



## Indoor Air Quality

http://www.epa.gov/iaq/schools/tfs/guide2.html

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# IAQ Reference Guide

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## Section 2 - Understanding IAQ Problems

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### IAQ TFS Action Kit

- IAQ Reference Guide;
- IAQ Coordinator's Guide
- IAQ Road Map;
- IAQ Backgrounder;
- IAQ Checklists;
- Fact Sheet on District-wide Implementation;
- Awards Program;
- Managing Asthma in the School Environment;
- Two Videos; and
- IAQ Problem Solving Wheel

Over the past several decades, exposure to indoor air pollutants has increased due to a variety of factors. These include the construction of more tightly sealed buildings; reduced ventilation rates to save energy; the use of synthetic building materials and furnishings; the use of personal care products, pesticides, and housekeeping supplies; and the increased use of vehicles and power equipment. In addition, activities and decisions, such as deferring maintenance to "save" money, can lead to problems from sources and ventilation.

The indoor environment in any building is a result of the interactions among the site, climate, building structure, mechanical systems (as originally designed and later modified), construction techniques, contaminant sources, building occupants, and outdoor mobile sources (cars, buses, trucks, and grounds maintenance equipment). This section contains a discussion on how these elements can cause IAQ problems, and **Section 6: "Solving IAQ Problems"** provides solutions. These elements are grouped into four categories:

1. Sources
2. Heating, Ventilation, and Air-Conditioning (HVAC) Systems
3. Pathways
4. Occupants

### Sources of Indoor Air Pollutants

Indoor air pollutants can originate within the building or be drawn in from outdoors. Air contaminants consist of numerous particulates, fibers, mists, bioaerosols, and gases. It is important to control air pollutant sources, or IAQ problems can arise -- even if the HVAC system is properly operating. It may be helpful to think of air pollutant sources as fitting into one of the categories in the following table, "[Typical Sources of Indoor Air Pollutants.](#)" The

examples given for each category are not intended to be an exhaustive list. **Appendix E: "Typical Indoor Air Pollutants"** contains a list of specific air pollutants with descriptions, sources, and control measures.

In addition to the number of potential pollutants, another complicating factor is that indoor air pollutant concentration levels can vary by time and location within the school building, or even a single classroom. Pollutants can be emitted from a variety of sources including:

- **Point sources** (such as from science storerooms);
- **Area sources** (such as newly painted surfaces); and
- **Mobile sources** (such as cars, buses, and power equipment).

Pollutants can also vary with time since some activities take place over a short period of time (such as stripping floors) or occur continuously (such as mold growing in the HVAC system).

Indoor air often contains a variety of contaminants at concentrations that are well below the published occupational standards. Given our present knowledge, it is often difficult to relate specific health effects to exposures to specific pollutant concentrations, especially since the significant exposures may be due to low levels of pollutant mixtures.

<b>Typical Sources of Indoor Air Pollutants</b>			
<b>OUTDOOR SOURCES</b>	<b>BUILDING EQUIPMENT</b>	<b>COMPONENTS/ FURNISHINGS</b>	<b>OTHER POTENTIAL INDOOR SOURCES</b>
<p><b>Polluted Outdoor Air</b></p> <ul style="list-style-type: none"> <li>• Pollen, dust, mold spores</li> <li>• Industrial emissions</li> <li>• Vehicle and non-road engine emissions (cars, buses, trucks, lawn and garden equipment)</li> </ul> <p><b>Nearby Sources</b></p> <ul style="list-style-type: none"> <li>• Loading docks</li> <li>• Odors from dumpsters</li> <li>• Unsanitary debris or building exhausts near outdoor air intakes</li> </ul> <p><b>Underground</b></p>	<p><b>HVAC Equipment</b></p> <ul style="list-style-type: none"> <li>• Mold growth in drip pans, ductwork, coils, and humidifiers</li> <li>• Improper venting of combustion products</li> <li>• Dust or debris in ductwork</li> </ul> <p><b>Non-HVAC Equipment</b></p> <ul style="list-style-type: none"> <li>• Emissions from office equipment (volatile organic compounds (VOCs) and ozone)</li> <li>• Emissions from shop, lab, and cleaning</li> </ul>	<p><b>Components</b></p> <ul style="list-style-type: none"> <li>• Mold growth on or in soiled or water-damaged materials</li> <li>• Dry drain traps that allow the passage of sewer gas</li> <li>• Materials containing VOCs, inorganic compounds, or damaged asbestos</li> <li>• Materials that produce particles (dust)</li> </ul> <p><b>Furnishings</b></p> <ul style="list-style-type: none"> <li>• Emissions from new furnishings and floorings</li> <li>• Mold growth on or in soiled</li> </ul>	<ul style="list-style-type: none"> <li>• Science laboratory supplies</li> <li>• Vocational art supplies</li> <li>• Copy/print areas</li> <li>• Food prep areas</li> <li>• Smoking lounges</li> <li>• Cleaning materials</li> <li>• Emissions from trash</li> <li>• Pesticides</li> <li>• Odors and VOCs from paint, chalk, adhesives</li> <li>• Occupants with communicable diseases</li> <li>• Dry-erase markers and similar pens</li> <li>• Insects and other pests</li> <li>• Personal care products</li> <li>• Stored</li> </ul>

