Guidance for

INDOOR AIR QUALITY PROFESSIONALS

Health Canada Santé Canada

Canada

Health Canada is the federal department responsible for helping the people of Canada maintain and improve their health. Health Canada is committed to improving the lives of all of Canada's people and to making this country's population among the healthiest in the world as measured by longevity, lifestyle and effective use of the public health care system.

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1.0 INTRODUCTION

This guidance is a resource for air quality professionals but may also be used by others such as building operators or employers. It is intended to provide information on the health effects of specific air contaminants, and on air sampling and monitoring.

Indoor air quality professionals include industrial or occupational hygienists, environmental public health professionals, health or medical professionals, environmental consultants, heating, ventilating and air conditioning (HVAC) engineers, and any other professional that has expertise in indoor air quality along with the training and equipment to investigate more detailed air quality issues, such as ventilation system and building envelope issues.

Indoor air quality is considered an important environmental determinant of health. A healthy indoor environment is one that contributes to productivity and comfort of occupants and protects their health and well-being.

Through awareness and education, building owners, operators and occupants can help prevent many indoor air quality issues from developing. Protecting and maintaining good indoor air can often be achieved using the following three key strategies:

- Reducing or eliminating the sources of air contaminants
- Ventilating by replacing contaminated indoor air with filtered air from outside
- Filtering the indoor air

It is also important that there are protocols in place for regular building maintenance, responding promptly to and rectifying identified moisture issues, and education of occupants and building staff on best practices for maintaining good indoor air quality.

While these strategies can be used to improve or solve indoor air quality issues, there may be situations where it is necessary to enlist the services of qualified professionals or organizations that have the necessary skills, training, and equipment to further investigate and remediate issues. These situations include chemical spills, mould and moisture issues, ventilation issues and other situations resulting in air quality concerns.

2.0 INDOOR AIR QUALITY RESOURCES FOR PROFESSIONALS

Health Canada assesses health risks posed by specific indoor air contaminants and provides recommendations on how to reduce those risks and improve indoor air quality. Health Canada develops guidance to help maintain and improve indoor air quality, including resources for professionals, such as:

- Residential Indoor Air Quality Guidelines (RIAQGs)
- Indoor Air Reference Levels (IARLs)
- Guidance documents for specific indoor air contaminants
- Guidance documents for non-residential (public) indoor spaces

The RIAQGs, IARLs, and guidance documents serve as a scientific basis for the evaluation and reduction of risk from indoor air contaminants through:

- assessments of health risks from indoor air contaminants in residential environments;
- performance standards that may be applied to contaminant-emitting materials, products, and devices, so that their normal use does not lead to air concentrations of contaminants exceeding the recommended exposure limits; and
- communication products informing people of actions they can take to reduce their exposure to indoor air contaminants and to help protect their health.

Additionally, there may be occupational exposure limits for certain contaminants that are regulated provincially, territorially, or federally, which are not developed by Health Canada. These limits are more relevant to employees who may be required to work with hazardous materials and exposed to higher concentrations of contaminants (e.g., janitorial and maintenance staff).

2.1 HEALTH-BASED EXPOSURE LIMITS

Health Canada has developed recommended health-based exposure limits for a number of contaminants commonly found in indoor air. These exposure limits are calculated to prevent health effects from contaminant exposure in the general public as well as in those more susceptible to these exposures (such as children, the elderly, and those with pre-existing health conditions).

2.1.1 Residential indoor air quality guidelines

Health Canada's Residential Indoor Air Quality Guidelines for indoor air contaminants include short- and long-term exposure limits, a summary of the known health effects, sources and exposure levels in Canadian homes, and recommendations (Health Canada 2024b). While the RIAQGs were developed for use in residential environments, exposure levels can be similar to those found in other environments where people can routinely spend as much time as they do at home, suggesting that the guidelines may be useful for other environments as well.

Recommended short- and long-term exposure limits (also referred to as guideline values) for contaminants are developed, representing indoor air concentrations below which health effects are unlikely to occur:

- short-term exposure limits for health problems that can occur immediately after a brief exposure.
- long-term exposure limits for health problems that can occur from continuous or repeated exposure over several months or years.

Note: Health Canada's RIAQGs were developed specifically for residential environments. However, they do provide an understanding of the health risks posed by air contaminants found in indoor public spaces as well as health-based exposure limits to support the implementation of mitigation measures to reduce exposure.

2.1.2 *Indoor air reference levels*

Health Canada has also developed screening values, called Indoor Air Reference Levels, for some volatile organic compounds (VOCs) for which RIAQGs have not been developed (Health Canada 2024c). These were developed to assist professionals who may need to assess the risk from exposure to VOCs potentially found in indoor air.

The IARL for chronic exposure to a VOC is an estimate of a concentration limit for continuous long-term inhalation exposures (up to a lifetime) below which adverse health effects are not expected to occur. In the case of carcinogenic VOCs, the IARL is an estimate of the continuous lifetime exposure associated with a negligible cancer risk. The IARL applies to the general population including susceptible subgroups.

Indoor air reference levels are intended to supplement Health Canada's RIAQGs, which are based on comprehensive reviews of the literature, are externally peer-reviewed, and are submitted for public comment. In developing IARLs, the Health Canada review is limited to hazard assessments from internationally recognized health and environmental organizations and the key studies identified in these assessments.

2.1.3 *Occupational exposure limits*

The occupational exposure limit is the level of admissible exposure for a length of time (usually eight hours) to a chemical or physical hazard that is not likely to affect the health of an employee (Canadian Centre for Occupational Health and Safety 2024). Indoor air quality professionals should be knowledgeable in occupational health and safety legislation applicable to their worksite, its applicability to their professional practice and how protective these limits are to sensitive occupants and disproportionally impacted populations.

2.2 GUIDANCE FOR OTHER INDOOR AIR CONTAMINANTS AND FOR INDOOR PUBLIC SPACES

For some contaminants, a recommended exposure limit cannot be determined from the available scientific evidence. In cases where the available scientific evidence justify reducing exposure as much as feasible, Health Canada has developed guidance documents that focus on actions to control contaminant sources and reduce exposure.

Additionally, Health Canada has developed guidance on maintaining and improving air quality in non-residential (public) indoor spaces. Local jurisdictions, public officials, indoor air quality professionals, and anyone else who has a role to play in indoor air quality can use these documents.

Indoor air quality professionals are invited to consult Health Canada's indoor air quality resources for professionals web page for the most up-to-date information on RIAQGs, IARLs, and guidance documents (Health Canada 2024b, 2024c).

3.0 SPECIFIC CONTAMINANTS

Exposure to several contaminants commonly found in indoor air has been associated with adverse health effects. This section reviews specific contaminants found in indoor air, describes their characteristics, health effects, exposure limits, and suggests methods to reduce exposure indoors. It may be warranted to measure the level of exposure to indoor air contaminants to refine risk assessments.

The guideline values are intended for professional audiences to support evaluation of potential risk and provide justification for risk management actions. Refer to the guideline document for each specific contaminant for information on how to evaluate exposure and how to compare to the recommended guideline value.

