Indoor Pollution Research and its Applications in Office Building Development and Operation

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applications in office building development and operation. Various stages in project design and development which can be enhanced by an ecological approach are described in terms of the architectural and engineering services to control or eliminate indoor pollution.

Since the Arab oil embargo of 1973 brought about widespread awareness of the need for energy conservation, reduced ventilation rates in buildings have increased levels of many irritating and toxic substances in indoor air. This change in the quality of indoor air along with other economically-motivated changes in building design, planning, construction, furnishing and operation has resulted in increasing numbers of complaints filed with builders, employers, government agencies, and the courts about physiologic and health problems associated with indoor pollution. These complaints vary from reports of dizziness, drowsiness, headaches and weight loss to skin, eye or throat irritation to pneumonia, and cancer (Levin, 1981; WHO, 1983; Melius, 1984).

While the causes of many building occupant complaints have not been established definitively, there is strong evidence linking them to occupancy of particular buildings. The available evidence suggests that the complaints are caused by irritating and toxic gases released from modern building products, furnishings and equipment; micro-organisms bred in or entering through building ventilation systems; new lighting sources; and odors and gases which build up in indoor air due to inadequate ventilation (Turiel, 1985). Other contaminants (Wineman, 1982; Zimring, 1982).

Several critical problems are under investigation by indoor pollution researchers. These include "building sickness," ventilation, air sampling and analysis, emissions from indoor pollution sources, and indoor pollution control methods. Following is a review of some current research and its implications for the office building developer, designer, operator or user.

"BUILDING SICKNESS"

Building sickness or "Sick building syndrome" refers to a set of physiologic and health problems commonly found among occupants of modern office buildings. Many investigations of building occupant

TABLE 1. SYMPTOMS OF BUILDING SICKNESS

Nasal symptoms such as blocked, itchy or runny nose.
Eye symptoms such as itching, irritation, or watering of the eyes
Mucous membrane symptoms such as dry throat or stuffy nose.
Work-related asthma symptoms such as chest tightness, difficulty in breathing or shortness of breath, wheeze.
Humidifier fever symptoms including fever, joint and muscle pains, tiredness and headache.

complaints in new or remodelled buildings have determined that the occurrence of these symptoms is significantly higher than in "normal"

Indoor Air Pollutants: Exposure and Health Effects, incidents of "building sickness" have many common features usually including the symptoms listed above. These symptoms have been widely reported in Scandinavia and the United States in association with the interior environment. Between 15 and 30 % of the population surveyed in a Danish study reported the symptoms shown in Table 1.

An illuminating study by Danish researcher Lars Molhave and his coworkers provides a plausible explanation for the widespread occurrence of building sickness in modern buildings. Molhave reviewed the 62 chemicals most frequently found inside Danish buildings and found that 36 % are suspected and 48 % are known mucous membrane or eye irritants. Thus, a total of 84 % may be causal agents in Building Sickness. Over one-fourth are known or suspected human carcinogens (Molhave, 1982).

In 203 Indoor Air Quality Investigations conducted by NIOSH (the National Institute of Occupational Safety and Health) through 1983, inadequate ventilation was found nearly half the time. Contamination inside and outside the building or of the building fabric itself was found in nearly a third of the buildings. The remaining problems were found to be humidity, hypersensitivity pneumonitis, cigarette smoking, and miscellaneous other causes (Melius, 1984).

The sick building syndrome has been studied in Great Britain by a group of physicians who interviewed the majority of occupants of nine buildings. Two of the buildings were studied due to complaints results are presented in Table 2.

TABLE 2. PREVALENCE OF SYMPTOMS (%) BY TYPE OF VENTILATION SYSTEM.

	VENTILATION SYSTEM TYPE (No of buildings / No. of people interviewed)			
SYMPTOM:	NATURAL VENTILATION ONLY (3 / 328)	MECHANICAL ONLY, NO HUMIDIFICATION (1 / 78)	MECHANICAL HUMIDIFIED WITH NO RECIRCULATION (2 / 411)	MECHANICAL HUMIDIFIED WITH RECIRCULATION (3 / 561)
NASAL	5.8	13.7	22.4	17.2
EYE	5.8	8.2	28.3	17.6
MUCOUS MEMBRANE	8.1	17.8	37.9	32.6
WORK-RELATED ASTHMA	7.0	1.1	19.0	17.2
HUMIDIFIER FEVER	1.1	---	3.4	2.1

Source: Finnegan et al, 1984.

