

# The Basics of Indoor Air Quality

## *Introduction*

In the last several years, a growing body of scientific evidence has indicated that the air within buildings and other buildings can be more seriously polluted than the outdoor air in even the largest and most industrialized cities. Research indicates that people spend approximately 90 percent of their time indoors. Thus, for many people, the risks to health may be greater due to exposure to air pollution indoors than outdoors. In addition, people who may be exposed to indoor air pollutants for the longest periods of time are often those most susceptible to the effects of indoor air pollution. Such groups include the young, the elderly, and the chronically ill, especially those suffering from respiratory or cardiovascular disease.

Asthma afflicts about 20 million Americans, including 6.3 million children. Since 1980, the largest growth in asthma cases has been in children under five. In 2000 there were nearly two million emergency room visits and nearly half a million hospitalizations due to asthma, at a cost of almost \$2 billion, and causing 14 million school days missed each year.

Indoor pollution sources that release gases or particles into the air are the primary cause of indoor air quality problems in buildings. Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the building. High temperature and humidity levels can also increase concentrations of some pollutants.

## *Pollutant Sources*

There are many sources of indoor air pollution in any building. These include combustion sources such as oil, gas, kerosene, coal, wood, and tobacco products; building materials and furnishings as diverse as deteriorated, asbestos-containing insulation, wet or damp carpet, and cabinetry or furniture made of certain pressed wood products; products for cleaning and maintenance, personal care, or hobbies; central heating and cooling systems and humidification devices; and outdoor sources such as radon, pesticides and outdoor air pollution.

The relative importance of any single source depends on how much of a particular pollutant is given off and how hazardous those emissions are. In some cases, factors such as how old the source is and whether it is properly maintained are significant. For example, an improperly adjusted gas stove can emit significantly more carbon monoxide than one that is properly adjusted.

Some sources, such as building materials, furnishings, and products like air fresheners, candles and scented oils release pollutants more or less continuously. Other sources, related to activities carried out in the building, release pollutants intermittently. These include smoking, the use of un-vented or malfunctioning stoves, furnaces, or space heaters, the use of solvents in cleaning and hobby activities, the use of paint strippers in redecorating activities, and the use of cleaning products and pesticides in housekeeping. High pollutant concentrations can remain in the air for long periods after some of these activities.

### ***Factors Affecting Indoor Air Quality***

Recent EPA studies have identified indoor air pollution as one of the most important environmental risks to the nation's health. With the advancement of modern technology, the number and types of contaminants released into indoor air have increased dramatically.

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.

Four elements are involved in the development of indoor air quality problems:

**1. Source:** There is a source of contamination or discomfort indoors, outdoors, or within the mechanical systems of the building.

**2. HVAC:** The HVAC system is not able to control existing air contaminants and ensure thermal comfort (temperature and humidity conditions that are comfortable for most occupants).

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

**4. 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 indoor air quality issues.

### ***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 HVAC system is properly designed and well maintained.**

It may be helpful to think of air pollutant sources as fitting into one of the following categories. 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, parking lots, garages, or loading docks
- odors from trash cans or dumpsters
- re-entrained (drawn back into the 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

### *Exterior Moisture or standing water - promoting excess microbial growth*

- rooftops after rainfall
- water accumulation at outlet of the Condensate Drain
- crawl space

### **Sources from 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-HVAC equipment*

- emissions from office equipment (volatile organic compounds, ozone)
- supplies
- emissions from shops, kitchens, bathrooms, labs, cleaning processes
- elevator motors and other mechanical systems

### **Sources from Human Activities**

#### *Personal Activities*

- smoking
- body odor
- cosmetic odors

#### *Housekeeping Activities*

- cleaning materials and procedures
- emissions from stored supplies or trash
- use of deodorizers, candles and fragrances
- airborne dust or dirt

#### *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

### **Sources from 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 on or in wet air ducts
- standing water from clogged or poorly designed drains
- standing water from poorly installed humidifiers
- 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 and piping
- fire damage

*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
- microbiological contaminants from demolition or remodeling activities

Indoor air often contains a variety of contaminants that are far below any standards or guidelines for occupational exposure. Given our present knowledge, it is difficult to relate complaints of specific health effects to exposure 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 course applies to central HVAC systems.

A properly designed and functioning HVAC system provides thermal comfort (cooling and dehumidification or heating and humidification), and filters the air. In addition, commercial HVAC systems also; distribute adequate amounts of outdoor air to meet ventilation needs of all building occupants and isolate and remove odors and contaminants (through pressure control and exhaust fans).

### *Thermal Comfort*

A number of variables interact to determine whether people are comfortable with the temperature of indoor air. The activity level, age and physiology of each person affect the thermal comfort requirements of that individual.

Uniformity of temperature is important to comfort. When the heating and cooling needs of rooms within a single zone change at different rates, rooms that are served by a single thermostat may be at different temperatures. Temperature stratification is a common problem caused by convection, the tendency of light and warm air to rise, and heavier and cooler air to sink. If the air is not properly mixed by the ventilation system, the temperature near the ceiling can be several degrees warmer than at floor level. Even if the air is properly mixed, un-insulated floors over unconditioned spaces can create moisture problems, and discomfort in some climate zones. Large fluctuations of indoor temperature can also occur when controls have a wide dead band (a temperature range within which neither heating nor cooling takes place). Adjusting the thermostats dead band or replacing the thermostat with a new thermostat that uses a narrower dead band or an improved anticipating control algorithm, such as a PID controller, can easily remedy some of these problems. The installation of a Mainstream Humidity Control Board to a central AC system can provide reduced humidity, using the existing system AC unit and back-up electric heat simultaneously, to lower the humidity without making the conditioned space too cold.