3.1 ASBESTOS

3.1.1 Characteristics

Asbestos is comprised of a group of six different types of minerals, which have been used to increase the durability and strength of certain products or increase their fire resistance (Health Canada 2021a). Before 1990, asbestos was commonly used for insulating buildings and homes against cold weather and noise. It was also used for fireproofing steel structural elements in buildings. Industry, construction, and commercial sectors have used asbestos in products such as:

- insulation for pipes,
- cement and plaster,
- industrial furnaces and heating systems,
- building insulation,
- floor and ceiling tiles,
- house siding,
- car and truck brake pads, and
- vehicle transmission components, such as clutches.

There are no significant health risks if materials containing asbestos in a building are left undisturbed and kept away from the interior environment (e.g., sealed behind walls and floorboards), or are tightly bound in products that are in good condition (e.g., such as cement piping or vinyl floor tiles).

An asbestos management plan is a critical part of preventing exposure to any remaining asbestos-containing material in a building. The plan should include strict requirements for containment or isolation of such materials before entering spaces where they are present (Public Services and Procurement Canada [PSPC] 2019). Contractors and building occupants must be made aware of such requirements prior to accessing any spaces containing these materials, in accordance with applicable legislation.

3.1.2 Health effects

Breathing in asbestos fibres in sufficient concentration and duration can increase the risk for certain kinds of cancer and other diseases (Health Canada 2021a), such as:

- lung cancer: the combination of smoking and asbestos exposure can greatly increase this risk;
- mesothelioma: a rare cancer of the lining of the chest or abdominal cavity; and
- asbestosis: scarring of the lungs, which makes it difficult to breathe.

3.1.3 Limits

Federal, provincial, and territorial occupational health and safety agencies are responsible for setting workplace limits for exposure to hazardous substances as well as any asbestos regulations such as the requirement for asbestos management plans and specified protocols for safe removal. The *Prohibition of Asbestos and Products Containing Asbestos Regulations* under the *Canadian Environmental Protection Act, 1999* prohibit the import, sale and use of asbestos and the manufacture, import, sale and use of products containing asbestos in Canada, with a limited number of exclusions. Subsections 14.1(1) and 14.1(2) of the *Hazardous Products Act*, which Health Canada administers, prohibits the sale or importation of hazardous products that contain asbestos and that are intended for use, handling or storage in a workplace in Canada unless the applicable labelling and safety data sheet requirements of the *Hazardous Products Regulations* are met. Occupational health and safety legislation requires employers to inform and train their employees on the safe handling of hazardous products, including asbestos (Health Canada 2021a).

3.1.4 Managing the issue

To reduce the risk of exposure, it is important to verify that building materials that could be disturbed do not contain asbestos before performing any renovations, remodelling, demolitions or additions. Unless this has been previously done as part of an asbestos management plan, material will need to be tested in a laboratory to determine if it contains asbestos. In cases where the source is known, testing would not be necessary.

A qualified asbestos removal specialist should be hired to conduct a repair, or safely rid the location of any asbestos-containing materials before any work begins, in accordance with applicable regulations. These regulations are designed to protect workers and prevent the spread of the contamination during removal operations. In some situations, it may be permitted to encapsulate the asbestos or isolate it to avoid its disturbance (Health Canada 2021a).

Only a certified asbestos removal professional who is following appropriate procedures for asbestos abatement and removal should remove asbestos or suspected asbestos (Canada Labour Code 2024). In some jurisdictions (e.g., Manitoba, Ontario, Quebec, and New Brunswick), working with asbestos is closely regulated.

3.2 CARBON DIOXIDE

3.2.1 Characteristics

Carbon dioxide (CO_2) is an odourless, colourless, and non-flammable gas. Indoors, CO_2 is mainly produced through the respiration of occupants, but it can also originate from other sources, such as unvented or poorly vented fuel-burning appliances and cigarette smoke. The level of CO_2 in indoor air is a function of three main factors: outdoor CO_2 concentration, indoor sources of CO_2, and rate of removal or dilution of indoor CO_2 with outdoor air by ventilation (Health Canada 2021f).

As ventilation is the primary means of removing CO_2 from indoor environments, poorly ventilated buildings or buildings with unvented or poorly vented fuel-burning appliances may have elevated CO_2 concentrations, especially if there is high occupancy considering the size of the space and the room ventilation flow rate (Health Canada 2021f).

3.2.2 Health effects

Human studies have found associations between CO_2 exposure and symptoms affecting mucous membranes or the lower respiratory system, rhinitis, neurophysiological symptoms, lack of concentration, headaches, dizziness, heavy-headedness, tiredness, and decreased performance on tests or tasks (Health Canada 2021f).

Epidemiological studies on CO_2 concentrations and health effects showed that individuals exposed to CO_2 concentrations greater than 800 ppm were more likely to report mucous membrane or respiratory symptoms (e.g., eye irritation, sore or dry throat, stuffy, congested or runny nose, sneezing, and coughing) than those exposed to lower CO_2 levels (Health Canada 2021f).

3.2.3 Limits

Refer to Health Canada’s Residential Indoor Air Quality Guidelines for current exposure limits (Health Canada 2024b).

3.2.4 Managing the issue

These control measures will help manage the risks of exposure to CO_2 (Health Canada 2021f):

- Work with the building operator to determine how to increase the outdoor air supply or, if adequate, improve the distribution to problematic rooms or increase the run time if the building ventilation is shut off or reduced during periods of no occupancy. Installing demand-based ventilation relying on CO_2 sensors may also be an effective strategy. Increasing mechanical ventilation may be limited by system configurations (e.g., duct sizes, fan speeds) or building envelope limitations (propensity for condensation under very hot or cold outside conditions) and should consider air flow limitations for thermal comfort.
- Avoid overcrowding indoor environments with more people than the HVAC system can accommodate.

- Increase natural ventilation by opening windows, if these are operable, taking into account safety and impacts on the overall building mechanical system. Note that natural ventilation can impact indoor temperature and humidity, and is not ideal in settings with poor outdoor air quality.
- Allow additional ventilation with filtered outdoor air by operating a heat or energy recovery ventilator, which is more energy efficient.
- Follow protocols similar to those outlined for managing carbon monoxide (section 3.3.4) to ensure combustion equipment are operated correctly and properly vented.

3.2.4.1 Carbon dioxide as an indicator of ventilation

Health Canada's exposure limit for CO_2 is intended to protect susceptible populations, including children, from health effects due to exposure to CO_2 and other indoor air contaminants. Achieving this limit can also provide an indicator of adequate ventilation for an occupied building.

The concept of using indoor CO_2 levels as an indicator of ventilation has been discussed for decades (American Society of Heating, Refrigerating and Air-Conditioning Engineers [ASHRAE] 2022). With increased public awareness of the importance of ventilation and commercially-availability of CO_2 monitors, there is a renewed interest in using CO_2 monitoring as a method for quantifying ventilation.