The investigators' findings from these studies were as follows.

1. "Headaches and lethargy are very common complaints. It was therefore surprising to find such highly significant differences ($p<0.001$) between naturally ventilated buildings and those with mechanical ventilation with or without humidification."

2. "Another symptom that was in excess in the humidified buildings was chest tightness." Peak flow rate measurements did not show any evidence of work-related asthma. "The ...

4. "Finally, although the symptoms of the sick building syndrome do not represent a disease but rather a reaction to the working environment, the scale of the problem is probably considerable, and the high degree of dissatisfaction seen in this study demands attention from architects, engineers, and the medical profession. In particular, more research is needed, preferably of a longitudinal nature, into both air conditioned and naturally ventilated buidings."

While determination of the nature and causes of "building sickness" has been undertaken by many researchers, rarely are specific substances implicated. The timing and the extent of the investigations are determined by factors such as the ownership and operational control of the building, the organization of building occupants, and the availability of interested and capable researchers. In most instances, investigations are conducted considerably later than the onset of symptoms, thus obscuring the circumstances which existed at the onset of symptoms. While many investigations result in ventilation system improvements, "causal" factors are often difficult to isolate.

The World Health Organization Working Group suggests that there are temporarily and permanently sick buildings. The affected buidings have the following characteristics:

1. They nearly always have forced ventilation systems.
2. They are often relatively light construction.

5. They are characterized by airtight building envelopes (in the United States, windows cannot be opened) (WHO, 1983).

INDOOR POLLUTION

Building sickness appears to be one response to certain types of indoor pollution. Indoor pollution is not a new problem. It probably dates from the time of the first caveman (or woman) using fire inside the cave. While sick building syndrome or building sickness was recognized in Europe prior to 1960, the term "indoor pollution" did not come into commmon usage in the late 1970s. In 1978, the California Department of Consumer Affairs held two days of public hearings on indoor pollution leading to a report, Clean Your Room, A Compendium on Indoor Pollution, published in 1982. In 1980, the General Accounting Office, an agency of the U. S. Congress, issued a report describing the problem and warning of its seriousness. In 1981, the National Academy of Sciences gave scientific legitimacy to the problem when it issued its report titled Indoor Pollutants.

Forms of Indoor Pollution.

Indoor pollution includes air pollutants as well as many environmental factors other than contaminants in building air. Noise and other forms of mechanical vibration such as that coming from heavy equipment or traffic are examples of indoor pollution which cause physiological stress. Light and other electromagnetic

TABLE 3. FORMS OF INDOOR POLLUTION

Noise and other Mechanical Energy
Light and other Electromagnetic Radiation
Air (and surface) Pollutants
- Chemical Contaminants
- Micro-organisms
- Dust and Pollen

Sources of Indoor Pollution.

Some pollutant sources exist outdoors and are carried inside by building ventilation systems, or inadvertently by infiltration or people. These include pollutants generated by motor vehicles, industrial processes, agriculture, construction, and exhaust systems from other buildings. Thus, the siting of buildings and the location of the outside air intakes can be important determinants of indoor pollution levels.

TABLE 4. SOURCES OF INDOOR POLLUTANTS

- Outdoor Air
- Building Materials
- Building Equipment
- Furnishings
- Maintenance Materials
- Occupants
  - Metabolism
  - Activities

products, and human metabolism. Most of these are under the control of the building designers, builders, operators and users. Knowledge about them can improve our ability to control them.

Table 5 lists indoor pollutants and their building-related sources. The pollutants on the list are rank ordered according to scientific understanding of their known concentration and distribution in the indoor environment and on their human health effects. This rank ordering was done by a World Health Organization working group in 1981.

The specific indoor air pollutants which have been identified as most significant from a health perspective include tobacco smoke, radon, and Nitrogen dioxide. Radon and Nitrogen dioxide are not considered significant pollutants in office buildings. Volatile organic compounds are considered important, but their large number (more than 900 separate compounds have been isolated in indoor air), low concentrations and the high cost of monitoring for them have limited research efforts into their identification. However, some researchers have suggested that they may be involved in many cases of building sickness in offices (Hollowell and Miksch, 1981).

