use of natural gas as the cooking and heating fuel of choice. However, high levels of toxic pollutants from cooking practices and the often real need for poorer households to use the gas range as a supplemental heater add to the burden of pollutants in the home. It may be doubtful that a satisfactory balance can ever be achieved between the high pollution levels resulting from use of the gas range and the ventilation needs under which a home's residents can enjoy a healthful existence (48).

Perhaps nowhere do we have as good an example of the destruction of human health brought about by conscious reliance on pure market factors to regulate the use of energy—and, with it, pollutants resulting from inappropriate use of energy—than in places in which humans work, including the ambient environment of the homemaker. To a lesser extent this is true also for hospitals. Energy as a resource belongs to society, and its adequate and equitable distribution requires planning. Where this planning is not properly conducted (as it has not been) to maintain a livable indoor environment, conditions are created by which the health of all is threatened.

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