Appendix B

Building Indoor Air Quality

A healthy indoor environment is one in which the surroundings contribute to productivity, comfort, and a sense of health and well-being. The indoor air is free from significant levels of odors, dust and contaminants and circulates to prevent stuffiness without creating drafts. Temperature and humidity are appropriate to the season and to the clothing and activity of the building occupants. There is enough light to illuminate work surfaces without creating glare and noise levels do not interfere with activities. Sanitation, drinking water, fire protection, and other factors affecting health and safety are well planned and properly managed.

Good air quality is an important component of a healthy indoor environment. For the purposes of this document, the definition of good indoor air quality includes:

- Introduction and distribution of adequate ventilation air
- Control of airborne contaminants
- Maintenance of acceptable temperature and relative humidity

A practical guide to indoor air quality (IAQ) cannot overlook temperature and humidity, because thermal comfort concerns underlie many complaints about "poor air quality." Furthermore, temperature and humidity are among the many factors that affect indoor contaminant levels.

Good indoor air quality enhances occupant health, comfort, and workplace productivity. Rental properties can gain a marketing advantage if they are known to offer a healthy and pleasant indoor environment. Failure to respond promptly and effectively to IAQ problems can have consequences such as:

- Increasing health problems such as cough, eye irritation, headache, and allergic reactions, and, in some rare cases, resulting in life-threatening conditions (e.g., Legionnaire's disease, carbon monoxide poisoning)
- Reducing productivity due to discomfort or increased absenteeism
- Accelerating deterioration of furnishings and equipment

- Straining relations between landlords and tenants, employers and employees
- Creating negative publicity that could put rental properties at a competitive disadvantage
- Opening potential liability problems

(Note*:* Insurance policies tend to exclude pollution-related claims)

Some indoor air quality problems are complex and may require the assistance of outside professionals. When contracting for services, you need to be an informed client to avoid unnecessary costs and delays in solving the problem.

Factors Affecting Indoor Air Quality

Indoor air quality is not a simple, easily defined concept like a desk or a leaky faucet. It is a constantly changing interaction of a complex set of factors. Four of the most important elements involved in the development of indoor air quality problems are: a source of odors or contaminants; a problem with the design or operation of the HV A C system; a pathway between the source and the location of the complaint; and the building occupants.

An IAQ profile is a "picture" of building conditions from the perspective of indoor air quality .A review of construction and operating records, combined with an inspection of building conditions, helps to reveal potential indoor air problems and identify building areas that require special attention to prevent problems in the future. Baseline data collected for the IAQ profile can facilitate later investigations, should problems arise. *Section* 4 suggests a three- stage approach to developing an IAQ profile and describes the products of each stage.

Many indoor air problems can be pre- vented by following common sense recommendations, such as: maintain good sanitation, provide adequate ventilation, and isolate pollutant sources. Other preventive measures may require a careful review of j ob descriptions, contracts, supplies, and schedules. It is important to designate an IAQ manager to bear responsibility for coordinating the effort in your building. *Section* 5 discusses key elements to include in your IAQ management plan.

The basic approaches to mitigating indoor air quality problems are: control of pollutant sources; modifications to the ventilation system; air cleaning; and control of exposures to occupants. Successful mitigation often involves a combination of these techniques.

Indoor air quality is an emerging and interdisciplinary field. *Section* 8 provides guidance in hiring professional assistance if you decide that outside expertise is needed to determine the cause of an IAQ problem.

Appendix F: Glossary and Acronyms

Appendix F explains scientific and engineering terminology that may be unfamiliar to some readers.

Appendix G: Resources

Appendix G is intended for readers who want to pursue more detailed information about indoor air quality .It includes the names, addresses, and telephone numbers of Federal, State, and private sector organizations with interests related to IAQ, as well as a list of

The indoor environment in any building is a result of the interaction between the site, climate, building system (original design and later modifications in the structure and mechanical systems), construction techniques, contaminant sources (building materials and furnishings, moisture, processes and activities within the building, and outdoor sources), and building occupants.