Pollutant	Sources	Control
Tobacco smoke	Cigarettes and other tobacco products	Smoke free zones, rooms, ventilation.
Nitrogen dioxide (NO_2)	Gas combustion appliances, e.g. stoves, water heaters, unvented space heaters, furnaces, kerosene heaters.	Modify flame temperature, vent appliance, tandem combustion chambers, room ventilation.
Carbon monoxide (CO)	Same as NO_2, and fireplaces, wood stoves.	Modify combustion parameters, vent appliance, room ventilation.
Radon and radon daughters	Soil, rocks, building material such as bricks, concrete, stone.	Vented crawl spaces, basements, seal conduits, sumps, provide vapor barrier below slab.
Formaldehyde	Building and insulating materials, furniture, adhesives, consumer products, combustion	Modify production process, substitute stable adhesives, modify combustion appliances. Room ventilation, cooling, . dehumidification.
Carbon dioxide CO_2	Kerosene heaters, gas heaters, people.	Modify combustion parameters, ventilation.
Asbestos	Ceiling and floor tiles, pipe insulation, thermal and acoustical insultating materials, concrete, spackling compound.	Removal, encapsulation, enclosure, sealants. Education of exposed individuals, warnings.
Organic Compounds	Building materials, consumer products, furnishings, polishes, waxes, maintenance materials, pesticides, room deodorants.	Substitute stable, non-toxic materials, room ventilation.
Particulate matter	Combustion sources, wood stoves, fireplaces; biological agents, e.g., microorganisms, molds, pollens, animal dander.	Air cleaning, filters, ventilation, cleaning of ventilation systems.

learning opportunities presented by current activity in asbestos hazard abatement has not yet been translated to other aspects of indoor pollution assessment and control.

The Significance of Indoor Pollutants.

The critical factors in determining the significance of indoor pollutants are the extent of human exposure to them and their health effects. Exposure is a function of the pollution levels in various types of building environments, and the amount of time various segments of the population spend in those environments. The health consequences of a given exposure are determined by the health status of the exposed population. For example, infants, the elderly, or the infirmed may have reduced resistance to certain exposures and consequently, may by more seriously affected by indoor pollutants than the healthy, adult population. Pregnant women may be at more serious risk than others when exposed to substances which are known to have adverse effects on the developing fetus. Unfortunately, not enough is known about the health consequences of exposure to many indoor pollutants, and researchers agree that this is an important problem in determining the overall significance of indoor pollution (WHO, 1982).

Odor.

Researchers agree that odor plays an important role in determining the acceptability of indoor air. ASHRAE uses acceptability as one of the criteria in determing many of its rate.

Research conducted in the Netherlands utilized odor detection as a criteria for determining ventilation requirements. Using 5 percent and 1 percent criteria for the percentage of occupants complaining that odor was no longer acceptable, 21 and 29 cubic feet per minute of ventilation were required. The article goes on to say: "It follows that reducing ventilation..." to 15 cfm per person "... is not justifiable in view of the increasing number of complaints to be expected."

In defining odor concentration as the dilution factor required to make diluted indoor air indistinguishable from outdoor air for half the study subjects, a dilution of 10 was required with moderate ventilation and no smoking while a dilution factor of 100 was required where considerable smoking occurred. Near "smelly" industry, concentrations of between 10 and 100 were required with some as high as 1000 (Fitzgerald, 1984).

Volatile Organic Compounds.

There is general agreement that VOCs are important indoor pollutants. Examples are pesticides, adhesives, paints, consumer products, room deodorants, disinfectants, dry cleaning fluids, and a host of other modern chemical products. They present complex barriers to effective, affordable air monitoring. State-of-the-art methods can be used, but their cost is high and there are fewer laboratories capable of the analysis required. Some researchers

(VOCs) has found a higher number (about 900) of chemical substances indoors than was previously expected. Indoor-outdoor ratios of these compounds are consistently greater than unity; usually the ratio is about ten to one, and sometimes it is as high as 100 to 1 (Wallace, 1984).

Carbon Dioxide.

Many researchers have found negative correlations between the acceptability of indoor air quality or the absence of complaints and the level of Carbon Dioxide. Since CO_2 is a metabolic gas, it indicates the relationship between ventilation and occupancy levels. Levels of CO_2 above 1000 to 1200 ppm (parts per million) are frequently associated with air quality complaints (Rajhans, 1983). CO_2 is relatively easy to measure with hand-held, direct-reading instruments. Some buildings employ CO_2 systems to control ventilation rates (Nagda, 1982).