Guidance provided by ASHRAE (2022) acknowledges that indoor CO_2 concentrations can be a useful tool in indoor air quality assessments as long as users understand the limitations. Indoor air quality professionals should be aware that sensor accuracy, location, frequency of monitoring, and calibration, among other parameters, are all critical for drawing meaningful inferences from measured indoor CO_2 concentrations prior to using this data in their investigations. The concentration of CO_2 indoors varies according to location, occupancy, and time of day, tending to increase during the day. Consequently, when measurements are taken, the factors influencing CO_2 should be noted. Continuous measurements can also be used to see how levels change over the course of the day and whether there are certain locations (i.e., meeting rooms by the end of the meeting) or certain times of day (i.e., before lunch and by end of day) that are more problematic.

3.3 CARBON MONOXIDE

3.3.1 Characteristics

Carbon monoxide (CO) is a tasteless, odourless, and colourless gas at room temperature. It is lighter than air and can move freely throughout indoor spaces. Carbon monoxide is produced during the incomplete combustion of organic materials such as natural gas, oil, propane, wood, wood pellets, coal, and gasoline. Many of these fuels are commonly used in appliances such as gas stoves, furnaces and fireplaces, wood and pellet stoves, and water heaters or boilers. These devices can release CO into indoor spaces if they are not installed or maintained correctly, or if they malfunction (Health Canada 2010, 2017).

Carbon monoxide is also produced by fuel-burning equipment and vehicles, including:

- generators
- lighting equipment, such as lanterns
- outdoor cooking appliances, such as grills, barbecues, jet boilers, and camping stoves
- thermal vehicles and boat engines
- outdoor equipment that use an internal combustion engine, such as yard equipment and snowblowers

Using these devices indoors, in unventilated or poorly ventilated areas, or near open doors and windows or air intakes can result in exposure to dangerous levels of CO.

In the absence of an indoor source, CO concentrations are generally equivalent to average outdoor concentrations (Health Canada 2010). Carbon monoxide can be found in indoor spaces at any time of the year, if there are sources present in the building or from infiltration from outdoors. However, the risk is greatest in colder months because many buildings in Canada are heated by fuel-burning appliances. Carbon monoxide is also found in second-hand smoke. A best practice is to investigate whenever CO is detected to identify the source and determine if it can be eliminated. More information is provided below under Carbon monoxide: Managing the issue.

3.3.2 Health effects

Breathing CO reduces the body's ability to carry oxygen in the blood and can affect an individual before they notice its presence. Exposure to this gas can cause CO poisoning, manifesting as flu-like symptoms, even at levels lower than those which would trigger an alarm from a traditional detector. Symptoms can include tiredness, headaches, shortness of breath, and impaired motor functions such as muscle weakness and partial or total loss of limb function. At high levels or at low levels for long periods of time, people can experience dizziness, chest pain, poor vision, and difficulty thinking. At very high levels, CO can cause convulsions, loss of consciousness, coma, and death.

3.3.3 Limits

Refer to Health Canada's Residential Indoor Air Quality Guidelines for current exposure limits (Health Canada 2024b).

3.3.4 Managing the issue

Carbon monoxide can only be detected with a CO alarm:

- Install CO alarms throughout the building, including where CO could potentially be generated and near sleeping areas, if applicable.
- Purchase CO alarms that have a battery backup when possible. Ensure that CO alarms are certified for use in Canada. Certified alarms have been tested by laboratory professionals and meet Canadian safety standards. Certification marks must be found on the CO alarm and the product packaging.

- Choose low-level CO alarms with a digital display. These devices can display levels below those that would trigger an alarm, allowing users to routinely monitor the levels of CO indoors and watch for increasing levels. Monitoring can help identify and respond to an issue early and protect those at greater risk of CO exposure.
- Ensure that CO alarms are installed, calibrated, tested, used, maintained, and replaced in accordance with requirements from local jurisdictions and the manufacturer's specifications (Health Canada 2010, 2017).
- Test CO alarms regularly and replace batteries and CO alarms as recommended by the manufacturer. As a reminder, write on the battery when it should be replaced. Check the expiry date of the CO alarms and replace them when necessary.

Preventing CO exposure:

- Regularly check areas (e.g., loading docks, parking garages, and air intakes) where fuel-burning appliances, equipment and vehicles are utilized to determine if there is potential for CO to enter occupied spaces from outside through air intakes, windows or doors, or from inside through diffusion or via the air distribution system.
- Regularly maintain and inspect fuel-burning appliances at least once a year or in accordance with the manufacturer's instructions.
- Frequently check fuel-burning appliances for leaks, cracks, blocked vents, poor connections of gas lines to appliances and vents, breaks or tears in connection tubes, and corroded or disconnected venting pipes. Make sure outdoor exhaust vents are clear.
- Do not block or restrict air circulation around fuel-burning appliances and equipment.
- Do not use any outdoor fuel-burning cooking equipment indoors, such as charcoal or gas barbecues, camping stoves, and portable burners. Do not operate this equipment in a shed or garage, even with the windows and doors open. Only use this equipment outdoors, away from air intakes, open doors and windows.
- Never operate a fuel-burning generator inside any building such as a workplace, home, garage, basement, crawlspace or shed, nor under a covered area (such as under an awning or gazebo).
- Operate portable fuel-burning generators at least 6 metres (20 feet) from any building. Direct the exhaust away from open windows and doors. Close all windows and doors on the side of the building closest to and downwind from the generator.

If a CO alarm sounds:

- Leave the building immediately and move to fresh air. Do not try to locate the source of the CO. Once outside, call 9-1-1 or the local emergency services. Do not re-enter the building until instructed to do so by a qualified professional.

3.4 DISEASES CAUSED BY BACTERIA, VIRUSES, AND FUNGI

3.4.1 Characteristics

Specific diseases and health effects can be related to microbes, including Legionnaires' disease (from exposure to *Legionella* bacteria in HVAC water systems) and inflammatory responses following exposure to endotoxins produced by Gram-negative bacteria in some humidification systems (Canadian Committee on Indoor Air Quality [CCIAQ] 2023). Other diseases include hantavirus pulmonary syndrome (from exposure to urine, saliva or droppings of infected wild rodents when cleaning) and psittacosis (from exposure to inhaled dust from dried bird droppings). Diseases caused by exposure to aerosolized bird and bat feces, and that can impact the indoor environment, include histoplasmosis and aspergillosis. This emphasizes the importance of keeping air handling units free of such contamination and preventing birds and bats from roosting in buildings.

Other microbes can originate from the building occupants (e.g., SARS-CoV-2 virus, influenza, respiratory syncytial virus). In most cases, transmission of a bacterial or viral infection between people will require contact with an infected individual or surface, the ability of the pathogen to be transmitted via respiratory particles, and/or a significant amount of infectious respiratory particles within the individual's direct breathing zone. However, with some viruses, such as SARS-CoV-2, transmission was also found to occur from particles remaining suspended in the air and travelling longer distances, hence the benefit of wearing masks, effective ventilation and building air filtration, and stand-alone air purifiers that utilize high efficiency particulate air (HEPA) filters when and where appropriate to reduce the risk of transmission.