The following four elements are involved in the development of indoor air quality problems:

- **Source:** there is a source of contamination or discomfort indoor, outdoors, or within the mechanical systems of the building.

- **HV AC:** the HV AC system is not able to control existing air contaminants and ensure thermal comfort (temperature and humidity conditions that are comfortable for most occupants).

- **Pathways:** one or more pollutant pathways connect the pollutant source to the occupants and a driving force exists to move pollutants along the pathway(s).

- **Occupants:** building occupants are present.

It is important to understand the role that each of these factors may play in order to prevent, investigate, and resolve indoors air quality problems.

Sources of Indoor Air Contaminants

Indoor air contaminants can originate within the building or be drawn in from outdoors. If contaminant sources are not controlled, IAQ problems can arise, even if the HV AC system is properly designed and well maintained. It may be helpful to think of air pollutant sources as fitting into one of the categories that follow. The examples given for each category are not intended to be a complete list.

Sources Outside Building

Contaminated outdoor air

- Pollen, dust, fungal spores. Industrial pollutants
- General vehicle exhaust
- Emissions from nearby sources
- Exhaust from vehicles on nearby roads or in parking lots, or garages .loading docks
- Odors from dumpsters
- Re-entrained (drawn back into the r" building) exhaust from the building itself or from neighboring buildings
- Unsanitary debris near the outdoor air intake

Soil gas

- Radon
- Leakage from underground fuel tanks
- Contaminants from previous uses of the site (e.g., landfills) pesticides

Moisture or standing water promoting excess microbial growth

- Rooftops after rainfall
- Crawlspace

Equipment

HVAC system

- Dust or dirt in ductwork or other components
- Microbiological growth in drip pans, humidifiers, ductwork, coils
- Improper use of biocides, sealants, and/ or cleaning compounds
- Improper venting of combustion products
- Refrigerant leakage

Non-HV A C equipment

- Emissions from office equipment (volatile organic compounds, ozone)
- Supplies (solvents, toners, ammonia) emissions from shops, labs, cleaning processes
- Elevator motors and other mechanical systems

Human Activities

Personal activities

- Smoking.
- Cooking
- Body odor
- Cosmetic odors

Housekeeping activities

- Cleaning materials and procedures
- Emissions from stored supplies or trash .use of deodorizers and fragrances
- Airborne dust or dirt (e.g., circulated by sweeping and vacuuming)

Maintenance activities

- Microorganisms in mist from improperly maintained cooling towers
- Airborne dust or dirt
- Volatile organic compounds from use of paint, caulk, adhesives, and other products
- Pesticides from pest control activities
- Emissions from stored supplies

Building Components and Furnishings

Locations that produce or collect dust or fibers

- Textured surfaces such as carpeting, curtains, and other textiles .open shelving
- Old or deteriorated furnishings
- Materials containing damaged asbestos

Unsanitary conditions and water damage

- Microbiological growth on or in soiled or water-damaged furnishings
- Microbiological growth in areas of surface condensation standing water from clogged or poorly designed drains
- Dry traps that allow the passage of sewer gas

Chemicals released from building components or furnishings

- Volatile organic compounds or
- Inorganic compounds

Other Sources

Accidental events

- Spills of water or other liquids. Microbiological growth due to flooding or to leaks from roofs, piping
- Fire damage (soot, PCBs from electrical equipment, odors)

Special use areas and mixed-use buildings.

- Smoking lounges
- Laboratories
- Print shops, art rooms
- Exercise rooms. Beauty salons
- Food preparation areas

Redecorating/remodeling/repair activities.

- Emissions from new furnishings
- Dust and fibers from demolition
- Odors and volatile organic and inorganic compounds from paint, caulk, adhesives
- Microbiologicals released from demolition or remodeling activities

Indoor air often contains a variety of contaminants at concentrations that are far below any standards or guidelines for occupational exposure. Given our present knowledge, it is difficult to relate com- plaints of specific health effects to exposures to specific pollutant concentrations, especially since the significant exposures may be to low levels of pollutant mixtures.

