Indoor Air Quality Measurements

Facility Managers and Residents can find it challenging to determine if their buildings have exceptional, fair, or even poor indoor air quality (IAQ). Measuring and testing indoor air quality is an imperfect science with many variables, and the path to establishing whether or not a building has healthy indoor air is rarely clear cut. The most important tools for evaluating indoor air quality are your nose, eyes, and ears; however, there are additional measurements that can help assess indoor air quality in buildings.

While investigating any indoor air quality situation, be aware of the entire picture. Many parameters that may be contributing to an overall problem must be considered and checked. Also keep in mind that it is not uncommon to find multi-layered problems; finding and solving one issue may not get to the root cause. Think of an investigation as peeling an onion; as each layer is removed, another is exposed. Be sure to understand the exact time and place that problems are suspected, since many indoor air quality problems are transitory. Use common sense along with the proper tools and keep investigating and correcting problems until complaints stop.

Measurement Guidelines

The measurement guidelines outlined in the links below will provide a basic introduction to various measurements that may help assess indoor air quality. In addition to these guidelines, you may need to refer to the operator's manual for details on operation of the instrument. We do not recommend specific instruments. You should select an instrument based on your goals and approach. For example, I look for instruments that are low cost and measure one parameter. I am generally working with large groups of students and want to get everyone involved in making the measurements.

- Carbon Dioxide
- Carbon Monoxide
- Radon
- Thermal Comfort (Temperature / Relative Humidity)
- Surface Temperature
- Ventilation (Air Flow)
- Particles
- Volatile Organic Compounds
- Ozone
- Moisture Control / Mold

Carbon Dioxide (CO_2)

Carbon dioxide is a colorless, odorless, tasteless gas. Carbon dioxide is an atmospheric gas comprised of one carbon and two oxygen atoms. A very widely known chemical compound, it is frequently known by its formula CO_2. In its solid state, it is commonly called dry ice.

Where does carbon dioxide come from?

Atmospheric carbon dioxide derives from multiple natural sources including volcanic out-gassing, the combustion of organic matter, and the respiration processes of living aerobic organisms. Carbon dioxide is also produced by various microorganisms from fermentation and cellular respiration. Man-made sources of carbon dioxide come mainly from the burning of various fossil fuels for power generation and transport use. In classrooms, exhaled air is usually the largest source of carbon dioxide levels above outdoor carbon dioxide

Why measure carbon dioxide?

Carbon dioxide is a surrogate for other pollutants that are difficult to measure. High carbon dioxide concentrations (ppm) indicate that other pollutants are probably also high. Carbon dioxide levels can also used to estimate the delivery of outdoor air (also called a ventilation rate).

How do I measure carbon dioxide?

There are a variety of meters for measuring carbon dioxide. You can Google “carbon dioxide meters” for a selection of meters. Pick a meter based on your needs and budget. You might want to consider also selecting a data logger or a carbon dioxide meter with data logging capacity. With data logging, you can collect data over time.

Carbon dioxide measurements for ventilation should be collected away from any source that could directly influence the reading (e.g., hold the sampling device away from exhaled breath). As with many other measurements of indoor air conditions, it is advisable to take one or more readings in “control” locations to serve as baselines for comparison. Readings from outdoors and from areas in which there are no apparent IAQ problems are frequently used as controls. In general, the room must be occupied to get a meaningful measurement using a carbon dioxide meter. Measurements taken in unoccupied areas will not give useful information about the ventilation.

You may also need to purchase a calibration kit for the meter.

What are normal levels that I might find?

As of March 2006, outside CO2 levels are at 381 parts per million (ppm). Concentrations of carbon dioxide above 1,100 ppm indicate crowded spaces and / or low ventilation rates. Even at elevated levels, carbon dioxide is usually not a hazardous pollutant. See the chart on the following page.

What standards are there for carbon dioxide?

The EPA has not established standards for carbon dioxide in indoor air.

Carbon dioxide is an asphyxiate. At concentrations above 1.5 percent (15,000 ppm) some loss of mental acuity has been noted.

Occupational Safety and Health Administration (OSHA) established a Permissible Exposure Limits of 5,000 ppm time weighed average.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62-2001 recommends 700 ppm above the outdoor concentration as the upper limit for occupied classrooms (usually around 1,100 ppm). This recommendation is to prevent body odor levels from being offensive. If there are additional pollutant sources besides humans, higher ventilation rates may be needed.

Carbon Dioxide Concentrations

Concentration (ppm)	**Approximate Ventilation Rate (cfm/person)**	**Air Quality**
380		Outdoor
800	20	
1,000	15	
1,100		Good
1,400	10	Poor
2,400	5	Unacceptable

Carbon Monoxide (CO)

Carbon monoxide is a colorless, odorless, tasteless gas. Carbon monoxide is a poisonous gas comprised of one carbon and one oxygen atom. Carbon monoxide is frequently known by its formula CO.

