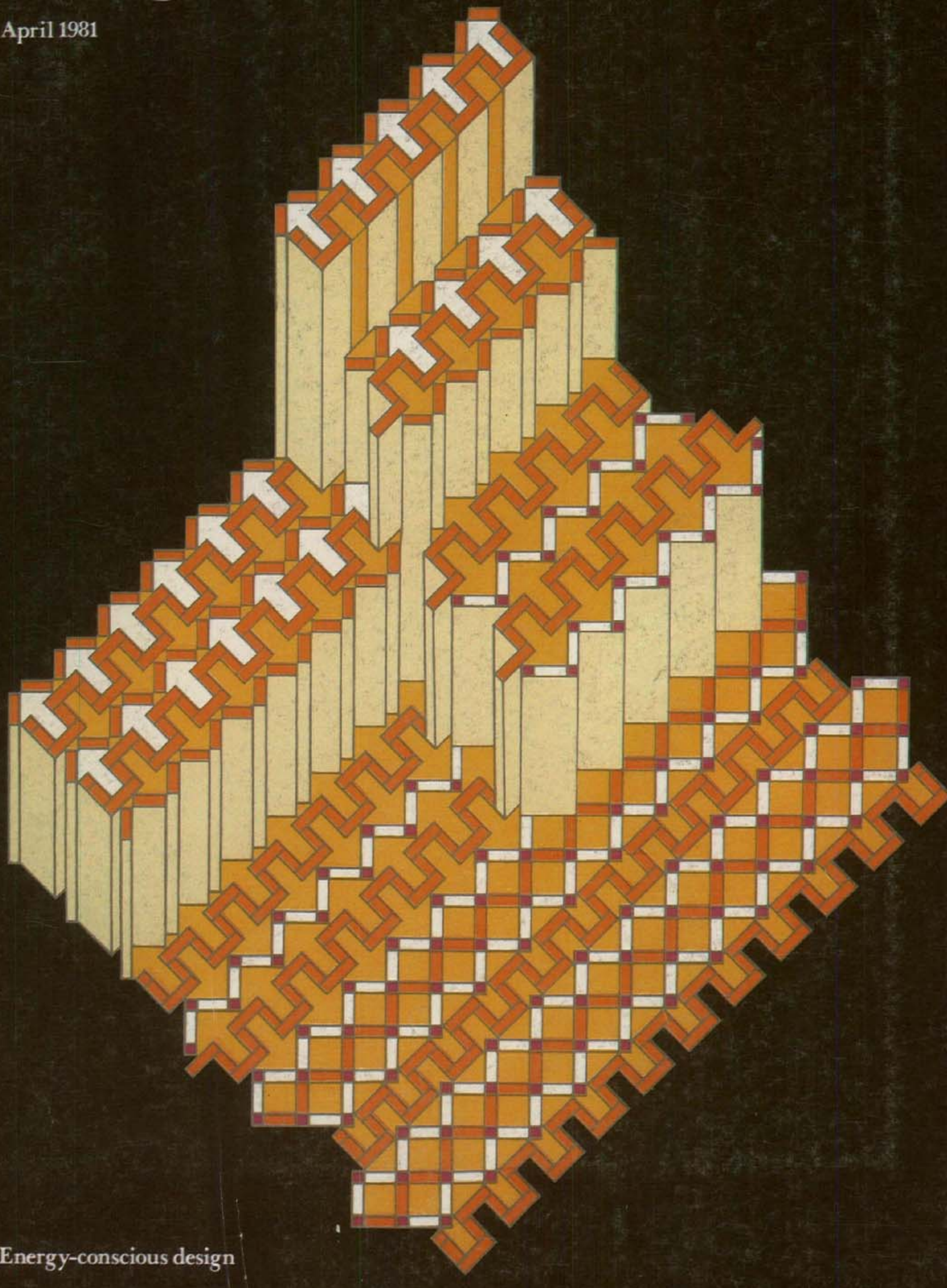
Progressive Architecture

April 1981



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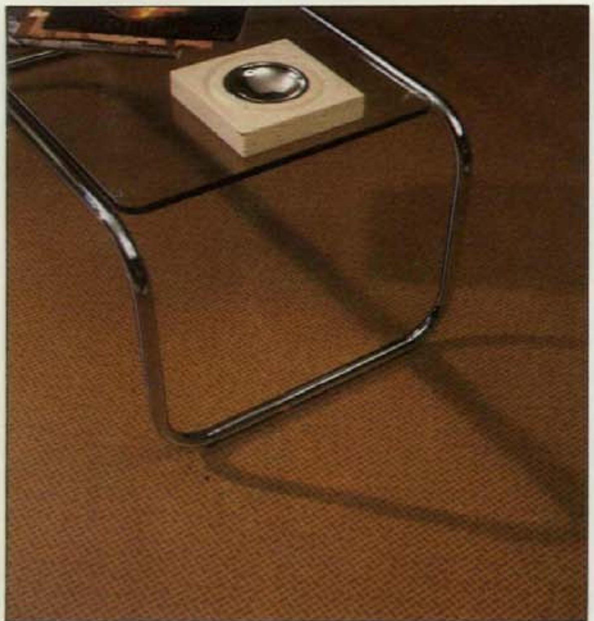

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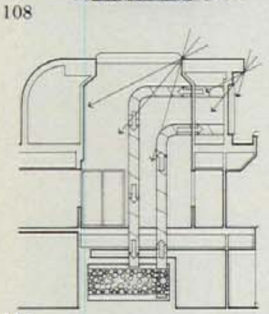

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ABP

Building ecology

Hal Levin

The life process has a way of reminding us that no single emphasis of design can exist to the exclusion of others. The world oil situation reminds us that energy conservation is vital. Building health problems remind us that energy conservation alone may make a building unhealthful.

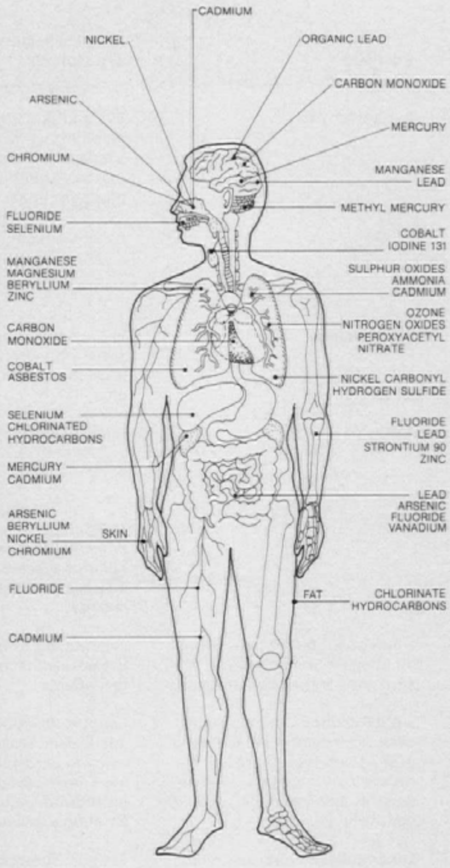
Modern buildings pose a number of new energy and health problems. These problems relate to changes in building practices begun mainly since World War II. They include the widespread shift from natural to synthetic materials generated by the chemical and materials industries after the war's end. Environmental controls including lighting, heating, cooling, and ventilating have necessitated a shift from largely architectural passive methods and systems to increasingly energy-intensive active mechanical systems in sealed (closed) buildings of great height and bulk.

Maintenance compounds, fire retardants, stain repellants, and other chemicals abound—most of the new products with considerable release to the environment. Building materials, furnishings, and equipment also consist primarily of modern chemical products often suspected or confirmed as toxic or carcinogenic.