HVAC System design and Operation

The HVAC system includes all heating, cooling, and ventilation equipment serving a building: furnaces or boilers, chillers, cooling towers, air handling units, exhaust fans, ductwork, filters, steam (or heating water) piping. Most of the HVAC discussion in this document applies both to central HVAC systems and to individual components used as stand-alone units.

Large buildings often have interior ("core") spaces in which constant cooling " is required to compensate for heat generated by occupants, equipment, and lighting, while perimeter rooms may require heating or cooling depending on outdoor conditions.

Good quality design, installation, and testing and balancing are critically important to the proper operation of all types of HVAC systems, especially V A V systems, as are regular inspections and maintenance.

The amount of outdoor air considered adequate for proper ventilation has varied substantially over time. The current guideline issued by ASHRAE is ASHRAE Standard 62-1989. The building code that was in force when your building HV AC system was designed may well have established a lower amount of ventilation (in cubic feet of outdoor air per minute per person) than is currently recommended.

Control Odors and Contaminants

One technique for controlling odors and contaminants is to dilute them with outdoor air. Dilution can work only if there is a consistent and appropriate flow of supply air that mixes effectively with room air. The term "ventilation efficiency" is used to describe the ability of the ventilation system to distribute supply air and remove internally generated pollutants. Researchers are currently studying ways to measure ventilation efficiency and interpret the results of those measurements.

Another technique for isolating odors and contaminants is to design and operate the HV AC system so that pressure relationships between rooms are con- trolled. This control is accomplished by adjusting the air quantities that are supplied to and removed from each room. If more air is supplied to a room than is exhausted, the excess air leaks out of the space and the room is said to be under **positive pressure**. If less air is supplied than is exhausted, air is pulled into the space and the room is said to be under **negative pressure.**

A third technique is to use local exhaust systems (sometimes known as dedicated exhaust ventilation systems) to isolate and remove contaminants by maintaining negative pressure in the area around the contaminant source. Local exhaust can be linked to the operation of a particular piece of equipment (such as a kitchen range) or used to treat an entire room (such as a smoking lounge or custodial closet). Air should be exhausted to the outdoors, not recirculated, from locations, which produce significant odors and high concentrations of contaminants (such as copy rooms, bathrooms, kitchens, and beauty salons).

Air cleaning and filtration devices designed to control contaminants are found as components of HVAC systems (for example, filter boxes in ductwork) and can also be installed as independent units. The effectiveness of air cleaning depends upon proper equipment selection, installation, operation, and maintenance. Caution should be used in evaluating the many new technological developments in the field of air cleaning and filtration.

Pollutant Pathways and Driving Forces

Airflow patterns in buildings result from the combined action of mechanical ventilation systems, human activity, and natural forces. Pressure differentials created by these forces move airborne contaminants from areas of relatively higher pressure to areas of relatively lower pressure through any available openings.

The HVAC system is generally the predominant pathway and driving force for air movement in buildings. However, all of a building's components (walls, ceilings, floors, penetrations, HVAC equipment, and occupants) interact to affect the distribution of contaminants.

The basic principle of air movement from areas of relatively higher pressure to areas of relatively lower pressure can produce many patterns of contaminant distribution, including:

- Local circulation in the room containing the pollutant source
- Air movement into adjacent spaces that are under lower pressure *(Note:* Even if two rooms are both under positive pressure compared to the outdoors, one room is usually at a lower pressure than the other.)
- Recirculation of air within the zone containing the pollutant source or in adjacent zones where return systems overlap
- Movement from lower to upper levels of the building
- Air movement into the building through either infiltration of outdoor air or reentry of exhaust air

Air moves from areas of higher pressure to areas of lower pressure through any available openings. A small crack or hole can admit significant amounts of air if the pressure differentials are high enough (Which may be very difficult to assess).