Biological Contaminants.

In spite of the widespread attention given to Legionnaires disease, until recently relatively little attention has been devoted to biological aerosols as causes of building sickness and other complaints in problem buldings. Most indoor pollution investigators are not capable of conducting investigations into the levels and identity of biological aerosols suspended in indoor air. However, work reported recently indicates that microorganisms may be important sources of indoor-pollution-related complaints in

There are many reported instances of building contamination by particular substances or organisms. In these instances, large numbers of samples are collected of single substances, and the role of ventilation and the building fabric becomes better understood. Examples are the Pentachlorophenol contamination of an office building (Levin, 1984), Legionnaires disease (Morey, 1984), and PCB contamination as in the Binghamton, New York and San Francisco, California office buildings (Hahn, 1984) just to mention a few.

Environmental Lighting and Health.

The impact of environmental lighting on human health and well-being has been related recently to concern about excess exposure to Ultraviolet light from the new, high efficiency fluorescent lights (Cole, 1985). Concern about the spectral distribution and its effects has given rise to much research, but conclusive findings which would support the use or avoidance of certain light sources do not yet exist (Wurtman, 1985).

Researchers have been experimenting with the use of bright lights to reduce the effects of seasonal affective disorders (SAD) or depression which many people experience during the winter or spring (Lewy, 1985). This work has been stimulated by the well-established relationship between light exposures and human endocrine system functioning.

CONTROL OF INDOOR POLLUTION

Removal is required for asbestos and PCBs, as examples, when their presence in buildings presents unacceptable levels of risk to building occupants. Dilution is used for air pollutants which cannot be adequately controlled otherwise and which do not warrant removal.

Indoor Air Quality and Ventilation.

Dr. James Woods, chairman of the ASHRAE committee which developed the Standard 62-1981, Ventilation for Acceptable Indoor Air Quality, has suggested that the dominant current practice of tying ventilation to temperature control may exacerbate indoor air quality problems. Typically, cooling in internal-load dominated buildings results in reduced air supply volumes. Most large buildings, including office buildings, are internal load dominated. Yet high temperatures result in increased emissions of toxic and irritating chemicals from materials and furnishings. Thus, the ventilation rate is lowest when air quality requires it to be highest. Where heating is done with the air supply system, supplying increased volumes of warm air is counterproductive; it increases air movement and counteracts the warming effect by increasing convective and evaporative cooling losses on the skin.

Since ventilation problems are often implicated as causes of building sickness, the determination of appropriate ventilation rates for buildings is a significant concern for building scientists. Many current efforts are intended to establish occupant have been considered acceptable by different authorities. The presence of smoking, the quality of personal hygiene practices, the density and activity of building occupants, the chemical composition and stability of building materials, furnishings and consumer products, and ventilation system design affect ventilation requirements (ASHRAE, 1981; Repace, 1984; Weber, 1984).

Efforts to define a generally-applicable, standard minimum ventilation rate are hampered by the significant differences among buildings; these differences affect the need for ventilation and the actual effective ventilation rate in the occupied zone. The need is determined by the pollution levels in the air, which in turn is affected by the source strengths, temperature and humidity. Higher temperatures will increase off-gassing rates when ventilation rates are typically reduced by variable air volume systems. Humidity will affect occupant comfort, formaldehyde concentrations, and biological aerosol concentrations. The effectiveness of the air distribution system in mixing air within the space and particularly within the breathing zone can significantly affect ventilation requirements for acceptable indoor air quality. Lower velocities at the supply registers or higher supply air temperatures can result in poorer mixing within the occupied space.

Complex interactive factors in building environments present barriers to the acceptance of universal standards for ventilation rates. Ultimately, means may be sought to control air quality on a occupant control of environmental conditions or the means to change them is important to occupant acceptance of minimally-ventilated buildings (WHO, 1983). New and emerging technologies such as direct digital controls (DDC), electronic sensors, microprocessors, and changes in "wire management" facilitate decentralized monitoring and occupant input in building environmental control.