Brightly illuminated (fluorescent-lighted) interiors have replaced incandescent- and day-lighted spaces. Increasing use of electric equipment has significantly changed the electromagnetic and electrostatic environments indoors. Many office and factory workers and students spend their days at computer or microfilm screens. Considerable concern has emerged about the impacts of these systems on their users' health and functioning.

Building occupancy patterns have also changed considerably. Occupations have shifted most workers from outdoors to indoor jobs. Modern building technology has increased settlement in hostile climates where people spend more time indoors. The result is that most Americans now spend from 70 to 90 percent of their time indoors.

The rapid decrease in cheap, readily available energy supplies has resulted in a rush to save money/energy by tightening building envelopes and reducing ventilation rates. Pre-Arab oil embargo rates of 3 to 10 air changes per hour have been revised downward to 1.5 air changes per hour or less, and many serious health hazards result from increased concentrations of air pollutants. Many contaminants are generated by the buildings themselves; some are produced by the occupants; and some, like the bacteria linked to Legionnaires Disease, originate outside. Many of these contaminants are concentrated, bred, or intensified by the building itself.



MAIN TARGETS OF MAJOR POLLUTANTS

After an illustration by Waldbott "Health Effects of Environmental Pollutants"

From the energy crisis (and the drought in California) we have learned that we can get by on far less, that we had acquired careless habits of design and consumption during years of abundant, cheap supplies of these and other resources. Now we are facing a squeeze on resources of all types, and we do not yet know the implications of adapting our buildings to new constraints.

Research conducted recently suggests that simple modification of existing approaches and technologies will often result in serious health hazards. Many of these hazards are related to substances or problems with which we have frightfully little experience. What experience we do have suggests that the interactive effects of diverse hazards and components of the built environment may have impacts several orders of magnitude greater than the individual or even additive effects of combined hazards.

Currently we are confronted with problems in newly constructed or remodeled structures. The examples given below only suggest the range and complexity of these problems.

Oakland High School

In September 1980, some of the faculty and students who were moving into the new $9.5 million *Oakland High School in Oakland, Ca,* reported eye irritation and difficulty in breathing. The woman responsible for the textbook room complained of severe headaches, skin irritation, and nausea. In a survey, one-half of the student and faculty respondents said their health had deteriorated since coming to the new campus.

Particle board shelving in the new storage units was suspected of giving off formaldehyde. Cal-OSHA investigators found that the school's air contained 1.2 to 1.6 ppm (parts per million) of formaldehyde. While the state has no indoor air quality standards, its occupational exposure ceiling for formaldehyde is 2 ppm. A majority of people, however, suffer eye, skin, nose, or throat irritations at formaldehyde concentrations above 1 ppm.

The school's air-handling system was not functioning according to the design specifications when school sessions began. So it is difficult to know which factor—the releasing of fumes from new building materials or the inadequate ventilation system—contributed most to the formaldehyde levels detected.

In contrast to the old building (constructed in the late 1920s and abandoned because of its reportedly inadequate resistance to withstand earthquakes), the new structure is totally sealed. A mechanical system ventilates, heats, and cools the building. The few windows cannot be opened when occupants want fresher air. Most spaces are illuminated by fluorescent lights.

Some of the original environmental problems of new buildings like Oakland High School do diminish with time. The presence of formaldehyde actually results in the numbing of the sense of smell, lessening detection of other noxious chemicals occupying the building. Gradually some of the worst odors recede, and some of the most offensive chemicals are released. People gradually adapt to many other aspects of the building, developing a tolerance for artificial lighting, sealed windows, higher noise levels, etc. But this adaptation does not come without a price—in annoyance, frustration, and physiological and psychological change.