3.4.2 Health effects

The health effects will be specific to the particular agent of concern.

3.4.3 Limits

There are no exposure limits for the range of microbial agents found indoors that can cause disease, as these are dependent on the infectious dose needed to cause an infection. Levels should be kept as low as possible.

3.4.4 Managing the issue

Many of the recommendations for managing mould concerns (section 3.5.4) will apply to bacteria, viruses, and pathogenic fungi. Hygienic operation of any HVAC system will ensure delivery of clean air, removal of contaminated indoor air, and prevention of conditions that will allow microbes to grow within the HVAC system of the building (CCIAQ 2013).

The proper design and operation of the domestic water system is essential for *Legionella* control (Public Works and Government Services Canada [PWGSC] 2016). The most effective way to prevent excessive *Legionella* growth in the water of HVAC evaporative cooling towers is proper maintenance and operation of the water coolant systems, especially during spring and summer.

This includes regular testing of the cooling tower water and the use of disinfectants (ASHRAE 2020; Employment and Social Development Canada 2018). A water management program can establish, track, and improve operation and maintenance activities (CCIAQ 2023; Centers for Disease Control and Prevention 2021). Culture and polymerase chain reaction methods are the most commonly used methods to test for *Legionella* in cooling towers and evaporative condensers. Some test methods may be performed on-site by the user or a qualified technician, while other methods may require contracting a commercial laboratory. Regular testing can be used to confirm the effectiveness of *Legionella* control activities and identify when further actions (e.g., maintenance) may be necessary.

Effective ventilation is important for reducing indoor transmission of respiratory infectious diseases (Public Health Agency of Canada [PHAC] 2021b, 2022; CCIAQ 2021) and includes:

- Avoiding or reducing the recirculation of potentially contaminated air;
- increasing indoor/outdoor air exchange with exhaust fans and mechanical ventilation systems;
- filtering air efficiently; and
- opening external windows and doors (where possible).

Ventilation can help reduce viral transmission in indoor spaces by preventing the accumulation of potentially infectious respiratory particles in the air. Good ventilation, combined with other personal protective measures, can further reduce the risk of infection.

In addition to improving indoor ventilation, the following should be considered (PHAC 2021a, 2022, 2023a, 2023b, 2023c):

- Encourage occupants to stay home and away from others if they are not feeling well.
- Limit the amount of people in areas where ventilation is poor.
- Have policies that require or strongly recommend people to wear a well-fitting N-95 or KN-95 respirator mask in indoor public settings.
- Provide supplies for people to clean their hands often (e.g., soap and water, or alcohol-based hand sanitizer containing at least 60% alcohol). Remind occupants to clean their hands after contact with shared surfaces and objects, and after coughing or sneezing.
- Regularly clean and disinfect high-touch surfaces and objects.
  - Develop and put into effect routine cleaning and disinfecting protocols that focus on shared surfaces, objects, and equipment.
  - Use disinfectant products with a valid drug identification number and follow manufacturer’s instructions for cleaning and disinfection.

3.5 MOULDS

3.5.1 Characteristics

Mould is the common word for any fungus that grows on food or damp building materials. It often looks like a stain and can come in a variety of colours. In some cases, however, mould may be in a location where it cannot be seen; there may be only a musty odour. If it is present in significant quantities, mould can contribute to poor indoor air quality.

Damp or wet areas indoors caused by water leaks, flooding or high humidity can promote mould growth. Mould can grow on wood, paper, fabrics, drywall, insulation, and other surfaces. It can be hidden inside walls and above ceiling tiles. Mould inside a building can contribute to poor indoor air quality and lead to health problems (Health Canada 2016).

3.5.2 Health effects

People exposed to mould and damp conditions are more likely to have eye, nose and throat irritation; coughing and mucous (phlegm) build-up; wheezing and shortness of breath; worsening of asthma symptoms; and other allergic reactions.

Some people are more susceptible to the effects of mould than others, including children, seniors, and people with medical conditions (like asthma and severe allergies). Some airborne moulds can cause severe lung infections in people with very weakened immune systems (like those with leukemia or HIV/AIDS, or transplant recipients).

3.5.3 Limits

Mould is a natural part of the environment and will always be present; simply finding mould spores in an air test does not necessarily indicate there is an issue (CCIAQ 2015).

Considerable expertise is required to correctly interpret air sampling results, and such sampling may or may not be reflective of the presence or absence of a problem due to limitations in air sampling and the highly variable nature of mould levels in air.

The results of air sampling are normally of limited utility in terms of understanding the health risk of mould in the indoor environment and typically are of little to no value in developing a remediation plan to rectify a mould problem in a building. Consequently, neither Health Canada (2016) nor the National Institute for Occupational Safety and Health (NIOSH 2022) recommend testing for mould or similar substances in offices, schools or non-industrial buildings.

The most important steps for determining the success of a mould remediation project include:

- verifying and correcting the real cause of the moisture problem that led to the mould growth—this may require building science expertise in the determination of the problem, design of the remediation and verification that the work was done properly;
- removing the mould and moisture-damaged building materials, with adequate containment of work areas to prevent dissemination of the mould spores and mould fragments to non-contaminated areas of the building; and
- thoroughly and diligently cleaning to remove all visible dust, which can most accurately and immediately be verified with a "white glove" test prior to completing any remediation work and following with a final cleaning. Added certainty related to the quality of the work completed can be best provided through direct supervision and verification of the remedial work by a qualified professional, who can independently verify the work of the remediation contractor.

3.5.4 Managing the issue

Health Canada (2016, 2023) recommends controlling dampness indoors, removing sources of moisture, cleaning surfaces, and inspecting for conditions that lead to the growth of microbials to prevent mould growth and its reoccurrence.

For smaller buildings or smaller-scale mould problems, prevention activities include:

- Carry out regular preventative maintenance on the building envelope, especially roofs and flashings around penetrations such as sewer vents, roof drains, chimneys, exhaust vents, windows, doors, and bottom flashings. Ensure proper grading and movement of water away from the building.
- Find damp spots: check basements, closets, windowsills, roofs, and around sinks and pipes.
- Fix damp spots and moisture issues right away: repair water leaks as soon as they are noticed and clean up immediately after a flood. Insulate cold water pipes to prevent condensation.
- Use fans: when available, use kitchen and bathroom exhaust fans or ensure continuous exhaust fans are working properly.
- Vent outside: all exhaust fans should vent directly to the outdoors.
- Seal showers, sinks or other fixtures: make sure the seal is tight, so water does not leak into the walls.
- Throw out clutter: papers, cardboard boxes, and fabrics are common (and ideal) places for mould to grow and should never be stored directly on the floor or in damp places. Moisture and mould can get into soft or upholstered furnishings if these become wet or damp. Check non-washable furnishings and items for mould and discard whatever cannot be cleaned if mould was discovered.
- Keep the building well ventilated: where applicable, open windows in dry weather or use fans as needed.