<b>Sources</b> <ul style="list-style-type: none"> <li>• Radon</li> <li>• Pesticides</li> <li>• Leakage from underground storage tanks</li> </ul>	equipment	or water-damaged furnishings	gasoline and lawn and garden equipment
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### Interaction of Sources, HVAC Systems, Pathways, and Occupants

If independently evaluated, a minor roof leak and a dirty classroom carpet might not cause much concern. But if the water from the roof leak reaches the carpet, the water can wet the dirt in the carpet and the mold that has been dormant in the carpet. The mold can grow and become a pollutant source that releases spores into the classroom air. The HVAC system may act as a pathway that disperses the spores to other parts of the school, where occupants may experience allergic reactions.

### HVAC System Design and Operation

The HVAC system includes all heating, cooling, and ventilating equipment serving a school: Boilers or furnaces, chillers, cooling towers, air-handling units, exhaust fans, ductwork, and filters. Properly designed HVAC equipment in a school helps to:

- Control temperature and relative humidity to provide thermal comfort;
- Distribute adequate amounts of outdoor air to meet ventilation needs of school occupants; and
- Isolate and remove odors and other contaminants through pressure control, filtration, and exhaust fans.

Not all HVAC systems accomplish all of these functions. Some buildings rely only on natural ventilation. Others lack mechanical cooling equipment, and many function with little or no humidity control. The features of the HVAC system in a given building will depend on:

- Age of the design;
- Climate;
- Building codes in effect at the time of the design;
- Budget for the project;
- Designers' and school districts' individual preferences;
- Subsequent modifications;
- Space type; and
- Expected occupancy.

### Description of HVAC Systems

The two most common HVAC designs in schools are unit ventilators and central air-handling systems. Both can perform the same HVAC functions, but a unit ventilator serves a single room while the central air-handling unit serves multiple rooms. For basic central air-handling units, it is important that all rooms served by the central unit have similar thermal and ventilation requirements. If these requirements differ significantly, some rooms may be too hot, too cold, or under ventilated, while others are comfortable and adequately ventilated.

Most air-handling units distribute a mixture of outdoor air and recirculated indoor air. HVAC

designs may also include units that introduce 100 percent outdoor air or that simply recirculate indoor air within the building. Uncontrolled quantities of outdoor air enter buildings by leakage through windows, doors, and gaps in the building exterior. Thermal comfort and ventilation needs are met by supplying "conditioned" air, which is a mixture of outdoor and recirculated air that has been filtered, heated or cooled, and sometimes humidified or dehumidified. The basic components for a central air handling unit and a unit ventilator are illustrated in the [IAQ Backgrounder](#).

## Thermal Comfort

A number of variables interact to determine whether people are comfortable with the temperature and relative humidity of the indoor air. Factors such as clothing, activity level, age, and physiology of people in schools vary widely, so the thermal comfort requirements vary for each individual. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 55-1992 (summarized in the table below) describes the temperature and humidity ranges that are comfortable for 80 percent of people engaged in largely sedentary activities. The ASHRAE standard assumes "normal indoor clothing." Added layers of clothing reduce the rate of heat loss.