DOT in Augusta

When it opened in the summer of 1976, the three-story state *Department of Transportation (DOT) building in Augusta, Me,* was hailed as a model for energy-efficient structures. Heat is generated entirely from solar gain, workers' bodies, lighting, and equipment. Completely sealed and slightly pressurized, the building does not have operable windows. A Delta 2000 computer monitors the artificial environment, regulating temperature, humidity, and air flow. Eighty percent of the air is recycled throughout the building; the rest is pumped in by a roof-top fan, mixed with the recycled air, and distributed via ducts. Electric heating coils near the fan heat the air pulled in from the outside. Recovered air is cooled by seven air conditioners and maintained at 78 F.

After the first few days in the building, workers complained that it was stuffy and dry. Temperature and humidity levels were reset, but workers contracted colds and continuous coughs. A new, more powerful fan, installed to increase fresh-air capacity, caused the fiberglass ducts to fray.

A so-called "comfort" problem affected two-thirds of the 600 DOT workers. Symptoms included rashes, watery eyes, hoarseness, coughing, dizziness, lethargy, sores that would not heal, breathing problems, stiff shoulders and necks, and coughing up blood. One worker developed what her doctors called a "restrictive and obstructive lung disease," which may have been caused by cotton fibers and small shards of fiberglass in the building's air. In March of 1980, state investigators indeed found that the air supply contained minute particles of fibrous glass.

The president of the Salter Corporation, the building contractors, blamed the health problems on the workers' general frustrations and their "aggressive union." The employees' association has requested removal of all fiberglass air ducts. But there is general agreement that the fiberglass is just one of a combination of problems with the DOT building.

Pollutant	Possible health effects of pollutants	Some building uses where pollutants may be found
Formaldehyde	Eye and skin irritation; Upper respiratory problems; Headaches, dizziness, nausea, fainting; Suspected of causing nasal passage cancer.	Adhesive in particle board, plywood, insulation, furniture, and panelling. Cigarette smoke, gas combustion products, many consumer products.
Radon	Causes cancer.	Masonry materials (especially granite, concrete, brick). Soil under buildings. Water supply. Some wallboard.
Particulates	Various effects including upper respiratory problems, stomach and lung cancers, headaches, etc.	Combustion appliances; cigarette smoke; paper processes such as data handling, duplicating, copying.
Asbestos	Lung diseases including cancer.	Insulation sprayed on building components for fire-proofing and sound control, air duct linings, acoustical tiles.
Lead	Abdominal pain, headache, muscular aches, weakness, central nervous system damage, kidney damage, anemia, affects bone marrow.	Paints (no longer permitted, but still on older walls, in air during renovation). Pipe joint compounds.
Noise pollution: Human activity, building equipment, office machines, traffic, construction.	Hearing impairment or loss; cardiovascular and nervous system effects.	
Light Pollution: Intense brightness; poor color rendition; lack of shadows; flicker effects (fluorescent); luminaire "noise" (audible and inaudible); spectral deprivation.	Fatigue, epileptic seizures, Vitamin D deficiency, inadequate calcium absorption, bone disease, developmental deficiencies in laboratory animals; headache, emotional stress.	
Other EMR (Electro-magnetic radiation): Computer terminals; microfilm screens; business machines; copying machines; etc. radar (air traffic) equipment.	Fatigue, stress, headache, dizziness, nausea, nervous system disorders; operator errors.	

BUILDING SOURCES OF TYPICAL HEALTH HAZARDS AND THEIR EFFECTS

Social Services Building

The design-award-winning new headquarters for the *Social Services Building in San Francisco* was completed in the fall of 1978. Shortly after moving in, many employees complained of eye and skin irritation, and headaches and respiratory problems. Absentee rates were higher than in the older, previous quarters, and the Occupational Health Clinic at San Francisco General Hospital saw many of the workers who were suffering effects apparently caused by the new building.

