

Indoor Air Quality

- Four Factors Contribute to a Building's Indoor Air Quality
- Sources of Indoor Air Contaminants
- Heating, Ventilation, and Air Conditioning (HVAC) System Design and Operation
- Pathway of the Pollutant
- Occupants of the Building
- Indoor Air Quality Investigation Format
- Indoor Air Pollution Diagnosis
- Corrective Actions

Four Factors Contribute to a Building's Indoor Air Quality

- 1) Source of contamination
- 2) HVAC system
- 3) Pathway of the pollutant
- 4) Building occupants

Sources of Indoor Air Contaminants

Sources of contaminants may exist *outside* the building and be drawn in — or they may exist *inside* the building.

Outside Sources

- Outdoor air contaminants
 - Vehicle exhaust
 - Industrial pollution
 - Pollen, dust, fungal spores
- Emissions
 - Loading docks
 - Garbage near the outdoor air intake for the HVAC
 - Dumpster odors
 - Exhaust from idling vehicles parked near the building
- Moisture or standing water
 - Pooling of water on rooftops following rainfall
 - Basements/crawlspaces
- Off-gassing of the soil
 - Radon
 - Landfills
 - Underground fuel tanks
 - Pesticides
- HVAC equipment
 - Leakage of the refrigerant
 - Combustion by-products not vented correctly
 - Dust and dirt in ductwork
 - Incorrect use of biocides, cleaning compounds and sealant
 - Microbiological growth in coils, ductwork and humidifiers
- Equipment other than HVAC
 - Office supplies
 - Office equipment
 - Mechanical systems such as elevator motors
- Building occupants' activities
 - Body odor
 - Cosmetic and perfume odor
- Cooking
- Smoking

Safety Tips from the WorkSafe People

- Housekeeping and maintenance
 - The procedures and chemical agents used
 - Stored products' emissions
 - Use of deodorizers and fragrances
 - Dust or dirt from sweeping and vacuuming
 - Volatile organic compounds from paint, caulk, adhesives
 - Pest control
 - Microorganisms in mist from improperly maintained cooling towers
 - Accidental releases, flooding, or fires
 - Remodeling, redecorating, or repairing
- Furnishings that create or collect dust
 - Textile surfaces, carpeting
 - Open shelving
 - Old furnishings
- Water damage
 - Microbiological growth on water-damaged ceiling, walls, furniture
 - Clogged or poorly designed drainage
 - Dry traps

Heating, Ventilation and Air Conditioning (HVAC) System Operation

The HVAC system consists of the equipment necessary for heating, cooling and ventilating the building. Components of a system may include furnaces or boilers, chillers, cooling towers, air-handling units, exhaust fans, ductwork, filters, steam or hot-water piping. When a HVAC system is designed and maintained correctly, it can provide the building's occupants with good thermal comfort, isolate and remove odors and distribute an adequate amount of outdoor air.

- Thermal comfort — many variables impact a person's perception of indoor thermal comfort
 - Activity level (sedentary to active, or somewhere in between)
 - Age
 - Physiology (each individual's physiology affects his or her thermal comfort level)
- Uniformity of the temperature is an important comfort factor
 - Temperature stratification is a common problem which may be caused by convection — light, warm air rises and heavier, cold air sinks
 - Buildings with large window areas may have acute discomfort problems due to the radiant heat gains and losses — Close window coverings to reduce direct sun heat
 - Large vertical surfaces may produce naturally convecting air, which may result in complaints of draftiness
 - Additional wall insulation

Safety Tips from the WorkSafe People

- Relative humidity
 - Very high or very low relative humidity will cause discomfort
 - Mildew and mold growth will occur at high relative humidity

The following table is adapted from ASHRAE Standard 56-1981, Thermal Environmental Conditions for Human Occupancy. This information applies to individuals clothed in typical summer and winter attire, performing mainly sedentary activity.

Relative Humidity	Winter Temperature	Summer Temperature
30%	68.5°F–76.0°F	74.0°F–80.0°F
40%	68.5°F–75.5°F	73.5°F–79.5°F
50%	68.5°F–74.5°F	73.0°F–79.0°F
60%	68.0°F–74.0°F	72.5°F–78.0°F

- HVAC system design
 - Constant volume
 - Provides constant system airflow
 - Temperature varies to meet heating and cooling needs
 - Percent of outdoor air may be controlled manually or automatically
 - Variable air volume (VAV) system
 - Condition supply air to a constant temperature
 - Varies airflow to occupied work spaces
 - Earlier versions did not have control over the quantity of outdoor air

Safety Tips from the WorkSafe People

The following table is adapted from ASHRAE Standard 62-1989, Ventilation for Acceptable Air Quality.