Where does it come from?

Carbon monoxide is produced by incomplete burning of fuels; natural gas used in appliances, furnaces, water heater, boilers, and vehicles. Any combustion process (burning) can result in the production of carbon monoxide. Typical sources of carbon monoxide in buildings are improperly vented furnaces and hot water heaters or exhaust fumes (from vehicles or furnaces) that have been drawn back into the building. Additional sources of carbon monoxide could include un-vented kerosene and gas space heaters; leaking chimneys and furnaces; back-drafting from furnaces, gas water heaters, wood stoves, and fireplaces; gas stoves; generators and other gasoline powered equipment; automobile exhaust from attached garages; and tobacco smoke. Incomplete oxidation during combustion in gas ranges and un-vented gas or kerosene heaters may cause high concentrations of CO in indoor air. Worn or poorly adjusted and maintained combustion devices (e.g., boilers, furnaces) can be significant sources, or if the flue is improperly sized, blocked, disconnected, or is leaking. Auto, truck, or bus exhaust from attached garages, nearby roads, or parking areas can also be a source.

Why measure carbon monoxide?

Carbon monoxide is a poisonous gas that will cause illness and even death in high concentrations. Carbon monoxide poisoning can cause flu- like symptoms and also dizziness, fatigue, headaches, nausea, and irregular breathing. Higher doses or prolonged exposure of carbon monoxide can cause death without warning.

How do I measure carbon monoxide?

There are a variety of meters for measuring carbon monoxide. You can Google “carbon monoxide meters” for a selection of meters. Pick a meter based on your needs and budget. You should also consider collecting long term data using a data logger device and recording carbon monoxide over extended periods (1 week). A single reading can give a false sense of security. Various events can create problems such as back-drafting, which may not be detected with a single sampling event.

We would also recommend carbon monoxide alarms in every home. The US Consumer Product Safety Commission recommends carbon monoxide alarms that meet the requirements of ANSI/UL 2034-02.

What are normal levels that I might find?

Average levels in homes without gas stoves vary from 0.5 to 5 parts per million (ppm). Levels near properly adjusted gas stoves are often 5 to 15 ppm and those near poorly adjusted gas stoves may be 30 ppm or higher.

What standards are there for carbon monoxide?

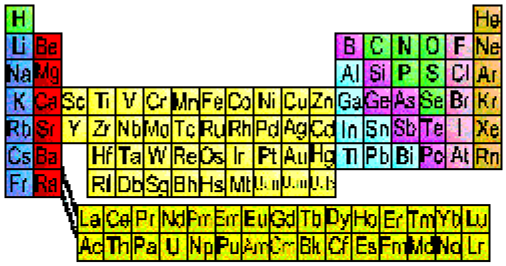
No standards for CO have been agreed upon for indoor air. The U.S. National Ambient Air Quality Standards for outdoor air are 9 ppm for 8 hours, and 35 ppm for 1 hour.

The Occupational Safety and Health Administration (OSHA) established a Permissible Exposure Limits of 50 parts per million (ppm). OSHA standards prohibit worker exposure to more than 50 parts of the gas per million parts of air averaged during an 8-hour time period.

Symptoms of mild poisoning include headaches and dizziness at concentrations less than 100 ppm. As a result, prolonged exposures of this level can be life-threatening.

Radon

Radon is a radioactive gas that is colorless, odorless and tasteless. Radon tends to accumulate in enclosed indoor spaces. The chemical symbol for Radon is Rn. On the following periodic chart, radon is found on the bottom left hand side of the chart.



Where does Radon come from?

Radon is a naturally occurring gas produced by the radioactive decay of uranium in soil and water. Radon will enter a building from area in contact with the earth and rock beneath the building. Radon can also enter through tap water coming from a well. Any building materials made from earth materials (cinder blocks, bricks) can also be a source of radon.

Why measure radon?

Radon is the second learning cause of lung cancer in the United States. The National Academy of Sciences BEIR VI Report has estimated that radon causes about 15,000 to 22,000 lung cancer deaths annually. Major scientific organizations continue to believe that approximately 12% of lung cancers annually in the United States are attributable to radon.

How do I measure radon?

There are several different technologies for measuring radon, depending on your purpose and budget. The Safety Siren Pro 3 Radon Detectors (Google “safety radon detectors”) are an electronic device can be used to get a measurement in 48 hours. This device is great for a quick check and for educational use. The manufacturer uses the term “EPA evaluated” on their webpage; the use of this term is misleading since EPA has not conducted a formal assessment of the device.

