http://www.epa.gov/iaq/largebldgs/i-beam/text/fundamentals_of_iaq.html
Last updated on Tuesday, October 21st, 2008.

IAQ in Large Buildings

IAQ Building Education and Assessment Model (I-BEAM)

Text Modules: Fundamentals of IAQ in Buildings

This module provides the fundamentals to understanding indoor air quality. It provides a rudimentary framework for understanding how indoor and outdoor sources of pollution, heat and humidity, together with the ventilation and air conditioning systems affect the indoor air quality in buildings. It also begins to address methods of controlling those factors in order that the quality of the air which occupants experience provides for their health, comfort and performance.

I-BEAM Text Modules

- **Fundamentals of IAQ in Buildings**
- Heating, Ventilation, and Air-conditioning (HVAC)
- IAQ Maintenance and Housekeeping Programs
- Indoor Air Quality and Energy Efficiency
- Diagnosing and Solving Problems
- Renovation and New Construction
- Managing for Indoor Air Quality
- IAQ Budgets and Accounts

- Overview of I-BEAM
- Overview of Text Modules
- Overview of Visual Reference Modules
- IAQ Budgets and Accounts
- I-BEAM Forms

Fundamentals of IAQ in Buildings
(PDF, 14 pp, 79KB)

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Indoor Air Quality (IAQ)

Overview of Indoor Air Quality in I-BEAM

What is Indoor Air Quality?

Indoor air quality (IAQ) in I-BEAM refers to the quality of the air inside buildings as represented by concentrations of pollutants and thermal (temperature and relative humidity) conditions that affect the health, comfort, and performance of occupants. Other factors affecting occupants, such as light and noise, are important indoor environmental quality considerations, but are not treated in I-BEAM as core elements of indoor air quality.

Why is IAQ Important to Building Managers?

Buildings exist to protect people from the elements and to otherwise support human activity. Buildings should not make people sick, cause them discomfort, or otherwise inhibit their ability to perform. How effectively a building functions to support its occupants and how efficiently the building operates to keep costs manageable is a measure of the building's performance.

The growing proliferation of chemical pollutants in consumer and commercial products, the tendency toward tighter building envelopes and reduced ventilation to save energy, and pressures to defer maintenance and other building services to reduce costs have fostered indoor air quality problems in many buildings. Occupant complaints of odors, stale and stuffy air, and symptoms of illness or discomfort breed undesirable conflicts between occupants or tenants and building managers. Lawsuits sometimes follow.

If indoor air quality is not well managed on a daily basis, remediation of ensuing problems and/or resolution in court can be extremely costly. So it helps to understand the causes and consequences of indoor air quality and to manage your building to avoid these problems.

How Can I-BEAM Help?

How to design, construct, and manage buildings economically and still satisfy indoor air quality needs of building occupants is a question which looms large for

many building managers. It is THE fundamental question addressed by I-BEAM. I-BEAM helps you manage your building to prevent indoor air quality problems and to solve them when they occur. The tools provided also help you to document your IAQ activities so you can market your IAQ program and support a legal defense. Finally you can use I-BEAM to evaluate the impact of IAQ activities on your bottom line.

Occupant Symptoms Associated with Poor Indoor Air Quality

Human responses to pollutants, climatic factors, and other stressors such as noise and light are generally categorized according to the type and degree of responses and the time frame in which they occur. Building managers should be generally familiar with these categories, leaving detailed knowledge to health and safety professionals.

Acute Effects

Acute effects are those that occur immediately (e.g., within 24 hours) after exposure. Chemicals released from building materials may cause headaches, or mold spores may result in itchy eyes and runny noses in sensitive individuals shortly after exposure. Generally, these effects are not long lasting and disappear shortly after exposure ends. However, exposure to some biocontaminants (fungi, bacteria, viruses) resulting from moisture problems, poor maintenance, or inadequate ventilation have been known to cause serious, sometimes life threatening respiratory diseases which themselves can lead to chronic respiratory conditions.

Chronic Effects

Chronic effects are long-lasting responses to long term or frequently repeated exposures. Long term exposures to even low concentrations of some chemicals may induce chronic effects. Cancer is the most commonly associated long term health consequence of exposure to indoor air contaminants. For example, long term exposures to environmental tobacco smoke, radon, asbestos, and benzene increases cancer risk.