<b>RECOMMENDED RANGES OF TEMPERATURE AND RELATIVE HUMIDITY</b>		
<b>Relative Humidity</b>	<b>Winter Temperature</b>	<b>Summer Temperature</b>
<b>30%</b>	<b>68.5°F - 75.5°F</b>	<b>74.0°F - 80.0°F</b>
<b>40%</b>	<b>68.0°F - 75.0°F</b>	<b>73.5°F - 80.0°F</b>
<b>50%</b>	<b>68.0°F - 74.5°F</b>	<b>73.0°F - 79.0°F</b>
<b>60%</b>	<b>67.5°F - 74.0°F</b>	<b>73.0°F - 78.5°F</b>

**Recommendations apply for persons clothed in typical summer and winter clothing, at light, mainly sedentary, activity.**

Source: Adopted from ASHRAE Standard 55-1992, *Thermal Environmental Conditions for Human Occupancy*

Uniformity of temperature is important to comfort. Rooms that share a common heating and cooling system controlled by a single thermostat may be at different temperatures. Temperature stratification is a common problem caused by convection—the tendency of light, warm air to rise, and heavier, cooler air to sink. If air is not properly mixed by the ventilation system, the temperature near the ceiling can be several degrees warmer or cooler than near the floor, where young children spend much of their time. Even if air is properly mixed, uninsulated floors over unheated spaces can create discomfort in some climate zones. Large fluctuations of indoor temperature can also occur when thermostats have a wide "dead band" (a temperature range in which neither heating or cooling takes place).

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. Schools with large window areas sometimes

All schools need ventilation, which is the process of supplying outdoor air to occupied

have acute problems of discomfort due to radiant heat gains and losses, with the locations of complaints shifting during the day as the sun angle changes. Poorly insulated walls can also produce a flow of naturally-convecting air, leading to complaints of draftiness. areas within the school.

Closing curtains reduces heating from direct sunlight and reduces occupant exposure to hot or cold window surfaces. Large schools may have interior ("core") spaces in which year-round cooling is required to compensate for heat generated by occupants, office equipment, and lighting, while perimeter rooms may require heating or cooling depending on outdoor conditions.

Humidity is a factor in thermal comfort. Raising relative humidity reduces a person's 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, high relative humidity can promote the growth of mold and mildew, and low relative humidity can accelerate the release of spores into the air. (See **Appendix H: "Mold and Moisture."**)

### **Ventilation For Occupant Needs**

Ventilation is the process of supplying outdoor air to the occupied areas in the school while indoor air is exhausted by fans or allowed to escape through openings, thus removing indoor air pollutants. Often, this exhaust air is taken from areas that produce air pollutants such as restrooms, kitchens, science-storage closets, and fume hoods.

Modern schools generally use mechanical ventilation systems to introduce outdoor air during occupied periods, but some schools use only natural ventilation or exhaust fans to remove odors and contaminants. In naturally ventilated buildings, unacceptable indoor air quality is particularly likely when occupants keep the windows closed due to extreme hot or cold outdoor temperatures. Even when windows and doors are open, inadequate ventilation is likely when air movement forces are weakest, such as when there is little wind or when there is little temperature difference between inside and outside (stack effect).

Stack effect is the pressure-driven airflow produced by convection, the tendency of warm air to rise. Stack effect exists whenever there is an indoor-outdoor temperature difference, and the effect becomes stronger as the temperature difference increases. Multi-story schools are more affected than single-story schools. As heated air escapes from upper levels, indoor air moves from lower to upper levels, and outdoor air is drawn into the lower levels to replace the air that has escaped. Stack effect can transport contaminants between floors by way of stairwells, elevator shafts, utility chases, and other openings.

The amount of outdoor air considered adequate for proper ventilation has varied substantially over time. Because updating building codes often takes several years, current building codes may require more ventilation than when the system was designed. ASHRAE ventilation standards are used as the basis for most building ventilation codes. A table of outdoor air quantities in schools as recommended by ASHRAE Standard 62-2001, "Ventilation for Acceptable Indoor Air Quality," is shown below. Please note that this is a limited portion of the Standard, and that the quantities listed are in units of cfm per person, which are cubic feet per minute of outdoor air for each person in the area served by that ventilation system.