- Reduce humidity: keep humidity low, below 50% in summer and around 30% in colder weather (depending on the maximum tolerances of the building envelope) to avoid condensation on interior surfaces. If needed, use a dehumidifier or air conditioner to reduce humidity levels.
- Clean: regularly clean and disinfect anything that holds water, such as humidifiers, de-humidifiers, air conditioners, cooling towers or evaporative condensers.
- Use vacuums with HEPA filters or a central vacuum system that exhausts to the outside.
- Clean and remove any visible signs of mould or fungi. Clean small areas (three or less patches totalling less than 1 m^2) or medium areas (three or more patches, or patches totalling more than 1 m^2 but less than 3 m^2) as follows (Health Canada 2023):
  - Use the appropriate protective equipment, including safety glasses or goggles, disposable N-95 respirator, and household disposable gloves. Ensure the respirator fits you properly.
  - Shut off power to any areas that are wet or flooded. Wear rubber boots when standing in water. Keep extension cords out of the water.
  - Clean washable surfaces such as windowsills, wood, hard surfaces, concrete, and tiles with a cloth and unscented soap solution. Wipe with a clean cloth and dry quickly.
  - Clean walls with a damp cloth using baking soda or a small amount of unscented soap solution. Do not allow the drywall to get wet. If the mould is under the paint, the drywall will need to be removed and replaced. Painting over mould will not address the issue.

3.6 NITROGEN DIOXIDE

3.6.1 Characteristics

Nitrogen dioxide (NO_2) is a gaseous air pollutant composed of nitrogen and oxygen and is one of a group of related gases called nitrogen oxides, or NO_x. Nitrogen dioxide forms when fossil fuels such as coal, oil, methane gas (natural gas) or diesel are burned at high temperatures. Potential indoor sources of NO_2 include unvented or improperly vented fuel-burning appliances, such as furnaces, stoves, and water heaters, as well as cigarette smoke (Health Canada 2015). Nitrogen dioxide may also infiltrate from the outdoors; potential outdoor sources of NO_2 include emissions from thermal vehicles and fuel-burning equipment such as generators.

3.6.2 Health effects

Exposure to NO_2 can decrease lung function and worsen asthma. Long-term exposure to low levels of NO_2 can increase the risk of developing breathing problems, such as coughing and wheezing. People who may be more sensitive to NO_2 include those with airborne allergies, asthma, and chronic obstructive pulmonary disease.

3.6.3 Limits

Refer to Health Canada's Residential Indoor Air Quality Guidelines for current exposure limits (Health Canada 2024b).

3.6.4 *Managing the issue*

These control measures will help manage the risks of exposure to NO_2 (Health Canada 2021c):

- Make sure that gas stoves have a range hood fan that vents to the outside. It is important to run the fan when cooking.
- Cook on the back burner of the gas stove. This helps direct NO_2 and other gases to the exhaust fan.
- Maintain fuel-burning appliances and inspect them at least once a year. This is especially important for gas appliances because leaks are difficult to detect.
- Ensure sources of NO_2 are vented to the outside.
- Avoid idling cars or other gas-burning equipment in enclosed spaces, such as inside an attached garage, or near intake vents.

3.7 OZONE

3.7.1 *Characteristics*

Ozone is a naturally occurring gas that is present in the upper atmosphere and can also be formed at ground level when sunlight interacts with air pollution. Ground-level ozone is a key component of urban smog and can enter buildings and contaminate indoor air (Health Canada 2021d). There can also be indoor sources such as photocopiers and some air cleaning devices (e.g., electrostatic precipitators, certain ultraviolet generators, portable air cleaners, and devices used in remediation projects such as smoke damage restoration).

3.7.2 *Health effects*

Exposure to ozone can cause a variety of health effects, including coughing, irritation of the eyes, nose and throat, chest discomfort, shortness of breath, and decreased lung function. Individuals may be more sensitive to ozone if they have an underlying breathing condition.

3.7.3 *Limits*

Refer to Health Canada's Residential Indoor Air Quality Guidelines for current exposure limits (Health Canada 2024b).

3.7.4 *Managing the issue*

These control measures will help reduce exposure to ozone:

- Use an air conditioner instead of opening windows when outdoor ozone is at its peak (usually in the afternoon during summer months). Pay attention to the Air Quality Health Index (AQHI), InfoSmog (Quebec), and air quality alerts (Health Canada 2024a) and modify or reschedule outdoor activities when air pollution levels are high.
- Avoid equipment that intentionally or unintentionally generates ozone. Some available ozone-generating devices claim to improve air quality, which is not true. Conversely, some air cleaning equipment produce ozone as a by-product, which degrades air quality. As ozone can cause health problems, these devices should be avoided.

3.8 PARTICULATE MATTER (INCLUDING DUSTS AND FIBRES)

3.8.1 Characteristics

Particulate matter that is present indoors consists of a mixture of substances, such as (Health Canada 2012; 2019a):

- pollen,
- fungal spores,
- endotoxins (toxins present in bacteria),
- tiny liquid or solid particles in aerosols,
- carbon produced when materials are burned (soot), and
- different chemical contaminants that attach to particles.

The size of particles determines whether they can reach the lungs. Particles are measured in micrometres (µm). Fine particulate matter is a general term for small particles that measure less than 2.5 µm in size ($PM_{2.5}$). Particles 2.5 µm and smaller can enter the lungs, which may affect health. Typically, particulates greater than 10 µm get trapped in the nose and throat, so their risk to health is lower (Health Canada 2012, 2019a).

Common indoor sources of $PM_{2.5}$ include:

- mould,
- tobacco smoke,
- cooking,
- surfaces that are not regularly cleaned such as floors, ledges, and carpeting, and
- printers and photocopiers.

Other indoor sources of $PM_{2.5}$ include:

- renovation activities;
- furnaces, wood stoves or fireplaces that are improperly installed or maintained; and
- infiltration of outdoor pollutants (e.g., traffic pollutants, industry, construction, wildfire smoke).

3.8.2 *Health effects*

While studies have investigated the relationship between indoor $PM_{2.5}$ and health, the majority of data comes from studies investigating exposure to outdoor $PM_{2.5}$. Outdoor $PM_{2.5}$ has been established to have important adverse effects on human health. There is extensive evidence that short- and long-term exposure to $PM_{2.5}$ is associated with a variety of adverse health effects, including increased heart and lung problems that require hospital admissions and medical visits, lung cancer and even premature death. Children, seniors, and people suffering from heart and lung diseases are most likely to be affected by these particles (Health Canada 2022). When considering the smaller set of indoor studies specifically, there is evidence for a relationship between indoor $PM_{2.5}$ levels and decline in lung function and increases in exhaled nitric oxide, a marker of airway inflammation, in asthmatic children. Associations between indoor $PM_{2.5}$ and subtle changes in markers of cardiovascular disease have been observed in older adults (Health Canada 2012, 2019a).