Discomfort

Discomfort is typically associated with climatic conditions but building contaminants may also be implicated. People complain of being too hot or too cold or experience eye, nose or throat irritation because of low humidity. However, reported symptoms can be difficult to interpret. Complaints that the air is "too dry" may result from irritation from particles on the mucous membranes rather than low humidity, or "stuffy air" may mean that the temperature is too warm or there is lack of air movement, or "stale air" may mean that there is a mild but difficult to identify odor. These conditions may be unpleasant and cause discomfort among occupants, but there is usually no serious health implication involved. Absenteeism, work performance and employee morale, however, can be seriously affected when building managers fail to resolve these complaints.

Performance Effects

Significant measurable changes in people's ability to concentrate or perform

mental or physical tasks have been shown to result from modest changes in temperature and relative humidity. In addition, recent studies suggest that the similar effects are associated with indoor pollution due to lack of ventilation or the presence of pollution sources. Estimates of performance losses from poor indoor air quality for all buildings suggest a 2-4% loss on average. Future research should further document and quantify these effects.

Building Associated Illnesses

The rapid emergence of indoor air quality problems and associated occupant complaints have led to terms which describe illnesses or effects particularly associated buildings. These include sick building syndrome, building related illness, and multiple chemical sensitivity.

Sick Building Syndrome (SBS)

Sick Building Syndrome (SBS) is a catch-all term that refers to a series of acute complaints for which there is no obvious cause and where medical tests reveal no particular abnormalities. The symptoms display when individuals are in the building but disappear when they leave. Complaints may include such symptoms as irritation of the eyes, nose and throat; headache; stuffy nose; mental fatigue; lethargy, and skin irritation. These complaints are often accompanied by non-specific complaints such as the air is stuffy or stale. A single causative agent (e.g., contaminant) is seldom identified and complaints may be resolved when building operational problems and/or occupant activities identified by investigators are corrected. Experience in resolving SBS complaints has led to many of the suggestions for "good practice" found in I-BEAM.

Increased absenteeism, reduced work efficiency, and deteriorating employee morale are the likely outcomes of SBS problems which are not quickly resolved.

Building Related Illness (BRI)

Building related illness refers to an defined illness with a known causative agent resulting from exposure to the building air. While the causative agent can be chemical (e.g., formaldehyde), it is often biological. Typical sources of biological contaminants are humidification systems, cooling towers, drain pans or filters, other wet surfaces, or water damaged building material. Symptoms may be specific or mimic symptoms commonly associated with the flu, including fever, chills, and cough. Serious lung and respiratory conditions can occur. Legionnaires' disease, hypersensitivity pneumonitis, and humidifier fever are common examples of building related illness.

Multiple Chemical Sensitivity (MCS)

It is generally recognized that some persons can be sensitive to particular agents at levels which do not have an observable affect in the general population. In addition, it is recognized that certain chemicals can be sensitizers in that exposure to the chemical at high levels can result in sensitivity to that chemical at much lower levels.

Some evidence suggests that a subset of the population may be especially sensitive to low levels of a broad range of chemicals at levels common in today's

home and working environments. This apparent condition has come to be known as multiple chemical sensitivity (MCS).

Persons reported to have MCS apparently have difficulty being in most buildings. There is significant professional disagreement concerning whether MCS actually exists and what the underlying mechanism might be. Building managers may encounter occupants who have been diagnosed with MCS. Resolution of complaints in such circumstances may or may not be possible with the guidance provided in I-BEAM. Responsibility to accommodate such individuals is subject to negotiation and may involve arrangements to work at home or in a different location.

Building Factors Affecting Indoor Air Quality

Factors Affecting Indoor Climate

The thermal environment (temperature, relative humidity and airflow) are important dimensions of indoor air quality for several reasons. First, many complaints of poor indoor air may be resolved by simply altering the temperature or relative humidity. Second, people that are thermally uncomfortable will have a lower tolerance to other building discomforts. Third, the rate at which chemicals are released from building materials is usually higher at higher building temperatures. Thus, if occupants are too warm, it is also likely that they are being exposed to higher pollutant levels.

Indoor thermal conditions are controlled by the heating, ventilating, and air conditioning (HVAC) system. How well the thermal environment is controlled depends on the design and operating parameters of the system, and on the heat gains and losses in the space being controlled. These gains and losses are principally determined by indoor sources of heat, the heat gains from sunlight, the heat exchange through the thermal envelope, and the outdoor conditions and outdoor air ventilation rate.