The EPA website gives an overview of various technologies that can be used for radon measurements. (http://www.epa.gov/radon/methods.html)

The detector should be placed in the lowest occupied area of the building in a location where it will not be disturbed. You could also place a detector in a basement area rarely used, however the results should be interpreted with care. Measurements taken in occupied areas are more valuable for making decisions on mitigation steps that might be required. Typical radon measurements may vary with the seasons. You may need to measure the radon in different seasons to make a good assessment of the average radon levels of a building.

You can also purchase simple “home” kits via the Internet, (Google “radon home test kit”), but if you are making important decisions based on the results of the test, you may want to work with a qualified radon service professional.

What are some normal levels of radon?

Based on a national residential radon survey completed in 1991, the average indoor radon level is about 1.3 picocuries per liter (pCi/L) in the United States. The average outdoor level is about 0.4 pCi/L.

What standards are there for radon?

There is not a standard for radon, but EPA suggests an action level if the radon level is greater than 4 pCi/L. If you have radon readings greater than 4 pCi/L, you should investigate mitigation for the building, which can involve measures such as increasing ventilation rates.

Thermal Comfort (Relative Humidity (RH) and Air Temperature)

Thermal comfort is determined by the room's temperature, humidity and air speed. There are many additional factors such as activity level, clothing, age, gender and health status that affect your comfort. Radiant heat (hot surfaces) or radiant heat loss (cold surfaces) are also important factors for thermal comfort.

Relative humidity (RH) is a measure of the moisture in the air, compared to the potential saturation level. Warmer air can hold more moisture. When you approach 100% humidity, the air moisture condenses – this is called the dew point.

Air temperature is a measure of the heat. Most thermometers are measuring ambient air heat. However, radiant heat loss or gain is also important. Radiant heat may not be reflected in the air temperature, but is the impact of cold or hot objects in the area. Radiant heat can be measured with a surface thermometer, which will be discussed separately.

(See also ventilation or air movement and surface temperature.)

Where does relative humidity and temperature come from?

The temperature in a building is based on the outside temperature and sun loading plus whatever heating or cooling is added by the HVAC or other heating and cooling sources. Room occupants also add heat to the room since the normal body temperature is much higher than the room temperature.

The relative humidity is based on the outside humidity plus whatever heating or cooling is added by the HVAC or other heating or cooling sources. Room occupants also add considerable moisture to the room through exhaled air which is at 100% relative humidity.

Since relative humidity depends on temperature. Relative humidity of cold air from the outside decreases as it is warmed up. Refrigerated air conditioning often removes moisture from the air as it is cooled. Evaporative air conditioning adds moisture to the air.

Why measure relative humidity (RH) and temperature?

Thermal discomfort is a common complaint of building occupants. There are individual differences in preferences for thermal comfort, so it may not be possible to achieve an acceptable comfort level for all occupants. At higher temperatures increased evaporation rates of chemicals and water in the room will increase chemical gases and water vapor in the air.

At higher relative humidity (RH) levels (more than 60%) can encourage the growth of mold and mildew. Dust mites, bacteria, and fungi all thrive under moist, humid conditions. At lower relative humidity (RH) (less than 30%), occupants might experience eye irritation or a stuffy nose. For some individuals low relative humidity (RH) may aggravate allergies. Low relative humidity can also lead to increased survival of some viruses, thereby increasing the spread of viral infections.

How do I measure relative humidity and temperature?

There are a variety of meters for measuring relative humidity and temperature. (Google "temperature and relative humidity measurements") Meters can also usually be found in a department store or a hardware store.

You may want to consider recommending a "Wall Plate Thermometer Model 22101" for bathrooms and kitchens. This Wall Plate Thermometer gives the resident a constant RH reading.

The temperature and relative humidity can vary considerably around the room. If you make one measurements at one location in a room, be aware that this measurement is just a "sample" for the room. Occupants sitting near a heat source may be experiencing considerably different conditions. The temperature and relative humidity can vary considerably throughout the day, so you might consider taking measurements over a 24 hour or even a one-week period.

What are some normal levels of relative humidity (RH) and temperature for indoor air?

The normal levels of relative humidity and temperature for indoor air will vary widely from region (climate) to region (climate). Individuals can also vary widely as to what they find acceptable.

What standards are there for relative humidity (RH) and temperature?

There are no EPA standards.

The American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc (ASHRAE) provides guidelines that are intended to satisfy the majority of building occupants wearing a normal amount of clothing while working at a desk. The ASHRAE guidelines recommend 68 F to 74 F in the winter and 72 F to 80 F in the summer. The ASHRAE guidelines recommend a relative humidity (RH) of 30 to 60 percent.