In the spring of 1979, the University of California, Berkeley's School of Public Health faculty and Lawrence Berkeley Laboratory Ventilation Program scientists were called in to determine the source of the problem. Air sampling indicated elevated levels of many organic chemicals including common industrial solvents known to be highly toxic. While precise sources of the air pollution were not identified, the ventilation system was implicated by the evidence gathered. Supply air diffusers were incorporated into the ceiling system and the space above was serving as a plenum. The diffusers were not getting air down to the workers, but were functioning to exchange air in the upper two feet of the space.

The organic compounds discovered in the building are not atypical of those found in similar offices currently constructed in the United States. They include constituents of cleaning products, waxes and polishes, office equipment including typewriters and copying machines, adhesives used in the manufacture of building materials and furnishings, and a host of other compounds. While the health effects of most of these substances at their commonly found concentrations are not yet fully understood, many of them are known to be highly toxic, and some are suspected carcinogens. The accompanying chart shows a comparison between the concentrations of these substances in outdoor air and in the Social Services building as measured by LBL.

The problem at the Social Services building represents the tip of the chemical pollution iceberg. Over one ton of chemicals is manufactured every year for each inhabitant of North America. More than 66,000 separate compounds are among these products. Most of them are intended to resist decomposition in the environment and a significant portion of them are intended to attack living organisms. A large portion of them ultimately find their way into the water above or below the ground or in the seas. The construction industry, building maintenance, and many of the activities conducted within buildings, are dependent upon these substances.

For example, formaldehyde, a suspected cancer-causing substance, is currently manufactured at the rate of about 6 billion pounds per year—about half of which is used in building products. It decomposes while in the building and is released into building air where it is inhaled or absorbed through the skin of building occupants. It is a widely used construction adhesive and is also used in the manufacture of modern office and home furnishings. Studies indicate that workers in furniture manufacturing develop nasal cancer at rates four times higher than the general population. Current use of formaldehyde continues unabated, although the U.S. Consumer Products Safety Commission is attempting to ban one building product, urea-formaldehyde foam insulation.

St. Elizabeth's Hospital

In August 1965, pneumonia broke out among 81 patients at *St. Elizabeth's Hospital*, a chronic-care facility in Washington, DC. The epidemic killed 14 people. The disease agent remained a mystery until 1977, with the discovery of a pathogenic bacterium in the lung tissues of those who became ill at the Legionnaire convention in Philadelphia. The bacterium was tied to several previous respiratory illness epidemics, including the 1968 incident in a Pontiac, Mi, health department building, when 95 out of 100 people developed high fever, headache, and muscle ache, but no pneumonia.

The bacterium responsible for the outbreak at St. Elizabeth's was traced to the soil. During that summer several sites on the hospital grounds had been excavated for installation of a sprinkler system, and it was theorized that contaminated dust raised in the process entered the building's air-conditioning cooling towers, and spread throughout the building.

"Legionella pneumophila" has been isolated from water found in cooling devices in at least three cases of the epidemic. Any airborne bacteria can now gain access into a building's cooling system, and from there into the fresh-air system. This argues for some form of bacterial air filtering, or perhaps the removal of air-conditioning systems altogether and the substitution of fresh-air circulation, which would at least prevent the possibility of bacterial infection brewing up in the cooling tower and emerging into the fresh-air system.

A new field of study

We have presented only a cursory overview of some building-related health problems (or health-related building problems) in order to acquaint the reader with the range of problems and their occurrence in buildings. It is useful to study the accompanying table, which lists some major problems, their sources or use in buildings, and some of the well-known health effects associated with them. The interested reader will wish to pursue individual research in connection with design and specifications by asking material manufacturers and suppliers for their product safety data sheets and chemical data sheets prepared for each product. In order better to understand and cope with problems like those described above, it is necessary to gather information from a variety of disciplines including public health, air quality management, environmental health, toxicology, and a host of others. As a researcher in the College of Environmental Design, University of California, Berkeley, I have been attempting to assemble the information into a coherent and useful body of knowledge for those who design our built environment: architects, engineers, interior designers, etc.