Factors Affecting Indoor Air Pollution

Much of the building fabric, its furnishings and equipment, its occupants and their activities produce pollution. In a well functioning building, some of these pollutants will be directly exhausted to the outdoors and some will be removed as outdoor air enters the building and replaces the air inside. The air outside may also contain contaminants which will be brought inside in this process. This air exchange is brought about by the mechanical introduction of outdoor air (outdoor air ventilation rate), the mechanical exhaust of indoor air, and the air exchanged through the building envelope (infiltration and exfiltration).

Pollutants inside can travel through the building as air flows from areas of higher atmospheric pressure to areas of lower atmospheric pressure. Some of these pathways are planned and deliberate so as to draw pollutants away from occupants, but problems arise when unintended flows draw contaminants into occupied areas. In addition, some contaminants may be removed from the air through natural processes, as with the adsorption of chemicals by surfaces or the settling of particles onto surfaces. Removal processes may also be deliberately incorporated into the building systems. Air filtration devices, for example, are commonly incorporated into building ventilation systems.

Thus, the factors most important to understanding indoor pollution are:

a. indoor sources of pollution,
b. outdoor sources of pollution,
c. ventilation parameters,
d. airflow patterns and pressure relationships, and
e. air filtration systems.

Types of Pollutants

Common pollutants or pollutant classes of concern in commercial buildings along with common sources of these pollutants are provided below.

Indoor Pollutants and Potential Sources

Pollutant or Pollutant Class	Potential Sources
Environmental Tobacco Smoke	Lighted cigarettes, cigars, pipes
Combustion Contaminants	Furnaces, generators, gas or kerosene space heaters, tobacco products, outdoor air, vehicles.
Biological Contaminants	Wet or damp materials, cooling towers, humidifiers, cooling coils or drain pans, damp duct insulation or filters, condensation, re-entrained sanitary exhausts, bird droppings, cockroaches or rodents, dustmites on upholstered furniture or carpeting, body odors.
Volatile Organic Compounds (VOCs)	Paints, stains, varnishes, solvents, pesticides, adhesives, wood preservatives, waxes, polishes, cleansers, lubricants, sealants, dyes, air fresheners, fuels, plastics, copy machines, printers, tobacco products, perfumes, dry cleaned clothing.
Formaldehyde	Particle board, plywood, cabinetry, furniture, fabrics.
Soil gases (radon, sewer gas, VOCs, methane)	Soil and rock (radon), sewer drain leak, dry drain traps, leaking underground storage tanks, land fill
Pesticides	Termiticides, insecticides, rodenticides, fungicides, disinfectants, herbicides.
Particles and Fibers	Printing, paper handling, smoking and other combustion, outdoor sources, deterioration of materials, construction/renovation, vacuuming, insulation.

Contaminant Sources

Indoor Sources

Identified below are some sources of contaminants commonly found in office buildings and offers some measures for maintaining control of these contaminants. Follow these measures to help maintain a healthy indoor environment.

Category/Common Sources

1. **Housekeeping and Maintenance (Includes)** - cleansers, waxes and polishes, disinfectants, air fresheners, adhesives, janitor's/storage closets, wet mops, drain cleaners, vacuuming, paints and coatings, solvents, pesticides, and lubricants

   Tips for Mitigation and Control

   - Use low-emitting products
   - Avoid aerosols and sprays
   - Dilute to proper strength (manufacturer's instructions)
   - Do not overuse; use during unoccupied hours
   - Use proper protocol when diluting and mixing
   - Store properly with containers closed and lid tight
   - Use exhaust ventilation for storage spaces (eliminate return air)
   - Clean mops: store mop top up to dry
   - Avoid “air fresheners”—clean and exhaust instead
   - Use high efficiency vacuum bags/filters
   - Use Integrated Pest Management

2. **Occupant-Related Sources (Includes) -** Tobacco products, Office equipment (e.g., Printers and copiers), cooking/microwave, art supplies, marking pens, paper products, personal products (e.g., perfume), and tracked in dirt/pollen

   Tips for Mitigation and Control

   - Smoking policy
   - Use exhaust ventilation with pressure control for major local sources
   - Low emitting art supplies/marking pens
   - Avoid paper clutter
   - Education material for occupants and staff