Application		Occupancy People/1000 ft ²	Cfm/ Person	Cfm/ft ²
Food and Beverage Service	Dining Rooms	70	20	
	Cafeteria	100	20	
	Kitchen (cooking)	20	15	
Offices	Office Space	7	20	
	Reception Area	60	15	
	Conference Rooms	50	20	
Retail Stores, Sales Floors, Showroom Floors	Basement & Street	30		0.30
	Upper Floors	20		0.20
	Malls and Arcades	20		0.20
Education	Classroom	50	15	
	Music Rooms	50	15	
	Auditorium	150	15	

- Proper operation of HVAC
 - Begin with good design
 - Correct installation
 - Test the system following installation
 - Balance the system
 - Plan regular inspection and maintenance
- Odor and contaminants control
 - Dilute the contaminants
 - Isolate the odors and contaminants — design and operate the HVAC system with a controlled pressure relationship between rooms
 - *Positive pressure* occurs when there is more air supplied to a room than is exhausted
 - *Negative pressure* occurs when there is more air exhausted from a room than is supplied to it
 - Local exhaust system is designed to isolate and remove contaminants

Pathway of the Pollutant

- The combination of mechanical ventilation systems, natural forces, and human activity determines the airflow patterns of the building.
- Air movement
 - Air moves from an area of relatively higher pressure to areas of relatively lower pressure through an available opening (e.g., a crack in the wall)
 - Air moves from lower to upper levels of the building
 - Air moves into the building through either reentry of exhaust air or outdoor infiltration
 - Air moves into adjacent spaces that have a lower pressure

Occupants of the Building

An occupant is defined as anyone who spends *extended* time periods in the building. The following are examples of individuals who are more susceptible to the effects of indoor air contaminants:

- Individuals who are allergic or asthmatic
- Contact lens wearers
- Individuals with an immune system suppressed because of chemotherapy, radiation therapy, or disease
- Individuals with respiratory disease
- Nonspecific symptoms commonly associated with indoor air quality:
 - Headache
 - Nausea
 - Dizziness
 - Skin irritation
 - Cough
 - Shortness of breath
 - Fatigue
 - Sneezing
 - Sinus congestion
 - Nose, eye, and throat irritation

All of the above symptoms *may be caused by factors not associated* with air quality deficiencies. Stresses from the work environment such as, but not limited to, lighting, noise, overcrowding, ergonomic issues, and vibration may cause similar symptoms.

Indoor Air Quality Investigation Format

Indoor air quality review is generally accomplished by a three-fold approach.

- Review all existing records
- Obtain detailed information on the HVAC system, building occupancy, building design, potential pollutant sources, and pathway
- Conduct a walk-through survey of the building

Record Review

- Obtain information to provide a focus for the investigation
 - Information may be gathered prior to an on-site investigation
 - Review building plans, floor plans, HVAC specifications and/or mechanical plans
 - Obtain HVAC adjusting and balancing reports, inspection records, and operating manuals
- On-site investigation
 - Interview individuals involved in the building's construction, renovation (if applicable), maintenance, and operations
 - Obtain copies of previous indoor air quality reports, if available
 - Identify the chemical use in the building:
 - Custodial cleaners, disinfectants, deodorizers, waxes
 - Pesticides and herbicides
 - HVAC chemicals
 - Photocopiers, printers, and blueprint copiers
 - Special-operation chemicals, such as graphic arts
 - Obtain MSDSs
- Establishing a cause and effect relationship
 - Gather information concerning the occupants' specific health and/or comfort complaints
 - With the help of the building's occupants, identify time patterns (season, day, and hour) at the onset of the specific health and/or comfort complaints
 - Note locations of the specific health and/or comfort complaints
 - Hypothesize the potential source material
 - Review HVAC design, operation, and maintenance schedule
 - Check fuel sources for combustion, location for air intake and exhaust
 - Smoking policy
 - With the help of the occupants, obtain the history associated with water leaks, flooding, or high humidity

Detailed HVAC Information

- Inspect the HVAC system conditions and operation
- Use a small floor plan to indicate chases, mechanical connections
- Look for any pollutant sources

Walk-through

Initial walk-through survey

The initial walk-through inspection is designed to provide an overview of the activities taking place in the building and the personnel involved, the functions of the building, and the surrounding community.