Surface Temperature

Surface temperature or radiant heat is the infrared energy emitted by surfaces warmer than the surroundings. Many human physiology studies in the past have determined that human comfort results from three fundamental factors:

- Up to 50% radiant heat exchange
- 40% convection/air movement/air temperature
- 10%-20% humidity/perspiration

In order to provide a total comfort system in your ideal home or office, you need some kind of radiant heating and cooling system, an air moving ventilation system and some form of room humidity control system.

(See Thermal Comfort – Relative Humidity and Air Temperature.)

Where does radiant heat (or cooling) come from?

- Surfaces and objects (computers / printers / walls / ceilings / floors / windows)
- Air ventilation systems (inlet and outlet ducts)

Why measure surfaces and objects?

A room occupant's comfort is dependent on temperature, humidity and air movement. (See the "Thermal Comfort (Relative Humidity (RH) and Temperature" section for more information.) An occupant's comfort is also influenced by radiant heat coming from surfaces and objects, which might not be included in the ambient air temperature measurement.

Cold spots on surfaces can also become an area for condensation of moisture. (Think of a cold drink on a hot humid day.) If enough moisture collects in an area, mold may grow.

Looking for hot spots or cold spots on a wall or ceiling may be an indicator of heat source or cooling source that warrant additional investigation. A hot or cold ceiling may indicate the lack of insulation. The addition of insulation may improve the comfort level and decrease the cost of heating and cooling a space.

How do I make infrared measurements?

The infrared thermometer uses a lens to focus the infrared (IR) energy on a detector in the instrument. The detector compensates for ambient temperature variation and displays the surface temperature of the object or surface. The user can quickly obtain the temperature of a surface without coming in contact with the surface. A device that will measure surface temperatures is called an infrared thermometer. (Google "infrared thermometers")

Factors that impact on your measurement are 1) Distance to Spot Ratio, and 2) Emissivity. More expensive infrared thermometers can compensate for differences in emissivity.

Distance to Spot Ratio: You want to be aware of the Distance : Spot ratio of the instrument. The temperature reading you get on the instrument is an average temperature of the detected region. The detected region is dependant on the distance of the instrument from the surface you want to measure.

Emissivity: The instrument is designed to read surface temperatures from most organic or painted surfaces. If the surface is metal or shiny, you will get inaccurate readings. If you need to get a reading from a metal or shiny surface, you can tape a thin black paper to the surface and take a reading from that surface after a couple of hours.

You will want to consider seasonal changes and make measurements during different seasons of the year.

What are normal levels that I might find?

Outside walls and ceilings on top floors will generally be impacted by the temperature outside, depending on insulation in the walls and circulation of air in the room. Objects in the room like computers will give off heat.

What are standards or guidelines for infrared thermometer measurements?

There are no standards or guidelines for infrared thermometer measurements.

With the infrared thermometer you are looking for areas or surfaces with temperatures different from the air temperature (higher or lower). These temperature differences may lead to further investigations that could identify some issues to work on. The differences could also identify some potential problem spots in the future.

Ventilation and Air Flow

Ventilation air, as defined in American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62.1, is that air used for providing acceptable indoor air quality. When people or animals are present in buildings, ventilation air is necessary to dilute odors and limit the concentration of carbon dioxide and airborne pollutants such as dust, smoke, and volatile organic compounds (VOCs). Ventilation air is often delivered to spaces by mechanical systems which may also heat, cool, humidify and dehumidify the space. Air movement into buildings can occur due to uncontrolled infiltration of outside air through the building fabric or the use of deliberate natural ventilation strategies. Advanced air filtration and treatment processes such as scrubbing, can provide ventilation air by cleaning and / or recirculating a proportion of the air inside a building.

Ventilation is one of the most important engineering controls available to the building manager for improving or maintaining the quality of the air in the occupational work environment. Broadly defined, ventilation is a method of controlling the environment with air flow.

The sense of thermal comfort (or discomfort) results from an interaction between air temperature, relative humidity, and air movement.

Air flow is also important for ensuring air moves from clean to dirty and out. In general, the air flow patterns should move from 'clean' spaces into 'more dirty' areas. A good rule of thumb is to keep air flowing from clean to dirty, so that children are not breathing polluted air. This is particularly important for places such as janitorial closets where cleaning supplies are often stored, unused locker rooms with dry traps and leaking sewer gases, and boiler rooms with back drafting heating appliances.

(See Thermal Comfort – Relative Humidity and Air Temperature.)

What is ventilation?

An air flow measurement tells you how fast the air is moving. If you know the cross section area this measurement will tell you Cubic Feet Per Minute (CFM), which is a measurement of ventilation. Ventilation rates can be measured indirectly with a carbon dioxide meter, but there are limitations of using a carbon dioxide meter. One important limitation is that the room must be occupied to get a meaningful measurement using a carbon dioxide meter.

Why measure the air flow?