3. **Building Uses as Major Sources (Includes) -** print/photocopy shop, dry cleaning, science laboratory, medical office, hair/nail salon, cafeteria, and pet store

   Tips for Mitigation and Control

   - Use exhaust ventilation and pressure control
   - Use exhaust hoods where appropriate; check hood airflows

4. **Building-Related Sources (Includes)** - plywood/compressed wood, construction adhesives, asbestos products, insulation, wall/ floor coverings (vinyl/plastic), carpets/carpet adhesives, wet building products, transformers, upholstered furniture, and renovation/remodeling

   Tips for Mitigation and Control

   - Use low emitting products
   - Air out in an open/ventilated area before installing
   - Increase ventilation rates during and after installing
   - Keep material dry prior to enclosing
   - Use renovation guidelines

5. **HVAC system (Includes)** - contaminated filters, contaminated duct lining, dirty drain pans, humidifiers, lubricants, refrigerants, mechanical room, maintenance activities, and combustion appliances (e.g., boilers/furnaces, DHW, generators, and stoves)

   Tips for Mitigation and Control

- Perform HVAC preventive maintenance
- Use filter change protocol
- Clean drain pans; proper slope and drainage
- Use potable water for steam humidification
- Keep duct lining dry; move lining outside of duct if possible
- Fix leaks/clean spills (see filter change protocol)
- Maintain spotless mechanical room (not a storage area)
- Avoid back drafting
- Check/maintain flues from boiler to outside
- Keep combustion appliances properly tuned
- Disallow unvented combustion appliances
- Perform polluting activities during unoccupied hours

6. **Moisture (Includes)** - Mold

Tips for Mitigation and Control

- Keep building dry
- Mold and Moisture Control Protocol

7. **Vehicles (Includes)** - Underground/attached garage

Tips for Mitigation and Control

- Use exhaust ventilation
- Maintain garage under negative pressure relative to the building
- Check air flow patterns frequently
- Monitor CO

Outdoor Sources

Identified below are common sources of contaminants that are introduced from outside buildings. These contaminants frequently find their way inside through the building shell, openings, or other pathways to the inside.

1. **Ambient Outdoor Air (Includes)** - air quality in the general area

Tips for Mitigation and Control

- Filtration or air cleaning of intake air

2. **Vehicular Sources (Includes) -** local vehicular traffic, vehicle idling areas, and loading dock

Tips for Mitigation and Control

- Locate air intake away from source
- Require engines shut off at loading dock
- Pressurize building/zone
- Add vestibules/sealed doors near source

3. **Commercial/Manufacturing Sources (Includes)** - laundry or dry cleaning, restaurant, photo-processing, automotive shop/gas station, paint shop, electronics manufacture/assembly, and various industrial operations

Tips for Mitigation and Control

- Locate air intake away from source
- Pressurize building relative to outdoors
- Consider air cleaning options for outdoor air intake
- Use landscaping to block or redirect flow of contaminants, but not too close to air intakes

4. **Utilities/Public Works (Includes)** - utility power plant, incinerator, and water treatment plant

Tips for Mitigation and Control

- Locate air intake away from source
- Pressurize building relative to outdoors
- Consider air cleaning options for outdoor air intake
- Use landscaping to block or redirect flow of contaminants, but not too close to air intakes

5. **Agricultural** (Includes) - pesticide spraying, processing or packing plants, and ponds

Tips for Mitigation and Control

- Locate air intake away from source
- Pressurize building relative to outdoors
- Consider air cleaning options for outdoor air intake
- Use landscaping to block or redirect flow of contaminants, but not too close to air intakes

6. **Construction/Demolition**

Tips for Mitigation and Control

- Pressurize building
- Use walk-off mats

7. **Building Exhaust (Includes)** - bathrooms exhaust, restaurant exhaust, air handler relief vent, and exhaust from major tenant (e.g., dry cleaner)

Tips for Mitigation and Control

- Separate exhaust or relief from air intake
- Pressurize building

8. **Water Sources (Includes) -** pools of water on roof and cooling tower mist

Tips for Mitigation and Control

- Proper roof drainage
- Separate air intake from source of water
- Treat and maintain cooling tower water

9. **Birds and Rodents (Includes)** - fecal contaminants and bird nesting

Tips for Mitigation and Control

- Bird proof intake grills
- Consider vertical grills

- Use Integrated Pest Management

10. **Building Operations and Maintenance (Includes)** - trash and refuse area, chemical/fertilizers/grounds keeping storage, and painting/roofing/sanding