- The building's immediate outside environment — what is the neighborhood like?
- Pest control
 - Schedule of activities
 - Type of controls used
 - Storage of chemical controls
- Housekeeping
 - Cleaning schedule
 - Trash storage and removal
- Potential problem areas
 - Unsanitary conditions
 - Visible fungal growth or moldy odors
- A non-problem area
- HVAC major system components
 - Position and control of outside dampers
 - Thermostat control
 - Unsanitary mechanical rooms
- Occupants' discomfort
 - Attempts to compensate HVAC system
 - Sensations of stuffiness or drafts
 - Overcrowding of the work area
 - Blocked airflow

In-depth walk-through survey

- Preliminary semi-quantitative measurements should be taken in the problem areas
 - Temperature
 - Relative humidity
 - Carbon monoxide
 - Carbon dioxide
 - Airflow

Safety Tips from the WorkSafe People

Indoor Air Pollution Diagnosis

Many of the signs and symptoms individuals may experience associated with indoor air pollution are nonspecific and are very similar allergies, influenza, and the common cold. This makes diagnosis *very* difficult for the health care professional. It becomes even more complicated if many pollutants are involved. Stress, work pressures, and seasonal discomforts may also be contributing factors to the individual's signs and symptoms.

The dose, the amount of material the individual may be exposed to, and the exposure duration will impact the signs and symptoms an individual may experience. The information provided in this section is associated with significant exposures. Lower exposures may result in milder and vaguer signs and symptoms.

Diagnostic Quick-Reference Table

The following table is adapted from *Indoor Air Pollution, An Introduction for Health Professionals*, sponsored by the EPA, the American Lung Association, the Consumer Product Safety Commission, and the American Medical Association.

Signs and Symptoms	Environmental Tobacco Smoke	Other Combustion Products	Biological Pollutants	Volatile Organics	Heavy Metals	Sick Building Syndrome
Respiratory						
Rhinitis, nasal congestion	Yes	Yes	Yes	Yes	No	Yes
Epistaxis (nose bleed)	No	No	No	Yes ¹	No	No
Pharyngitis cough	Yes	Yes	Yes	Yes	No	Yes
Wheezing, worsening asthma	Yes	Yes	No	Yes	No	Yes
Dyspnea	Yes ²	No	Yes	No	No	Yes
Severe lung disease	No	No	No	No	No	Yes ³
Other						
Conjunctival irritation	Yes	Yes	Yes	Yes	No	Yes
Headache or dizziness	Yes	Yes	Yes	Yes	Yes	Yes

Safety Tips from the WorkSafe People

Lethargy, fatigue, malaise	No	Yes ⁴	Yes ⁵	Yes	Yes	Yes
Nausea, vomiting, anorexia	No	Yes ⁴	Yes	Yes	Yes	No
Cognitive impairment, personality changes	No	Yes ⁴	No	Yes	Yes	Yes
Rashes	No	No	Yes	Yes	Yes	No
Fever chills	No	No	Yes ⁶	No	Yes	No
Tachycardia	No	Yes ⁴	No	No	Yes	No
Retinal hemorrhage	No	Yes ⁴	No	No	No	No
Myalgia	No	No	No	Yes ⁵	No	Yes
Hearing loss	No	No	No	Yes	No	No

¹Associated especially with formaldehyde.

²In asthma.

³Hypersensitivity pneumonitis, Legionnaires' Disease.

⁴Particularly associated with high CO levels.

⁵Hypersensitivity pneumonitis, humidifier fever.

⁶With marked hypersensitivity reactions and Legionnaires' Disease.

Corrective Actions

Environmental Tobacco Smoke

- Improve general ventilation of indoor spaces — this will eliminate the odor
- Eliminate or restrict all tobacco smoking
- Use higher efficiency cleaning systems (*not* the desktop model)

Stoves, Space Heaters, Furnaces, Fireplaces

- Perform periodic professional inspections and maintenance on equipment
- Vent equipment directly to the outside
 - Kitchen exhaust fans
- Never burn charcoal inside
- Install an Underwriters Laboratory (UL) carbon monoxide detector
 - Carbon monoxide is an odorless, colorless, asphyxiant gas
 - The compound combines with the hemoglobin to form carboxyhemoglobin (COHb)

Animal Dander, Molds, Dust Mites, Other Biologicals

- Provide adequate outdoor air
- Maintain the relative humidity in the workplace between 30 to 50 percent
- Any equipment water reservoirs must be kept clean
- Chlorinate potable water systems according the manufacturer's instructions
- Do not permit water to stand in air conditioners
- Repair leaks and seepage
- Vacuum carpet and upholstered furniture regularly

Volatile Organic Compounds: Formaldehyde, Pesticides, Solvents, Cleaning Agents

- Increase ventilation near the sources emitting volatile organic compounds
- Do not store opened containers of unused paints inside
- If possible, remove the following products from the work environment to reduce the exposure to formaldehyde:
 - Polyurethane or other sealant on cabinets, paneling, or other furnishings
 - Some permanent-press fabrics contain formaldehyde
 - Urea-formaldehyde foam insulation
 - Formaldehyde-based resins are components of plywood, paneling, fiberboard, and particleboard

Heavy Metals: Airborne Lead and Mercury Vapor

- Control lead dust by wet-mopping and wiping furniture frequently
- Hire professionals to remove or encapsulate paint containing lead
- Do not burn painted or treated wood

Sick Building Syndrome

Conduct an investigation of the building; involve the employer, the employees, the building owner, and the mechanical contractor. Use environmental agencies, occupational health professionals and public health officials if the conditions warrant it.