INTEGRATING POLLUTION CONTROL IN OFFICE BUILDING DEVELOPMENT PRACTICES INCLUDING PLANNING, DESIGN, CONSTRUCTION AND MANAGEMENT

Knowledge gained from indoor pollution research is being integrated gradually into architectural and engineering practice within the framework of traditional design tasks and through the addition of new tasks and consultants. Every aspect of project development is affected (Levin, 1985). Following are descriptions of some areas of practice where indoor pollution has affected office building development, architecture, engineering, and operation.

SITE SELECTION AND SITE PLANNING CONSIDERATIONS.

Air Quality at the Site.

Prior to site acquisition and during site planning, designers and planners should investigate local ambient air quality and upwind sources of contaminants from industrial, agricultural, commercial, waste storage and disposal activities and operations which may generate pollutants which will reach the site. Wind conditions should include prevailing and storm wind directions as well as materials manufacture, use or disposal) activities.

Adjacent, heavily-travelled roadways should be identified as possible sources of air pollutants such as fuel combustion by-products, dust from roadway and tire wear, and asbestos from brake linings.

Soil and Water Contamination at Site.

Some previous uses of the site or adjacent sites might have produced toxic residues; some of these uses are wood treatment, certain types of agriculture, manufacturing, waste handling, etc. Some of these are sources of potential surface or groundwater contamination from runoff, storage tank leakage, accidental or intentional, spillage.

Noise.

Developers and designers should avoid noisy locations or protect buildings from off-site noise sources such as road and railways; construction, industrial and commercial operations; and mechanical equipment serving nearby buildings.

BUILDING PLANNING AND PROGRAMMING CONSIDERATIONS.

Protect Building Interior from Pollution-generating Activities.

Designers can identify and isolate activities within the building which will be sources of pollution (noise, toxic chemicals, heat, etc.). Some of these sources are mechanical equipment; waste storage; printing; duplication and mailing; food preparation; bathroom and garage exhaust air vents; and manufacturing activities equipment properly. Ordinarily, insufficient time is available for these activities, and buildings are occupied prematurely. Many instances of building sickness are probably the result of premature occupancy. It is important to plan not to occupy spaces while they are being remodeled. Air supply to remodeled areas must be directly exhausted to the outside. Recirculation of air during any construction or remodelling activity should be avoided.

CONCEPTUAL (SCHEMATIC) DESIGN CONSIDERATIONS.

Perhaps the most important opportunity to control indoor pollution in architectural and engineering practice is during building conceptual design. By emphasizing environmental control strategies at this stage, the important decisions are made regarding factors which will determine indoor environmental quality. These factors include thermal, lighting, acoustic, ventilation, air quality, humidity, and odor control among others. Much more attention needs to be given to material selection and to ventilation system layout and operational strategies to control contaminant levels indoors.

DESIGN DEVELOPMENT.

Locate Air Intakes Clear from Pollution Sources.

It is essential that layout of ventilation system intak+es avoid possible entrainment of exhaust from cooking, plumbing stacks, restroom exhaust, garages, and mechanical ventilation system exhausts. Other sources of pollutants are trash storage, passenger affected by the location and type of difusers selected and by the volume and velocity of supply air into the occupied spaces. Designers must provide adequate distance between supply and exhaust registers within a space to avoid short circuiting of supply air or inadequate mixing of supply air within the space. "Dead" air in corners or other areas can also be eliminated during the layout of the ventilation system.

Plan Light Sources and Distribution for Lighting Efficiency.

Delivery of the quality and quantity of light where needed requires consideration of task lighting where appropriate, elimination of glare and over-illumination. Selection of user-controlled, variable level lighting delivery systems can minimize problems and complaints. Newer systems are allowing flexibility in wiring and controls for adaptive use and individual work station modifications.

Select Durable, Chemically-stable, Non-toxic Materials.

An area of great potential impact is the specification of building materials and furnishings which are chemically stable and safe. This is achieved through the following tasks: 1) Investigation of material contents; 2) Assessment of toxic or irritating chemicals identified in materials; 3) Testing of materials to further identify and quantify the chemical contents; and, 4) Testing to determine the instability or emanation (off-gassing) rate of chemical contents. A more complete description of against published information on the toxic or irritant properties of the chemical contents, various factors which will affect the stability of the chemicals in the finished products, and other data to assist in assessing the degree of hazard posed by the presence of the chemicals.