Air flow can be used to calculate ventilation is the mixing of outside air with inside air. The purpose of the mixing is to keep pollutants and carbon dioxide at the appropriate levels. The American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc (ASHRAE) issues guidelines to ensure the levels of carbon dioxide and other indoor air pollutants are kept at appropriate levels. These guidelines can be reviewed in the Carbon Dioxide section.

When designing air flows you want to move polluted air to the outside. You also want to keep air from places like the science classroom, kitchen, and restrooms from flowing into office space or classroom space. This can also be called “source control”.

In addition to being an important part of ventilation, air movement contributes to the perception of comfort. Room occupants will be more comfortable with some air movement.

How do I measurement air movement?

There are several ways to measure the air movement. Select the procedure and device that gives you the information you need. You can use Google to find any of the following:

<u>Smoke Puffer</u>
The Smoke Puffer cannot be used to measure a ventilation rate, but it does give an indication of the direction of air flows, which is another important consideration for proper ventilation. Chemical smoke can be helpful in evaluating HVAC systems, tracking potential contaminant movement, and identifying pressure differentials. Chemical smoke moves from areas of higher pressure to areas of lower pressure if there is an opening between them (e.g., door, utility penetration). Because it is heatless, chemical smoke is extremely sensitive to air currents. Investigators can learn about airflow patterns by observing the direction and speed of smoke movement. Puffs of smoke released at the shell of the building (by doors, windows, or gaps) will indicate whether the HVAC systems are maintaining interior spaces under positive pressure relative to the outdoors.

Safety

The Smoke Puffer uses a reactive chemical to produce smoke. The chemical is an acid and must be used with caution. Avoid inhaling smoke from the Smoke Puffer. Use the Smoke Puffer only under adult supervision.

<u>Wizard Stick</u>
Similar to the Smoke Puffer, except that the Wizard Stick does not use toxic chemicals.

Anemometer or air flow meter (Velocity Measurements)
Airflow in large ductwork can be estimated by measuring air velocity using an anemometer. Measure the air velocity in the ductwork and calculate the outdoor airflow in cubic feet per minute (CFM) at the outdoor air intake of the air handling unit or other convenient location. Additional measurements and calculations are required to get air flow.

Flow Hood
Flow-hoods measure airflow in cubic feet per minute (CFM) at a diffuser or grill. Taking the measurement is simply a matter of holding the hood up to the diffuser and reading the airflow value.

Carbon Dioxide Measurements

See the carbon dioxide section for more details. Carbon dioxide measurements for ventilation should be collected away from any source that could directly influence the reading (e.g., hold the sampling device away from exhaled breath). As with many other measurements of indoor air conditions, it is advisable to take one or more readings in "control" locations to serve as baselines for comparison. Readings from outdoors and from areas in which there are no apparent IAQ problems are frequently used as controls. In general, the room must be occupied to get a meaningful measurement using a carbon dioxide meter. Measurements taken in unoccupied areas will not give useful information about the ventilation.

What are normal levels that I might find?

Carbon Dioxide Concentrations

Concentration (ppm)	**Approximate Ventilation Rate (cfm/person)**	**Air Quality**
380		Outdoor
800	20	
1,000	15	
1,100		Good
1,400	10	Poor
2,400	5	Unacceptable

What standards are there for air flow?

There are no EPA standards for air movement, but there are Occupational Safety and Health Administration (OSHA) and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) guidelines.

Ventilation is addressed in specific OSHA standards for the general industry, shipyard employment, long-shoring, and the construction industry. There are two basic categories of ventilation in the OSHA standards: general exhaust ventilation (dilution ventilation) and local exhaust ventilating. OSHA is focused on providing guidelines for industry, but these basic categories also apply in residential or school building settings. For example, local exhaust ventilating might be used in the bathroom or kitchen.

ASHRAE Standards specify that outside air for ventilation purposes should be introduced at the lowest volume necessary to maintain adequate indoor air quality. ASHRAE Standard 62-l989, Ventilation for Acceptable Indoor Air Quality, specifies the outdoor air ventilation requirements at a minimum of 15 cfm per person in non-smoking areas, regardless of occupant usage, and a minimum of 60 cfm per person for smoking areas. Also the concentration of CO2 should not exceed 1,000 parts per million in conditioned spaces.

Notes about ventilation.
Be aware that exhaust fans can make lots of noise without moving any air.

Houses with appliances vented to the outside need to be tested for back-draft if the sum of the cfm ratings of the two largest exhaust fans is greater than 15 cfm per 100 square feet of habitable space.

Particles

Particle pollution is a mixture of microscopic solids and liquid droplets suspended in air. This pollution, also known as particulate matter (PM), is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, soil or dust particles, and allergens (such as fragments of pollen or mold spores).