Tips for Mitigation and Control

- Separate source from air intake
- Keep source area clean/lids on tight
- Isolate storage area from occupied areas

11. **Ground Sources (Includes)** - soil gas, sewer gas, and underground fuel storage tanks

Tips for Mitigation and Control

- Depressurize soil
- Seal foundation and penetrations to foundation
- Keep air ducts away from ground sources

Protocols for Managing Major Sources of Pollution in Buildings

Type of Protocol	Solution
Remodeling and Renovation	• Use effective strategies for material selection and installation. • Isolate construction activity from occupants.

Painting	• Establish a protocol for painting and insure that the protocol is followed by both in-house personnel and by contractors.
	  • Use low VOC emission, fast drying paints where feasible.
	  • Paint during unoccupied hours.
	  • Keep lids on paint containers when not in use.
	  • Ventilate the building with significant quantities of outside air during and after painting. Insure a complete building flush prior to occupancy.
	  • Use more than normal outside air ventilation for some period after occupancy.
	  • Avoid spraying, when possible.

Pest Control *Integrated Pest Management*	• Use or require the use of Integrated Pest Management by pest control contractors in order to minimize the use of pesticides when managing pests.
	  • Control dirt, moisture, clutter, foodstuff, harborage, and building penetrations to minimize pests.
	  • Use baits and traps rather than pesticide sprays where possible.
	  • Avoid periodic pesticide application for “prevention” of pests.
	  • Use pesticides only where pests are located.
	  • Use pesticide specifically formulated for the targeted pest.
	• Apply pesticides only during unoccupied hours.
	• Ventilate the building with significant quantities of outside air during and after applications.

	• Insure a complete building flush prior to occupancy. • Use more than normal outside air ventilation for some period after occupancy. • Notify occupants prior to occupation. • If applying outside, keep away from air intake.

Shipping and Receiving	• Establish and enforce a program to prevent vehicle contaminants from entering the building.
	
	  • Do not allow idling of vehicles at the loading dock. Post signs and enforce the ban.
	  • Pressurize the receiving area relative to the outside to insure that contaminants from the loading area do not enter the building. Use pressurized vestibules and air locks if necessary.
	  • Periodically check the pressure relationships and compliance with the protocol.
	  • Notify delivery company supervisors of policy.

Establish and Enforce a Smoking Policy	Environmental tobacco smoke (ETS) is a major indoor air contaminant. A smoking policy may take one of two forms: • A smoke-free policy which does not allow smoking in any part of the building. • A policy that restricts smoking to designated smoking lounges only. (Partial policies such as allowing smoking only in private offices are not effective.)
Smoking Lounge Requirements	A designated smoking lounge must have the following features to be effective in containing ETS. • The lounge should be fully enclosed. • The lounge should be sealed off from the return air plenum. • The lounge should have exhaust ventilation directly to the outside at 60cfm per occupant (using maximum occupancy). • Transfer air from occupied spaces may be used as make up air. • The lounge should be maintained under negative pressure relative to the surrounding occupied spaces.
Managing Moisture and Mold (See also EPA's Mold Remediation Guidelines)	Mold thrives in the presence of water. The secret to controlling mold is to control moisture and relative humidity • Keep relative humidity below 60% (50%, if feasible, to control dust mites) Keep all parts of the building dry that are not designed to be wet • Adequately insulate exterior walls or ceilings to avoid condensation on cold surfaces • Insulate cold water pipes to avoid sweating • Clean spills immediately. Thoroughly clean and dry liquid spills on porous surfaces such as carpet within 24 hours, or discard the material • Do not allow standing water in any location • Maintain proper water drainage around the perimeter of the building • Provide sufficient exhaust in showers or kitchen areas producing steam

	Thoroughly clean areas that are designed to be wet • Wash floors and walls often where water accumulates (e.g., showers) • Clean drain pans often and insure a proper slope to keep water draining • Insure proper maintenance and treatment of cooling tower operations Discard all material with signs of mold growth • Discard furniture, carpet, or similar porous material having a persistent musty odor • Discard furniture, carpet, or similar porous material that has been wet for more than 24 hours • Discard ceiling tiles with visible water stains

Pollution Transport

Air Movement and Pressure

Contaminants reach occupant breathing-zones by traveling from the source to the occupant by various pathways. Normally, the contaminants travel with the flow of air.