There are several sources of information about material contents of building products and furnishings. Manufacturer's Safety Data Sheets (MSDS) are required by OSHA for every hazardous material or substance used in industry covered by OSHA. MSDSs contain a list of the chemical composition of products used or to which workers are exposed. These sheets do not define the composition of finished building materials and furnishings, but they do identify any hazardous substances which might be present in the products supplied by each vendor.

For example, interior partiitions may be constructed of fabric covering, insulation, metal or wood frames, adhesives, and core materials - each from separate suppliers. In one such case, over thirty chemicals were used in the fabric alone, three adhesives were used, and several materials each contained some formaldehyde-based adhesives. This information led to chamber testing (see below) of the partitions before final selection. Potential suppliers can be asked to assemble and submit the information as part of the bid package.

Other information sources on material contents include texts on emitted by a product; and, to identify other factors which can make a testing program more cost effective.

There are pronounced differences among alternative products and among the similar products of various manufacturers and suppliers. The results of the investigation will assist in the selection of the materials and furnishings.

<u>Product Testing for Material Contents</u> includes two types of tests used for determining material contents. The first is known as "bulk testing" whereby a material is placed in a solvent, then the extract is analyzed. The second test for material contents uses air sampling to determine which compounds are emitted to the air during testing. Tests can be conducted in an environmental test chamber or in a small container - a quart or pint stainless steel can, for example. The chamber is large enough to accommodate full size samples of materials and provides reasonable conditions for extrapolating test results to the conditions in the completed structure. Researchers are using various size chambers to test material emissions, and the author has applied this approach to the development of major corporate facilities.

<u>Product Testing for Chemical Stability</u> involves product tests in an Environmental Test Chamber or in a laboratory container. A sample is placed inside and a known volume of air at a known temperature is passed through and collected. Air is well mixed in the container. The air sample is analyzed for specified chemical

testing can assist in determining the significance of operating temperature control in the occupied building. It will also allow determination of the efficacy of "bake-off" strategies (the superheating and ventilation of a building to reduce contaminant levels) if widespread complaints are anticipated or experienced after occupancy.

CONTRACT (CONSTRUCTION) DOCUMENTS PREPARATION.

Materials specifications.

Preparation of specifications can include limits on toxic chemical content, toxicity, and actual emission rates from building materials and furnishings. Limitations on toxic chemical content and emissions can be included as prescriptive or performance specifications.

Specify Ventilation System Performance.

Designers should base HVAC performance specifications on ventilation rate (outside air) and ventilation efficiency (distribution/mixing within the space). Methods and responsibility for verifying performance should also be included. Independent verification of performance is warranted in large projects.

CONSTRUCTION OBSERVATION, SHOP DRAWINGS, CHANGE ORDERS.

Designers should verify that all installations meet system performance requirements by walk-through visual inspection and spot performance tests. Change orders and shop drawings should be evaluated against specified design intent and specific performance

... operate as designed and specified.

Air balance and distribution (ventilation efficiency) should be verified with velometer and smoke tube tests. Smoke tubes or tracer gases are used to check the air supply stream for entrainment of contaminants including exhaust from building ventilation, plumbing exhaust, or garage and loading dock areas.

SHAKEDOWN (LAUNCHING) OF NEWLY CONSTRUCTED OR REMODELED STRUCTURES.

It is uncommon for all building equipment to operate correctly at the completion of normal construction. Therefore, it is important to operate all HVAC equipment in each operational mode (heating, cooling, economizer, minimum-maximum outside air supply, etc.) to verify acceptable functioning of controls, dampers, valves, fans and other components fefore accepting and occupying a building.

OPERATIONAL PROTOCOLS FOR HVAC EQUIPEMNT.

It may be necessary to utilize extended hours of operation and maximum air exchange (consistent with the lowest comfortable temperatures) until air quality is determined acceptable. A safe transition to normal operational protocols can be paced by using building occupants' subjective evaluation to control the rate of transition.

During Construction or Remodelling.

Builders should utilize 100% outside air during construction or remodeling with no return air operation. Install temporary exhaust during construction and remodelling, if necessary, to avoid recirculation of construction dusts and fumes, especially in

Building operators should consider the use of a "bake-off" procedure (elevated temperature with maximum ventilation) to reduce levels of volatile chemicals in building air. The longer the term, the higher the temperature, and the higher the ventilation rate of the bake-off, the more effective. Bake-off without ventilation is counterproductive; it merely distributes chemicals on other surfaces and materials. It is extremely important to cool and ventilate the building adequately after the bake-off and prior to initial occupancy. At least one week should be allowed for this procedure.