The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometers in diameter (PM10) pose the greatest problems, because they can get deep into your lungs, and some may even get into your bloodstream. Exposure to such particles can affect both your lungs and your heart. Larger particles are of less concern, although they can irritate your eyes, nose, and throat.

Small particles of concern include "fine particles" (such as those found in smoke and haze), which are 2.5 micrometers in diameter (PM2.5) or less; and "coarse particles" (such as those found in wind-blown dust), which have diameters between 2.5 and 10 micrometers.

Where do particles come from?

There are both natural and human sources of atmospheric particulates. The biggest natural sources are dust, volcanoes, and forest fires. The biggest human sources of particles are combustion sources, mainly the burning of fuels in internal combustion engines in automobiles and power plants, and wind blown dust from construction sites and other land areas where the water or vegetation has been removed. Some of these particles are emitted directly to the atmosphere and some are emitted as gases and form particles in the atmosphere .

Dust in homes, offices, and other human environments is mainly generated by humans from their skin cells that slough off: An average skin flake has an equivalent diameter of 14µm. It is estimated that the entire outer layer of skin is shed every day or two at a rate of 7 million skin flakes per minute. Tests of indoor environmental dust in homes and offices have shown it to be primarily (70-90%) composed of skin flakes. Some comes from domesticated pets such as dogs, cats and birds. Some atmospheric dust from the outdoors is also present.

House dust mites are on all surfaces and even suspended in air. Dust mites feed on minute particles of skin flakes, the main constituent of house dust. They excrete enzymes to digest dust particles; these enzymes and their feces, in turn, become part of house dust and can provoke allergic reactions in humans. Dust mites flourish in the fibers of bedding, furniture, and carpets. The particles that make up house dust can easily become airborne, so care must be exercised when removing dust, as the activity intended to sanitize or remove dust may make it airborne.

Additional particles come from a variety of indoor activities, such as a wood stove.

Why measure particles?

People with heart or lung disease, older adults, and children are considered at greater risk from particles than other people, especially when they are physically active. Exercise and physical activity cause people to breathe faster and more deeply and to take more particles into their lungs.

People with heart or lung diseases such as coronary artery disease, congestive heart failure, and asthma or chronic obstructive pulmonary disease (COPD) are at increased risk, because particles can aggravate these diseases. People with diabetes also may be at increased risk, possibly because they are more likely to have underlying cardiovascular disease. Older adults are at increased risk, possibly because they may have undiagnosed heart or lung disease or diabetes. Many studies show that when particle levels are high, older adults are more likely to be hospitalized, and some may die of aggravated heart or lung disease.

Children are likely at increased risk for several reasons. Their lungs are still developing; they spend more time at high activity levels; and they are more likely to have asthma or acute respiratory diseases, which can be aggravated when particle levels are high.

Many different kinds of particles can also be asthma triggers.

Measuring particles in various indoor locations can help identify sources of particles for clean-up and remediation efforts. Particle measurements are also taken to identify the impact of activities such as operating wood burning stoves.

How do I measure particles?

Two basic methods typically are used to measure particles: air sampling over time and measurements employing real-time instruments. The type to use depends on the purpose for doing the measurements. For IAQ Building Assessments, the real-time instruments provide the information needed to conduct a timely investigation.

Start the measuring process outdoors to establish a baseline. In rural areas with low particle counts this outside measurement could become the goal for indoor measurements. If the building's intake air is filtered, you can subtract from the base-line measurement a percentage of particulates roughly equal to the efficiency rating of the filter to establish an indoor goal. For example, a 75% efficient filter effectively removes about three-quarters of all particles leaving 25% of the outside reading as the goal.

Inside, measurements are taken and compared to the baseline established. Seek levels of ultrafine particles greater than the goal to find sources of particles that might contribute to air quality problems. Often particle sources are activity related. For example a couch with no disruption may not give off particles; however, a couch with a person sitting on it may become a significant source of particles.

If levels of particles significantly higher than the baseline are found anywhere in the building, take steps to locate and identify the source. Using the particle counter much like a Geiger counter, particles can be traced directly to their source. Once a source is located, remedial action to control, repair or remove the source can be done.

For a selection of real-time particle counters you can Google “particle counters” for a selection of meters. Pick a meter based on your needs and budget. For a selection of filter based particle measurement devices, Google “mini vol”.

What are normal levels that I might find?

Normal levels of particles are not well defined in the literature. In general, the goal is to keep particle levels low enough so they are not causing health issues.

What standards are there for particulate matter?

The EPA has not established standards for particles in inside air.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard ASHRAE 62 recommends a maximum exposure limit for PM10 particles of 0.15 mg/m3 for a 24-hour average and 0.05 mg/m3 for an annual average exposure. This is consistent with the EPA's National Ambient Air Quality Standards.