Air moves from areas of high pressure to areas of low pressure. That is why controlling building air pressure is an integral part of controlling pollution and enhancing building IAQ performance.

Air movement should be from occupants, toward a source, and out of the building rather than from the source to the occupants and out the building. Pressure differences will control the direction of air motion and the extent of occupant exposure.

Driving Forces

Driving forces change pressure relationships and create airflow. Common driving forces are identified in the table below.

Major Driving Force	Effect
Wind	Positive pressure is created on the windward side causing infiltration, and negative pressure on the leeward side causing exfiltration, though wind direction can be varied due to surrounding structures.
Stack Effect	When the air inside is warmer than outside, it rises, sometimes creating a column of rising air -- up stairwells, elevator shafts, vertical pipe chases etc. This buoyant force of the air results in positive pressure on the higher floors and negative pressure on the lower floors and a neutral pressure plane somewhere between.
HVAC/Fans	Fans are designed to push air in a directional flow and create positive pressure in front, and negative pressure behind the fan

Flues and Exhaust	Exhausted air from a building will reduce the building air pressure relative to the outdoors. Air exhausted will be replaced either through infiltration or through planned outdoor air intake vent.
Elevators	The pumping action of a moving elevator can push air out of or draw air into the elevator shaft as it moves.

Common Airflow Pathways

Contaminants travel along pathways - sometimes over great distances. Pathways may lead from an indoor source to an indoor location or from an outdoor source to an indoor location.

The location experiencing a pollution problem may be close by, in the same or an adjacent area, but it may be a great distance from, and/or on a different floor from a contaminant source.

Knowledge of common pathways helps to track down the source and/or prevent contaminants from reaching building occupants.

Common Airflow Pathways for Pollutants

Common Pathway	Comment
Indoors	
• Stairwell • Elevator shaft • Vertical electrical or plumbing chases	The stack effect brings about air flow by drawing air toward these chases on the lower floors and away from these chases on the higher floors, affecting the flow of contaminants.
Receptacles, outlets, openings	Contaminants can easily enter and exit building cavities and thereby move from space to space.
Duct or plenum	Contaminants are commonly carried by the HVAC system throughout the occupied spaces.
Duct or plenum leakage	Duct leakage accounts for significant unplanned air flow and energy loss in buildings.
Flue or exhaust leakage	Leaks from sanitary exhausts or combustion flues can cause serious health problems
Room spaces	Air and contaminants move within a room or through doors and corridors to adjoining spaces
Outdoors to Indoors	
Indoor air intake	Polluted outdoor air or exhaust air can enter the building through the air intake
Windows/doors Cracks and crevices	A negatively pressurized building will draw air and outside pollutants into the building through any available opening
Substructures and slab penetrations	Radon and other soil gases and moisture-laden air or microbial contaminated air often travel through crawlspaces and other substructures into the building.

Ventilation

Ventilation can be used to either exhaust pollutants from a fixed source, or dilute pollutants from all sources within a space.

Exhaust Ventilation

Ideally, exhaust airflow should be sufficient to draw pollutants from the source into the exhaust and away from occupants. The source should be located between the exhaust and the occupants. Rooms with major sources should be under negative pressure relative to the surrounding spaces. Some sources, such as cooking stoves and laboratory benches, may require exhaust hoods. Also see Exhaust Systems.

Dilution Ventilation

Contaminants from area sources such as, people, building materials, office equipment, are diluted with outdoor air from natural or mechanical ventilation. Ventilation systems should be operated to provide sufficient outdoor air ventilation. Reducing outdoor air ventilation rates below required levels saves little energy and is not advisable. If capacity is available, outdoor air ventilation rates should meet applicable standards under all operating conditions. Problems with reduced outdoor air during part-load in certain VAV systems should be addressed.

Ventilation Measurements

Measurement instruments and techniques, which are generally available to building personnel, can be extremely useful in assessing the performance of the right ventilation system for both exhausting and diluting pollutants. Useful measuring tools include:

- Smoke tube to measure airflow
- Flow hood to measure air volume
- Velocity meter to measure air velocity
- Measuring carbon dioxide to estimate the percentage of outdoor air or to generally evaluate outdoor air ventilation