<u>MAINTENANCE PROCEDURES AND MATERIALS</u>.

Maintenance activities indoors should be scheduled to avoid unnecessary contamination from cleaning or polishing solvents during occupancy. It is also important to limit the use of biocides (pesticides, rodenticides, fungicides, disinfectants) and "air fresheners" to minimums required for preventive or remedial purposes. Utilizing 100% outside air during all maintenance and repair applications involving volatile organic compounds. Applications of volatile or toxic landscape materials near outside air intakes should be avoided.

<u>EVALUATION OF COMPLETED STRUCTURES</u>

Review of building performance and diagnostic testing of environmental control systems can provide valuable information on necessary adjustments to building operations, maintenance or use and can be useful in improving future work. The common practice of studying only problems does not enhance professional and corporate

Problem-building investigations related to health and comfort complaints should begin with ventilation system performance, layout, operational protocols. It is also important to assess maintenance program design and implementation in light of building use patterns, changes since programming and design, and the patterns of complaints or problems. Investigators can survey occupants for spatial or temporal distribution of problems in the building. If this is not fruitful, then it may be necessary to monitor air quality. This should begin with a survey for suspected contaminants; then, if necessary, a full chemical scan. Control and measurement of ventilation rates and temperatures during air sampling should include typical or worst case conditions.

CONCLUSION

Indoor pollution is a significant issue warranting attention during office building development. Many approaches to addressing the problems are available. The successful designer, developer, or building operator will judiciously employ a combination of these suited to the particular building project. Appropriate use of competent, experienced consultants can assist in identifying critical issues and resolving them. Ultimately, an understanding of office environments as ecologically complex systems will emerge as we approach and master the challenges presented by the creation of healthy, productive office buildings.

1.0 SITE SELECTION AND SITE PLANNING CONSIDERATIONS:
   1.1 Air quality evaluation at site and nearby.
   1.2 Soil and water contamination evaluation
   1.3 Noise sources and control
2.0 BUILDING PLANNING AND PROGRAMMING CONSIDERATIONS:
   2.1 Pollution generating activities
   2.2 Plan for adequate building shakedown before occupancy
3.0 CONCEPTUAL (SCHEMATIC) DESIGN CONSIDERATIONS:
   3.1 Ventilation, lighting, thermal and humidity control strategy
   3.2 Construction and finish material types
4.0 DESIGN DEVELOPMENT:
   4.1 Locate air intakes clear from pollution sources:
   4.2 Plan air distribution for ventilation efficiency:
   4.3 Plan light distribution for lighting efficiency:
5.0 CONTRACT (CONSTRUCTION) DOCUMENTS PREPARATION:
6.0 CONSTRUCTION OBSERVATION, SHOP DRAWINGS, CHANGE ORDERS:
7.0 JOB CLOSE-OUT, INSPECTION OF COMPLETED STRUCTURE:
8.0 SHAKEDOWN (LAUNCHING) OF NEWLY-CONSTRUCTED OR -REMODELED STRUCTURES:
9.0 OPERATIONAL PROTOCOLS FOR HVAC EQUIPMENT, LIGHTING:
   9.1 During construction or remodelling:
   9.2 During pre-occupancy period
   9.3 During initial occupancy period:
10.0 MAINTENANCE PROCEDURES AND MATERIALS:
11.0 EVALUATION OF COMPLETED STRUCTURES:
12.0 TROUBLESHOOTING; INVESTIGATION OF PROBLEM BUILDINGS:

1) reduce sources of chemical contamination through elimination, substitution, or alteration of building materials and furnishings containing unstable pollutants;
2) increase outside air to dilute air contaminants, at least during initial occupancy period after construction or refurnishing;
3) improve ventilation efficiency to dilute more completely contaminants and increase occupant comfort;
4) increase air movement to improve ventilation efficiency and comfort;
5) reduce indoor air temperature during occupancy;
6) control humidity to limit off-gassing and improve comfort;
7) phase move-in or re-occupancy of remodeled space to avoid conflicting construction and occupancy schedules;
8) carefully verify proper balance, operation and control of HVAC system prior to occupancy; and,
9) temporarily supplement air handling systems in place during move-in and early occupancy period.

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