The National Ambient Air Quality Standards (NAQS) for particulate matter for outside air measurement is

Particulate Matter (PM10) 150 µg/m3 24-hour
Particulate Matter (PM2.5) 35 µg/m3 24-hour

Volatile Organic Compounds

Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. This is a very broad set of chemicals. VOCs include a variety of chemicals, some of which may have short and long-term adverse health effects. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors. VOCs are emitted by a wide array of products numbering in the thousands.

Where do Volatile Organic Compounds come from?

Volatile Organic Compounds (VOCs) come from paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids and carbonless copy paper, graphics and craft materials including glues and adhesives, permanent markers, and photographic solutions. Organic chemicals are widely used as ingredients in household products. Paints, varnishes, and wax all contain organic solvents, as do many cleaning, disinfecting, cosmetic, degreasing, and hobby products. Fuels are made up of organic chemicals. All of these products can release organic compounds while you are using them or when they are stored.

Why measure Volatile Organic Compounds?

Volatile Organic Compounds (VOCs) are a health hazard resulting in eye, nose, and throat irritation, headaches, loss of coordination, nausea, damage to liver, kidney, and central nervous system. Some organics can cause cancer in animals; some are suspected or known to cause cancer in humans. Key signs or symptoms associated with exposure to VOCs include conjunctival irritation, nose and throat discomfort, headache, allergic skin reaction, dyspnea, declines in serum cholinesterase levels, nausea, emesis, epistaxis, fatigue, and dizziness.

The ability of organic chemicals to cause health effects varies greatly from those that are highly toxic, to those with no known health effect. As with other pollutants, the extent and nature of the health effect will depend on many factors including level of exposure and length of time exposed. Eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment are among the immediate symptoms that some people have experienced soon after exposure to some organics. At present, not much is known about what health effects occur from the levels of organics usually found in homes. Many organic compounds are known to cause cancer in animals; some are suspected of causing, or are known to cause, cancer in humans.

How do I measure Volatile Organic Compounds (VOCs)?

There are a variety of VOC meters or gas detector tubes available for making measurements. You should select a measurement device based on your purpose for measuring. You can Google "VOC meters" for a selection of meters. For a less expensive VOC measurement, you can Google "VOC gas detector tubes". The meter provides a continuous reading, while the tubes will provide a snapshot.

What are normal levels of Volatile Organic Compounds (VOCs) that I might find?

Studies have found that levels of several organics average 2 to 5 times higher indoors than outdoors. During and for several hours immediately after certain activities, such as paint stripping, levels may be 1,000 times background outdoor levels.

What standards or guidelines are there for Volatile Organic Compounds (VOCs)?

No standards have been set for VOCs in non industrial settings. There are thousands of VOC compounds. Some of the compounds have been recognized as a specific health risk and have specific guidelines.

When the USEPA built their own building, they used a Maximum Allowable Air Concentration Standard of <0.20 mg/m3 Total Volatile Organic Compounds (TVOCs).

Occupational Safety and Health Administration (OSHA) regulates formaldehyde, a specific VOC, as a carcinogen. OSHA has adopted a Permissible Exposure Level (PEL) of .75 ppm, and an action level of 0.5 ppm. US Department of Housing and Urban Development (HUD) has established a level of 0.4 ppm for mobile homes. Based upon current information, it is advisable to mitigate formaldehyde that is present at levels higher than 0.1 ppm.

Ozone (O_3)

Ozone or trioxygen (O3) is a triatomic molecule, consisting of three oxygen atoms. It is an allotrope of oxygen that is much less stable than the diatomic oxygen, O_2. Ground-level ozone is an air pollutant with harmful effects on the respiratory systems of animals or humans. The ozone layer in the upper atmosphere filters potentially damaging ultraviolet light from reaching the Earth's surface. It is present in low concentrations throughout the Earth's atmosphere. Ozone has many industrial and consumer applications.

Where does ozone come from?

Ozone is produced by ultraviolet light from the Sun hitting the Earth's atmosphere (especially in the ozone layer), lightning and as a byproduct of other types of pollution.

Certain electric devices (such as air ionizers) can also produce ozone. Ozone generators that are sold as air cleaners intentionally produce the gas ozone. Often the vendors of ozone generators make statements and distribute material that lead the public to believe that these devices are always safe and effective in controlling indoor air pollution. For almost a century, health professionals have refuted these claims.

Why measure ozone?

Ozone can be "good" or "bad" for people's health and for the environment, depending on its location in the atmosphere. The stratosphere, or "good" ozone layer extends upward from about 6 to 30 miles and protects life on Earth from the sun's harmful ultraviolet (UV) rays. In the troposphere, the air closest to the Earth's surface, ground-level or "bad" ozone is a pollutant that is a significant health risk, especially for children with asthma. It also damages crops, trees and other vegetation. It is a main ingredient of urban smog.