<b>SELECTED OUTDOOR AIR VENTILATION RECOMMENDATIONS (MINIMUM)</b>	
<b>Application</b>	<b>Cubic Feet per Minute (CFM) Per Person</b>
Classroom	15
Music Rooms	15
Libraries	15
Auditoriums	15
Spectator Sport Areas	15
Playing Floors	20
Office Space	20
Conference Rooms	20
Smoking Lounges	60
Cafeteria	20
Kitchen (cooking)	15

*Source: ASHRAE Standard 62-2001, Ventilation for Acceptable Indoor Air Quality*

### **Pollutant Pathways and Driving Forces**

Airflow patterns in buildings result from the combined forces of mechanical ventilation systems, human activity, and natural effects. Air pressure differences created by these forces move airborne pollutants from areas of higher pressure to areas of lower pressure through any available openings in building walls, ceilings, floors, doors, windows, and HVAC systems. For example, as long as the opening to an inflated balloon is kept shut, no air will flow. When opened, however, air will move from inside (area of higher pressure) to the outside (area of lower pressure).

Even if the opening is small, air will move until the inside pressure is equal to the outside pressure. If present, the HVAC ducts are generally the predominant pathway and driving force for air movement in buildings. However, all of a building's components (walls, ceilings, floors, doors, windows, HVAC equipment, and occupants) interact to affect how air movement distributes pollutants within a building.

As air moves from supply outlets to return inlets, for example, it is diverted or obstructed by walls and furnishings, and redirected by openings that provide pathways for air movement. On a localized basis, the movements of people have a major impact on pollutant transport. Some of the pathways change as doors and windows open and close. It is useful to think of the entire building -- the rooms with connecting corridors and utility passageways between them -- as part of the air-distribution system.

Air movement can transfer emissions from the pollutant source:

- Into adjacent rooms or spaces that are under lower pressure.
- Into other spaces through HVAC system ducts.
- From lower to upper levels in multi-story schools.
- Into the building through either infiltration of outdoor air or reentry of exhaust air.
- To various points within the room.

Natural forces exert an important influence on air movement between a school's interior and exterior. Both the stack effect and wind can overpower a building's HVAC system and disrupt air circulation and ventilation, especially if the school envelope (walls, ceiling, windows, etc.) is leaky.

Wind effects are transient, creating local areas of high pressure (on the windward side) and low pressure (on the leeward side) of buildings. Depending on the size and location of leakage openings in the building exterior, wind can affect the pressure relationships within and between rooms. Entry of outdoor air contaminants may be intermittent or variable, occurring only when the wind blows from the direction of the pollutant source.

Most public and commercial buildings are designed to be positively pressurized, so that unconditioned air does not enter through openings in the building envelope causing discomfort or air quality problems. The interaction between pollutant pathways and intermittent or variable driving forces can lead to a single source causing IAQ complaints in an area of the school that is distant from the pollutant source.

### **Building Occupants**

Occupant activities can directly affect pollutant sources, the HVAC system (operation, maintenance, controls), pathways, and driving forces. Occupants can also be carriers of communicable disease and allergens, such as pet dander. Teachers may use dry-erase markers or laboratory chemicals that emit pollutants. Similarly, many cleaning materials used in schools contain VOCs that can degrade IAQ.

It is important for occupants to understand how their activities directly affect ventilation pathways and sources of pollutants in their school.

Teachers and administrators often obstruct proper air movement in their classrooms and offices by using ventilation units as bookshelves, unknowingly restricting the pathway for fresh air to enter the area. Similarly, covering air return ducts (with posters, for example) restricts proper air circulation. Therefore, it is important for occupants to understand how their activities directly affect ventilation pathways and sources of pollutants in their school.

Occupants can contribute to a healthy indoor environment by completing the IAQ checklists, monitoring their own behavior, and immediately alerting the IAQ Coordinator of any IAQ problems.

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