Building Occupants

The term "building occupants" is generally used in this document to describe people who spend extended time periods (e.g., a full workday) in the building. Clients and visitors are also occupants; they may have different tolerances and expectations from those who spend their entire workdays in the building, and are likely to be more sensitive to odors.

Groups that may be particularly susceptible to effects of indoor air contaminants include, but are not limited to:

- Allergic or asthmatic individuals
- People with respiratory disease
- People whose immune systems are suppressed due to chemotherapy, radiation therapy, disease, or other causes
- Contact lens wearers

Some other groups are particularly vulnerable to exposures of certain pollutants or pollutant mixtures. For example, people with heart disease may be more affected by exposure at lower levels of carbon monoxide than healthy individuals. Children exposed to environ- mental tobacco smoke have been shown to be at higher risk of respiratory illnesses and those exposed to nitrogen dioxide have been shown to be at higher risk from respiratory infections.

Because of varying sensitivity among people, one individual may react to a particular IAQ problem while surrounding occupants have no ill effects. (Symptoms that are limited to a single person can also occur when only one workstation receives the bulk of the pollutant dose.) In other cases, complaints may be widespread.

A single indoor air pollutant or problem can trigger different reactions in different people. Some may not be affected at all. Information about the types of symptoms can sometimes lead directly to solutions. However, symptom information is more likely to be useful for identifying the timing and conditions under which problems occur.

Types of Symptoms and Complaints

The effects of IAQ problems are often non- specific symptoms rather than clearly defined illnesses. Symptoms commonly attributed to IAQ problems include:

- Headache
- Fatigue
- Shortness of breath
- Sinus congestion
- Cough
- Sneezing
- Eye, nose, and throat irritation

- Skin irritation
- Dizziness
- Nausea

All of these symptoms, however, may also be caused by other factors, and are not necessarily due to air quality deficiencies.

Environmental stressors such as improper lighting, noise, vibration, overcrowding, ergonomic stressors, and job-related psychosocial problems (such as job stress) can produce symptoms that are similar to those associated with poor air quality.

The term **sick building syndrome** (SBS) is sometimes used to describe cases in which building occupants experience acute health and comfort effects that are apparently linked to the time they spend in the building, but in which no specific illness or cause can be identified. The complaints may be localized in a particular room or zone or may be widespread throughout the building. Many different symptoms have been associated with SBS, including respiratory complaints, irritation, and fatigue. Analysis of air samples often fails to detect high concentrations of specific contaminants. Any or all of the following may cause the problem:

- The combined effects of multiple pollutants at low concentrations
- Other environmental stressors (E.g., overheating, poor lighting, noise)
- Ergonomic stressors
- Job-related psychosocial stressors (E.g., overcrowding, labor-management problems)
- Unknown factors

Look for IAQ problem indicators

The walkthrough inspection can be used to identify areas with a high potential for IAQ problems. The following are general indicators of IAQ problems:

- Odors
- Dirty or unsanitary conditions (e.g., excessive dust)

- Visible fungal growth or moldy odors (often associated with problem of too much moisture)

- Sanitary conditions at equipment such as drain pans and cooling towers

- Sanitary conditions in equipment such as drain pans and cooling towers

- Poorly-maintained filters

- Signs of mold or moisture damage at walls (e.g., below windows, at columns, at exterior corners), ceilings, and floors

- Staining and discoloration *(Note:* Make sure that stains are removed after leaks are repaired so that there will be visible evidence if the leak recurs.)

- Smoke damage *(Note:* If a fire has occurred involving electrical equipment, determine whether PCBs (polychlorinated biphenyls) may have been released from the equipment.)

- Presence of hazardous substances

- Potential for soil gas entry (e.g., unsealed openings to earth, wet earth smells)

- Unsanitary mechanical room, or trash or stored chemicals in mechanical room unusual noises from light fixtures or mechanical equipment