My inquiries and investigations to date have led to the term "building ecology" to describe the interrelationships between people, the built environment, and the natural environment. Building ecology draws heavily from the ecologists who have developed techniques for studying complex interrelationship in the natural environment—the "eco-systems approach." I have attempted to incorporate the major features of this approach, which derive from the systems approach, ecology, and bio-energetics—the study of energy flows through living systems.

Conclusion

The new building problems described above do not occur only in energy-conserving buildings; even pre-1973 buildings where air sampling has been done commonly show pollutant levels higher than in outdoor air—in some cases worse than levels found during severe air pollution episodes. The effort to conserve energy in buildings has accelerated our recognition and understanding of indoor pollution. But we must recognize the importance of reducing or eliminating toxic substances and other forms of pollution and learn to control pollution levels through ventilation, natural light, acoustical control, and other design strategies. A preliminary set of guidelines will help while we learn to understand and deal with these new problems.

1 Maximize the use of natural ventilation, cooling, heating, and sun control with user control wherever feasible; passive solar approaches are desirable.

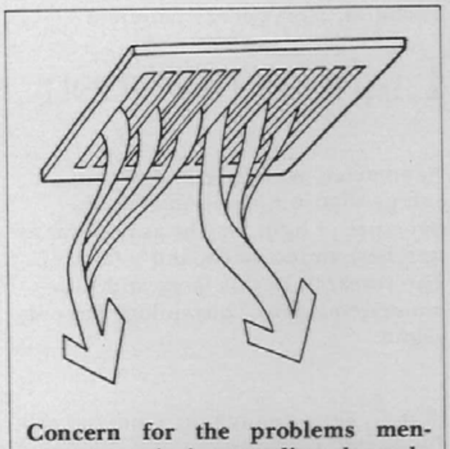
2 Diversify and carefully locate sources of air intake and distribution.

3 Utilize state-of-the-art air filtration and cleaning as well as heat exchangers where air supply is mechanical.

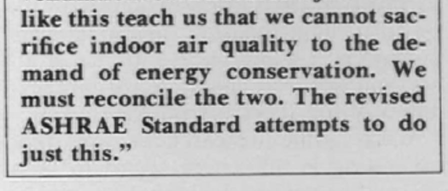
4 Select durable, stable materials for exposed finishes, especially those subject to heavy use or possible surface damage. Avoid materials which require frequent painting or other chemical treatment.

5 Request manufacturers' product chemical data sheets when considering materials for specification; seek out non-toxic products wherever possible.

Awareness of the health problems in buildings has emerged rather rapidly. While we cannot adequately respond overnight, aware designers can evolve strategies such as those suggested above to modify current practice. By understanding the "building" in *building ecology* as both noun and verb, architects and others can move toward the design of healthful environments. □



Concern for the problems mentioned herein is spreading throughout the architectural and related professions. The Board of Directors of ASHRAE recently accepted a draft report, for example, calling for further broad-based research on Legionnaires Disease. The Board also approved a revised standard designed to avert indoor air pollution. ASHRAE Standard 62-1981 calls for the measurement of the various pollutants and provides specific steps to deal with them. At a seminar on indoor air quality at the recent ASHRAE Convention in Chicago, Dr. Jan A.J. Stolwijk of the Yale University School of Medicine cited an incidence of death from heart attack that was related to insufficient ventilation. Said Dr. Stolwijk: "Cases like this teach us that we cannot sacrifice indoor air quality to the demand of energy conservation. We must reconcile the two. The revised ASHRAE Standard attempts to do just this."



COMPARISON OF INDOOR AND OUTDOOR ORGANIC SUBSTANCE CONCENTRATIONS

EACH PEAK REPRESENTS A SEPARATE SUBSTANCE. PEAK HEIGHT INDICATES STRENGTH. VENTILATION PROGRAM TAKEN AT THE DEPARTMENT OF SOCIAL SERVICES BUILDING.

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