3.8.3 *Limits*

Health Canada (2012, 2019a) recommends keeping indoor levels of $PM_{2.5}$ as low as possible, as there is no apparent threshold below which no health problems are expected. It is impossible to entirely eliminate $PM_{2.5}$ indoors, as it is caused by essential and everyday activities such as cooking and cleaning, as well as infiltration from outdoor sources. Nonetheless, any reduction in $PM_{2.5}$ is expected to result in health benefits, especially for susceptible individuals, such as those with underlying health conditions, the elderly or children.

3.8.4 *Managing the issue*

The main strategies to lower indoor levels of particulates are:

- Reducing indoor sources (e.g., no smoking or vaping).
- Controlling dust generation during renovation activities.
- Vacuuming rather than sweep carpets using a vacuum fitted with a HEPA filter.
- Making sure that kitchen exhaust fans are vented outdoors and are operated properly.
- Making sure there is adequate filtration in the ventilation systems, with potential addition of stand-alone HEPA-based portable air cleaners as needed.
- Ensuring air intakes are not close to idling zones or heavy traffic areas. If they are, close them during peak traffic times.

In addition, to help reduce exposure to particulate matter, pay attention to the AQHI, InfoSmog (Quebec), and air quality alerts (Health Canada 2024a) and modify or reschedule outdoor activities when air pollution levels are high.

3.9 RADON

3.9.1 Characteristics

Radon is a radioactive gas that comes from the breakdown of uranium in soil and rock. It is invisible, odourless, and tasteless. When radon is released from the ground into the outdoor air, it is diluted and is not an issue. However, in enclosed spaces like buildings, it can accumulate to hazardous levels and become a health risk. Radon gas can enter any building where the floor rests on the ground through cracks in foundation floors and walls, construction joints, gaps around service pipes, support posts, window casements, floor drains, sumps or cavities inside walls (Health Canada 2021e).

3.9.2 Health effects

Radon exposure is the number one cause of lung cancer in non-smokers, with 16% of lung cancers estimated to be from radon exposure, resulting in more than 3000 lung cancer deaths in Canada each year (Health Canada 2024g). People who smoke and are exposed to radon have a significantly increased risk of developing lung cancer. The health risk from radon is long-term, not immediate. The longer the exposure to high levels of radon, the greater the risk (Health Canada 2019b).

3.9.3 Limits

Refer to Health Canada's Radon Guideline (Health Canada 2024e) for current exposure limits. The guideline recommends that techniques to minimize radon entry should be used for new constructions and remediation measures should be taken for existing buildings in cases where concentrations exceed the limit.

3.9.4 Managing the issue

All buildings in contact with the ground will have some radon gas in them; the only way to know how much is to test. Health Canada recommends that all buildings be tested. A radon test should be done for a minimum of three months, ideally during the fall and winter timeframe. A long-term, 3-month test provides an estimate of the annual average radon level that can be compared to the guideline level to determine if remediation is necessary. Radon levels can vary across the different spaces within a building. To properly assess the radon levels throughout a building, multiple tests may be required. A testing program should be developed in accordance to Health Canada's Guide for radon measurements in public buildings (Health Canada 2021b).

Health Canada, in collaboration with experts in the field of radon mitigation and construction, developed two Canadian standards for radon mitigation, one for new constructions (Health Canada 2024d) and one for existing buildings (Health Canada 2024f). These standards include detailed technical guidance about installing radon control measures in new and existing low-rise residential buildings. The technical principles of these standards have been applied to other building types and may be applicable to developing a mitigation strategy.

If a high level of radon is found in the building, building owners should consult a certified radon mitigation professional to determine the best and most cost-effective way to reduce the radon level. Health Canada recognizes the Canadian National Radon Proficiency Program for certified professionals and laboratories. Consult the list of certified mitigation professionals.

3.10 VOLATILE ORGANIC COMPOUNDS

3.10.1 Characteristics

Volatile organic compounds (VOCs) are a large group of chemicals that are present in indoor and outdoor air. Formaldehyde, benzene, toluene, ethylbenzene, xylenes, acetaldehyde, and naphthalene are all considered VOCs. Exposure to certain VOCs commonly found in indoor air may affect human health, depending on the levels of VOCs present, and the duration of exposure (Health Canada 2021g).

3.10.2 Health effects

Short-term exposure to high levels of some VOCs can cause breathing problems, irritation of the eyes, nose and throat, and headaches.

Certain groups are considered more susceptible to health effects from VOC exposure, including children, the elderly, pregnant people, and people with pre-existing health conditions such as asthma.

The potential for adverse health impacts from exposure to VOCs depends on the specific compound and its inherent toxicity. As with other pollutants, the risk to human health is dependent on the concentration, duration and frequency of exposure.

3.10.3 Limits

Refer to Health Canada's Residential Indoor Air Quality Guidelines and Indoor Air Reference Levels for current exposure limits (Health Canada 2024b, 2024c).

3.10.4 Managing the issue

The main strategies to reduce exposure to VOCs indoors include (Health Canada 2021g):

- Avoiding smoking or vaping.
- Choosing low-emission products when possible. Some paints, varnishes, and chemical cleaning products emit fewer VOCs than others.
- Where available, opening windows or ensure adequate ventilation when using cleaning products, especially those with strong chemicals. Always read and follow label and safety data sheet instructions available. It may be preferable to use certain products on weekends or evenings when regular building occupants are not present.
- Opening windows or ensuring adequate ventilation and use of administrative controls to minimize exposure to occupants during renovations when using products such as glues, paints, varnishes, and adhesives.
- Minimizing or eliminating the use of scented products, such as air fresheners, as they typically produce VOCs.

If there are occupants susceptible to health effects from VOC exposure, activities should be scheduled and communicated with sufficient notice to:

- ensure they are outside the building during cleaning, renovations, and the use of chemicals; and
- allow the opportunity to consult with a medical professional if they are concerned about experiencing adverse health effects associated with exposure to VOCs.

3.11 TOTAL VOLATILE ORGANIC COMPOUNDS

3.11.1 Characteristics

Total VOCs refer to the sum of all of the VOCs detected or measured in a given air sample. The specific VOCs included in the total reported VOC value will depend on which VOCs are present as well as the methods of sampling, detection, and measurement.

3.11.2 Health effects

Known or suspected health effects of exposure to certain VOCs include irritation of the eyes, nose, throat and respiratory system, dizziness and fatigue, and exacerbation of respiratory conditions such as asthma. Most people are not affected by short-term exposure to low levels of VOCs typically found in indoor non-occupational environments in Canada. For long-term exposure to low levels of multiple VOCs, research is ongoing to better understand health effects (Health Canada 2021g). For more information on specific VOCs, refer to section 3.10—Volatile organic compounds. Health effects of a mixture of VOCs found in indoor air will depend on the presence and concentration of individual components, including potential interactions between individual VOCs in mixtures. In other words, the composition of the mixture is more important than the sum total concentration of VOCs.