- There is no definitive answer for sick building syndrome, but the following patterns exist:
 - Not all building occupants have complaints
 - Symptoms are nonspecific or subjective
 - Forced ventilation and/or central air conditioning is present
 - Sometimes room humidifiers are involved
 - Work areas are under-ventilated
 - Buildings have carpets

Safety Tips from the WorkSafe People

- Air is perceived to be dry
- Occupants who are complaining perceive they have little control over their environment
- People with allergies and asthma are more likely to experience sick building syndrome
- No single air contaminant is the cause of sick building syndrome
- The occupant's symptoms disappear after leaving the building

Black mold, or in other words, *Stachybotrys chartarum*

Black mold appears slimy when wet and may be white around the edges. The Centers for Disease Control (CDC) studies have indicated that molds are very common in buildings and homes. The most common indoor molds are *Cladosporium*, *Penicillium*, *Aspergillus*, and *Alternaria*. The CDC does not have the database to determine how often *Stachybotrys chartarum* is found in public buildings and homes. It appears to be less common, but it is *not* rare. For any form of mold to grow, the following three conditions must be available:

1) A food source

- Building material
 - Ceiling tiles
 - Wood
 - Wood products
 - Insulation material
 - Drywall
 - Carpet
- Wet cellulose material
 - Paper
 - Paper products
 - Cardboard
- Other material
 - Dust
 - Paints
 - Wallpaper
 - Fabric
 - Upholstery

2) A place to grow

3) A source of constant moisture

- Indoor moisture sources include:
 - Flooding
 - Backup sewers
 - Leaky roofs
 - Humidifiers
 - Mud or ice dams
 - Clothes dryers vented indoors

Safety Tips from the WorkSafe People

- Damp basement or crawl space
- Stoves not exhausted to the outside
- Constant plumbing leaks
- Shower/bath steam and leaks
- Wet clothes on indoor drying lines
- House plants — watering can generate large amounts of moisture
- Steam from cooking

Molds grow naturally in the indoor environment. They may enter through open doorways and windows, or heating, ventilation, and air conditioning vents or ducts. Spores may cling to people, animals, clothing, shoes, and bags.

Mold Cleanup General Procedures

- Prior to cleaning up any mold infestation, identify and remove the moisture source
- Clean, disinfect, and dry the moldy area
 - If a mass is greater than 2-foot square, or if the mold is in the carpet, insulation, or drywall, *remove* these materials or contact a mold-abatement expert
 - Small infestation:
 - Wear protective equipment — *at least* gloves; respirators, eye protection, and protective clothing which may be easily discarded are suggested
 - Use *non-ammonia* soap or detergent, or a commercial cleaner and hot water, and **scrub the affected area**
 - Use a stiff brush or cleaning pad on uneven surfaces
 - Rinse with water
- Disinfect surfaces
 - Wear protective equipment — *at least* gloves; respirators, eye protection, and protective clothing which may be easily discarded are suggested
 - Use a disinfectant solution of 10% household bleach
 - 1½ cups of bleach per gallon of water — *never* use bleach straight out of the bottle
 - **Never mix bleach with ammonia**
 - Large exteriors may be sprayed
 - Permit disinfected areas to dry overnight naturally — this time aids in killing the mold
- Dispose in bags any material that has moldy residues
 - Bag and remove porous material
 - Ceiling tiles
 - Drywall
 - Carpeting
 - Wood products

Safety Tips from the WorkSafe People

- Prevent mold growth
 - Keep relative humidity level below 50%
 - Use air conditioner during humid months
 - Remove and replace flooded carpets
 - Good ventilation

Health Effects

Exposures to mold *do not always* create a health problem. Individuals who are sensitive to molds, however, may experience some of the following symptoms:

- Nasal stuffiness
- Eye irritation
- Wheezing

Molds, including *Stachybotrys chartarum*, may cause health symptoms that are nonspecific. The CDC has researched the possible association between acute idiopathic pulmonary hemorrhage among infants and *Stachybotrys chartarum*.