Radiant heat transfer may cause people located near very hot or very cold surfaces to be uncomfortable even though the thermostat setting and the measured air temperature are within the comfort range. Buildings with large window areas sometimes have acute problems of discomfort due to radiant heat gains and losses. The locations where complaints are usually made can shift during the day as the sun angle changes. Large vertical surfaces can also produce significant natural convection flows resulting in complaints of drafts. Adding insulation to walls helps to moderate the temperature of interior wall surfaces. Closing curtains reduces heating from direct sunlight and isolates building occupants from exposure to window surfaces (which, lacking insulation, are likely to be much hotter or colder than the walls).

Humidity is a factor in thermal comfort. Raising relative humidity reduces the ability to lose heat through perspiration and evaporation, so that the effect is similar to raising the temperature. Humidity extremes can also create other IAQ problems. Excessively high or low relative humidity can produce discomfort, while high relative humidity can promote the growth of mold and mildew. **To prevent mold and mildew the relative humidity must be less than 55% in all areas of the building.**

### *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 opening.

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. For example, as air moves from supply registers or diffusers to return air grilles, it is diverted or obstructed by partitions, walls and furnishings, and redirected by openings that provide pathways for air movement. The movement of people throughout the building also has a major impact on the movement of pollutants. Some of the pathways change as doors and windows open and close. It is useful to think of the entire building--the rooms and the connections (e.g., chases, corridors, stairways, elevator shafts) between them--as part of the air-distribution system.

Natural forces exert an important influence on air movement between zones and between the building's interior and exterior. Both the stack effect and the wind can overpower a building's mechanical system and disrupt air circulation and ventilation, especially if the building envelope is leaky.

Stack effect is the pressure-driven flow produced by natural convection (the tendency of warm air to rise). The stack effect exists whenever there is an indoor-outdoor temperature difference and becomes stronger as the temperature difference increases. As heated air escapes from upper levels of the building, indoor air moves from lower to upper floors, and replacement outdoor air is drawn into openings at the lower levels of buildings. The resulting airflow can transport contaminants between floors by way of stairwells, elevator shafts, utility chases, or other openings. Stack effects can be so strong as to prevent ground floor doors from closing, instead they are blown inward by the replacement air rushing into the building.

Wind effects are transient and create local areas of high pressure (on the windward side) and low pressure (on the leeward side) of buildings. Depending on the leakage openings in the building exterior, wind can affect the pressure relationships within and between rooms.

The basic principle of air movement from areas of higher pressure to areas of relatively lower pressure can produce many patterns of contaminant distribution. 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).

Even when the whole building is maintained under positive pressure, there is always some location (for example, the outdoor air intake) that is under negative pressure relative to the outdoors. Entry of contaminants may be intermittent, occurring only when the wind blows from a particular direction. The interaction between pollutant pathways and intermittent or variable driving forces can lead to a single source causing IAQ complaints in areas of the building that are distant from each other and from the source.

### ***Ventilation***

If too little outdoor air enters a structure, pollutants can accumulate to levels that can pose health and comfort problems. Unless they are built with special mechanical means of ventilation, buildings are designed and constructed to minimize the amount of outdoor air that can "leak" into and out of the building. The tighter the building, the higher the pollutant levels, when compared to buildings with more outdoor air leakage.

Outdoor air enters and leaves a building through infiltration, natural ventilation and mechanical ventilation. In the process known as infiltration, outdoor air flows into the

building through openings, joints and cracks in walls, floors and ceilings, and around windows and doors. In natural ventilation, air moves through opened windows and doors. Air movement associated with infiltration and natural ventilation is caused by indoor and outdoor air temperature differences and by wind. Finally, there are a number of mechanical ventilation devices, from outdoor-vented fans that intermittently remove air from a single room, such as bathrooms and kitchen, to air handling systems that use fans and duct work to continuously remove indoor air and distribute filtered and conditioned outdoor air to strategic points throughout the building. When there is little infiltration, natural ventilation, or mechanical ventilation pollutant levels can increase.

### ***Types of Duct Work***

While commercial air ducts are fabricated from sheet metal, most modern residential air duct systems are constructed of fiberglass duct board or sheet metal ducts that are lined on the inside with fiberglass duct liner. Since the early 1970s, a significant increase in the use of flexible duct has occurred. Flexible duct is generally lined internally with plastic or some other type of material. Internal insulation provides better acoustical (noise) control. Flexible duct is very low cost. These products are engineered specifically for use in ducts or as ducts themselves, and are tested in accordance with standards established by Underwriters Laboratories (UL), the American Society for Testing and Materials (ASTM), and the National Fire Protection Association (NFPA).

Many insulated duct systems have operated for years without supporting significant mold growth. Keeping them reasonably clean and dry is generally adequate. However, there is substantial debate about whether porous insulation materials (e.g., fiberglass) are more prone to microbial contamination than bare sheet metal ducts. If enough dirt and moisture are permitted to enter the duct system, there may be no significant difference in the rate or extent of microbial growth in internally lined or bare sheet metal ducts. However, treatment of mold contamination on bare sheet metal is much easier.

**Note:** Once fiberglass duct liner is contaminated with mold, cleaning is not sufficient to prevent re-growth and there are no EPA-registered biocides for the cleaning of porous duct materials. In this situation, the replacement of the wet or moldy fiberglass duct material is required. We also recommend the treatment of the replacement duct board as well as treatment of the adjacent areas with QwikTreat® Porous Duct Sealant with Biocide.

All experts agree that moisture should not be present in ducts and if moisture is present, the potential exists for biological contaminants to grow and distribute throughout the building. Controlling moisture is the only effective way to prevent biological growth on any type of air ducts.