Exposure duration and frequency is also a factor, as some health effects may occur after a short time, whereas others may manifest only after a longer exposure. In addition, the toxicity of a given VOC may be impacted by concurrent exposure to other chemicals; for example, effects of a mixture may be synergistic (i.e., combined effects are worse than the additive effects of individual components). However, many of the VOCs present in indoor air are not well characterized in terms of effects on human health.

3.11.3 Limits

A scientifically supported health-based exposure limit cannot be derived for total VOCs. Total VOCs are not consistently defined nor measured across studies and therefore often cannot be compared. Exposure to contaminants in indoor air is highly variable and generally not well characterized; as such, study results are difficult to extrapolate to real-life conditions of continuous exposure to a varied and changing mixture of VOCs.

A reported total VOC concentration is dependent on the measurement methods used and does not provide sufficient information on the identities and concentrations of the individual VOC components to evaluate health risk. A low total VOC concentration does not necessarily indicate low risk of health effects, as very potent contaminants may be present at a level sufficient to cause harm. Similarly, a high total VOC concentration does not necessarily indicate high risk of health effects. Without knowing the identities and concentrations of individual components of the total VOC mixture, the short- and long-term health effects of a given total VOC concentration cannot be predicted or estimated.

Therefore, keeping VOC concentrations as low as possible remains the best strategy to reduce potential health risks of VOC exposure in indoor air.

3.11.4 Managing the issue

The main strategies to reduce exposure to total VOCs indoors are the same as those applicable for reducing exposure to individual VOCs (section 3.10.4).

Total VOC measurements might be considered for use as a low-cost screening method in certain circumstances, bearing in mind the limitations of this approach. High or increasing total VOC concentrations could indicate inadequate ventilation or the presence of a source of elevated VOC emissions. There is no specific concentration of total VOCs that would indicate that a ventilation flow rate is too low.

Measuring total VOCs and monitoring their spatial or temporal variations may be useful for source identification. For example, real-time monitoring of total VOCs can indicate a time of day or location within a building at which concentrations increase or decrease, which may help identify a particular event or activity that changes VOC concentrations. For example, a study of total VOC levels before and after an event such as a renovation or a change in heating source, flooring or furnishings can help identify the contribution of specific sources and determine whether ventilation remains adequate. A change in total VOCs over time following one of these events may also be observed, although it should be noted that some VOCs are expected to decrease quickly, while others may take days or months to reach a steady state. Therefore, along with a change in total VOC concentration, the composition of the indoor air VOC mixture will also change over time following an event.

Total VOC measurements can also be used to evaluate and optimize interventions for reducing exposure to VOCs. For instance, total VOC monitoring before and after an upgrade to a building's ventilation system or removal of a particular source would show a decrease in total VOCs if the intervention was effective. Similarly, measuring total VOC levels during renovations can provide a quick indication of potential exposure of occupants to VOC-containing products and the effectiveness of any measures to isolate the work area from occupants.

Risk mitigation is best achieved through reduction of exposure to VOCs, which can be done in part by identifying the source and monitoring total VOC. Maintaining adequate ventilation is an important method for reducing exposure to VOCs and other contaminants. While absolute total VOC concentrations cannot be used to assess ventilation flow rates, temporal or spatial changes in total VOC levels could help identify the need for increased ventilation.

4.0 PROFESSIONAL PRACTICE

Investigating indoor air quality issues requires gathering information to determine their potential causes. This information may be collected remotely or may require a site visit to investigate the issue in person. Activities such as building system checks using remote sensing and monitoring capabilities, walkthroughs, site inspections, equipment checks and servicing, and air sampling and monitoring may be carried out as required to provide additional information to support the indoor air quality investigation. A professional should be selected according to the requirements of the investigation or remediation activities. They should have the required subject matter expertise and ability to provide the services needed for the resolution of the indoor air quality or building issues.

The professional should work with their client to develop an agreement that covers the scope of the work they will complete.

The agreement should include a description of:

- the methods that will be used;
- the schedule, costs, and deliverables, such as air sampling, reports, and training for building staff;
- who will complete which tasks (e.g., some tasks may be completed by building staff); and
- the type and frequency of communications between the professional and the client or their representatives.

A written agreement is valuable because it describes how the professional will achieve the expected outcomes (deliverables), in what timeframe and for what cost, including costs of any third-party contractors or laboratories. In addition to the agreement elements listed above, the scope of work may:

- outline the professional's duties and authority;
- clarify any procedural expectations by the client (e.g., how the professional will access the work site, read records or conduct research with building occupants);
- outline the tasks to be performed and results required with respect to the various aspects of the issues or project (e.g., recommendations, interpretation of results, corrective actions);
- list any requirements for final reports or any restrictions on developing recommendations; and
- outline steps to be taken to ensure confidentiality, payment terms, termination clauses, etc.

It can also be important to understand the steps after the identification of any deficiencies, such as who will carry out this work and the process by which it will be awarded. For example, if a mould or asbestos issue is identified, it is important to understand in advance who will identify, hire, and oversee the work to ensure any conflict of interest issues are appropriately documented and managed.

5.0 SAMPLING OR MONITORING INDOOR AIR CONTAMINANTS

In general, Health Canada does not recommend the sampling and analysis of indoor air, as the guidance provided to help remediate an air quality issue is similar regardless of the airborne concentration of a contaminant, i.e., source reduction, ventilation, and filtration. As many, if not most, indoor air quality assessments can be completed without air sampling, it is not recommended as a first step. Air sampling can be expensive, so this should be weighed against its potential benefits to the assessment or investigation. However, in some cases air sampling may be needed to ensure regulatory or legal compliance, or to help further define the issue.

Radon and CO are the exceptions. Radon tests are readily available and provide information necessary to determine whether remediation above and beyond normal ventilation is required. CO monitoring is an ongoing requirement to protect occupants against exposure levels which can immediately impact health and in the extreme, lead to asphyxiation.

Air sampling for other indoor air contaminants uses specialized equipment to determine the level of a contaminant in the air and should only be conducted by a qualified professional. Canada does not have air sampling standards and instead recommends methods defined by the NIOSH and the United States Environmental Protection Agency. They must be properly followed to ensure the results are valid.

Air sampling can be complicated, costly, and can generate results that are difficult to interpret. Therefore, careful consideration should be given to whether there is a need for measuring specific air contaminant levels to support the assessment or investigation and how the results will be used.

5.1 PURPOSE OF SAMPLING

Air sampling can be used to establish baseline measurements, confirm that a control method has had the desired effect of reducing concentrations, and measure existing elevated levels of specific contaminants.

Air sampling results are interpreted and compared to exposure limits or guidelines, where available. In some cases, such as where complaints are limited to certain areas of a building, it can be useful to compare sampling results between complaint and non-complaint locations to see if there is a difference that could shed insight to help resolve the situation. There are also situations where it is important to sample the outside air to better understand the contribution of contaminants in outdoor air to the indoor air sample results. Indoor and outdoor air samples should be taken as closely in time as possible.