Ozone is highly volatile and is not likely to remain present in a building unless an ozone generating device is operating, therefore you may not need to test for indoor ozone during an IAQ Building Assessment. If you suspect high concentrations of outdoor ozone, you may want to test for ozone outdoors. Ozone gas from outdoors may enter the building and react with other building materials (as an oxidant) to produce secondary out-gassing products which are also irritants or potentially unsafe.

A study conducted by the U.S. Department of Energy’s Lawrence Berkley National Laboratory has discovered that as ozone levels rise outside so does the incidence of sick building syndrome. The indoor concentrations of sensory irritants such as formaldehyde, and organic acids, including pentanal, hexanal and nonanal, increased with rising outdoor ozone as well.

How do I measure ozone?

If you are going to measure ozone, there are a variety of meters for measuring ozone. You can Google "ozone meters" for a selection of meters. Pick a meter based on your needs and budget. You can Google "passive ozone measurement" for alternative measurement devices.

What are normal levels that I might find?

Ozone is highly reactive and volatile and will not last long in an indoor environment.

What standards are there for ozone?

The EPA has not established standards for ozone in indoor air, however ozone is a criteria pollutant and an outside standard has been established. The outdoor air quality standard for ozone is 0.075 ppm over an 8 hour average. (To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.075 ppm.)

Occupational Safety and Health Administration (OSHA) established a Permissible Exposure Limits over an 8-hour, time-weighted average value of 0.1 ppm.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62.1-2007 recommends ozone be limited to 0.08 ppm.

Moisture Control and Mold

Mold spores are found everywhere. Mold spores require three things to grow: moisture, source of food, and adequate temperatures. Since mold likes the same temperatures as humans, and buildings are built out of mold food; to control mold, we must control moisture. There are many different kinds of mold. Molds can produce allergens, toxins, and irritants. Molds can cause discoloration and odor problems, deteriorate building materials, and lead to health problems -- such as asthma episodes and allergic reactions -- in susceptible individuals.

Where does moisture come from?

Moisture can come from leaks in the roof or plumbing leaks or it can come up from the ground. Moisture also comes from the air when the relative humidity of the air is high. When air contains all of the water vapor it can hold, it is at 100 percent RH or greater, and the water vapor condenses, changing from a gas to a liquid. The temperature at which condensation occurs is the "dew point." Reaching 100 percent RH without changing the air temperature is possible by increasing the amount of water vapor in the air (the "absolute humidity" or "vapor pressure"). It is also possible to reach 100 percent RH without changing the amount of water vapor in the air, by lowering the air temperature to the "dew point."

The highest RH in a room is always next to the coldest surface. This is referred to as the "first condensing surface," as it will be the location where condensation happens first, if the relative humidity of the air next to the surface reaches 100 percent. Understanding this is important when trying to understand why mold is growing on one patch of wall or only along the wall-ceiling joint. The surface of the wall is likely to be cooler than the room air because of a gap in the insulation or because the wind is blowing through cracks in the exterior of the building.

Why measure mold?

Molds are a major source of indoor allergens. Molds can also trigger asthma. Even when dead or unable to grow, mold can cause health effects such as allergic reactions. The types and severity of health effects associated with exposure to mold depend, in part, on the type of mold present, and the extent of the occupants' exposure and existing sensitivities or allergies. Prompt and effective remediation of moisture problems is essential to minimize potential mold exposures and their potential health effects.

How do I measure mold and moisture?

Generally, it is not necessary to identify the species of mold, and Center for Disease Control (CDC) does not recommend routine sampling for molds. Current evidence indicates that allergies are the type of diseases most often associated with molds. Since the susceptibility of individuals can vary greatly either because of the amount or type of mold, sampling and culturing are not reliable in determining your health risk. If you are susceptible to mold and mold is seen or smelled, there is a potential health risk; therefore, no matter what type of mold is present, you should arrange for its removal. Furthermore, reliable sampling for mold can be expensive, and standards for judging what is and what is not an acceptable or tolerable quantity of mold have not been established.

A microscope can help identify spores or mold growth. This can be done with a microscope to look at a surface or by doing a tape-lift. A microscope that can view mold with a top viewing light is convenient and a 150X magnification provides adequate detail. If you get a microscope that uses a battery light, it will be portable for building assessment work. Google "microscope +"wide stand"".

A moisture meter can help identify moisture in walls that cannot be seen or felt. There are two basic types of meters – destructive and nondestructive. Google "moisture meter".

Air sampling for mold or mold spores is generally not recommended.

What standards are there for mold and moisture?

The EPA has not established standards for mold or moisture in indoor air. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recommend maintaining relative humidity (RH) from 30% to 60%.

If there is mold impacting on indoor air quality, it should be removed. For more details on mold removal, go to the EPA website.