To assess risk to human health, a statistically significant sample size with a sampling time of at least 24 hours taken under normal conditions is recommended. Averaging of results of repeated samples taken at different times of the year will provide a more representative estimate of the average long-term exposure. In some cases, the mode of action of a particular substance may also justify the use of samples of short durations and their consideration in risk assessment. Such data may not be available under certain circumstances, such as at a contaminated, remote, or hard-to-access site. In such circumstances, the use of either fewer measurements or measurements of shorter duration may be unavoidable, and it is recommended to apply the maximum measured value to assess potential human health risks. In general, and especially where these conditions cannot be met, professional judgement should be used to consider all uncertainties that may impact a conclusion of potential risk.

5.2 LIMITATIONS OF SAMPLING AND SAMPLING RESULTS

Indoor air is a complex mixture of components and relative concentrations are constantly changing, as they are subject to many factors such as varying indoor and outdoor sources, the impact of indoor and outdoor temperature and relative humidity conditions, ventilation system operation, door and window opening and outdoor wind conditions. These factors among others result in air samples representing only one moment in time. There is no one simple measurement or factor that can easily establish if the air quality in a building is acceptable.

Most sampling methods are designed to detect a specific contaminant. Knowledge of the possible contaminants for which you are sampling is required before testing begins to ensure the correct method is used.

Many indoor air contaminants are present at very low concentrations. Knowing which to sample for in response to an indoor air quality complaint may not be clear, and most have no guidelines or standards to facilitate the interpretation of results. A chosen sampling method may not be sensitive enough to accurately detect the contaminant of interest. In addition, different sampling protocols may be required for the same chemical (long-term exposure to low levels vs. short-term exposure to high levels). It is possible that air sampling or monitoring during a complaint investigation will not identify any indoor air quality issues even though the occupants are reporting health effects that they are attributing to poor indoor air quality. Air sampling or monitoring, even when conducted by a qualified professional who will also interpret the results, may not be able to provide the evidence to support or definitively rule out indoor air as the cause of adverse health effects experienced by occupants. This is one of the greatest limitations of air sampling and can be due to many factors, including the lack of appropriate methods, not sampling for right contaminant(s), challenges with results interpretation or sampling at a time when contaminant levels from an intermittent source are low.

5.3 WHEN TO SAMPLE

The results from walkthroughs, assessments, occupant surveys, building inspections, and operational log reviews should be used to inform the decision of whether sampling is required or if the results will be informative.

Many indoor air quality issues can be addressed without air sampling. In most situations, identifying the potential sources of indoor air contaminants and taking measures to reduce these sources is more informative, cost effective, efficient, and health protective than air testing.

5.4 SAMPLING METHODOLOGY

All air sampling should be conducted by qualified professionals in accordance with applicable legislation and best practices. These professionals can make informed choices for the contaminants to be sampled and use the most appropriate sampling methodology. A Sampling Guide for Air Contaminants in the Workplace was developed by the Institut de recherche Robert-Sauvé en santé et sécurité du travail (2013) to help professionals determine the most appropriate sampling method for the contaminant. When performing air sampling, the professional conducting the sampling should consider the following factors to help ensure that meaningful results are obtained:

- Select appropriate contaminants to be measured.
- Use appropriate testing equipment and protocols for each contaminant.
- Determine if the sampling method will provide the required results with sufficient accuracy; determine whether any existing guidance value can be appropriately compared to the results, taking into account methodology differences.
- Determine the location, timing, and duration of sampling to establish a meaningful representation of indoor air quality patterns, by considering the following:
  - Sampling locations and conditions that are representative of occupant activities and exposures, occupancy patterns, ventilation system zones, ventilation flow rates, sources of contaminants (both indoors and outdoors), and areas of concern.
  - Time of day:
    - Contaminants arising from the building structure or furnishings (e.g., formaldehyde, VOCs, potential microbial contamination) or distributed via the ventilation system are expected to be elevated in the morning if the ventilation system is turned off overnight or over the weekend.
    - Contaminants generated by the occupants (e.g., CO_2) or their activities (e.g., use of photocopiers) are best checked during working hours, potentially at the end of the day if accumulation needs to be considered. Consequently, it is often recommended that CO_2 be continuously sampled over the course of a day with normal occupancy or in meeting rooms that may have insufficient ventilation.

- Time of year:
  - Temperature and humidity can affect levels of indoor air contaminants. Consider measuring over multiple seasons, if possible. Compare time of year when the outdoor air supply may be very cold and dry, or hot and humid.
  - Carbon dioxide levels may also be highest when the intake of outdoor air is lowest, such as during extreme cold periods or heat events, or when outdoor air quality is poor (e.g., due to wildfire smoke or smog).
  - Depending on the contaminant, duration of sampling can go from short (hours) characterizing a “worst-case scenario”, to long (days), characterizing an average exposure. Optimal duration should be carefully considered when choosing or designing the sampling methodology for the individual contaminants, as it is an important consideration if intending to compare results with existing reference values.
- Understand the limitations of each factor (location, timing, duration, method) and what the results do and do not indicate.

An occupational hygienist or other qualified individual will develop a sampling strategy (if needed), collaborating with the employer and occupants to determine the best method for conducting sampling. Internal resources may be used to conduct the sampling where appropriate resources and equipment are available; however, external consultants and resources may be required.

It is recommended that occupants working in the area be notified before the sampling is conducted. It is important that they cooperate with the sampling and do not intentionally or unintentionally contaminate collected samples. The person conducting the sampling should monitor the equipment or otherwise ensure it is not tampered with during the sampling period to make sure it is operating correctly and has not been disturbed.

For sampling techniques that require the use of an external laboratory for analysis, only laboratories that are accredited by programs such as the National Voluntary Laboratory Accreditation Program, the American Industrial Hygiene Association Laboratory Accreditation Programs or the Canadian Association for Environmental Analytical Laboratories should be used. The laboratory needs to be certified for the individual parameters to be analyzed, and appropriate chain of custody procedures must be followed.

5.5 SAMPLING PARAMETERS AND INSTRUMENTS

There is no one method or instrument that will provide an overall indication of indoor air quality. All instruments must be maintained, calibrated, and repaired in accordance with the manufacturer’s instructions.

The following sections illustrate some sampling parameters and measurement technologies available to assess indoor air contaminants.

5.5.1 *Humidity*

- Psychrometers: measure the relative humidity using the temperature difference between two sensors, one of which is moist and cooled by air. Available as sling or powered instruments.
- Hygrometers: use a sensor to measure resistance or capacitance as humidity varies.

5.5.2 *Air movement and thermal comfort*

- Smoke tubes: use a smoke diffuser to produce a visible vapour that can indicate air movement (such as direction and speed). These are generally not used in occupied buildings to avoid exposing occupants to smoke.
- Thermal anemometers: use sensors to provide a direct readout of air velocity.
- Thermal comfort (environmental) meters: use sensors to measure radiant temperature, air temperature, humidity, and air movement.

5.5.3 *Various gases*

- Direct-reading monitors: use a variety of technologies and chemical properties unique to each compound. Some gas monitors may incorporate an air pump or rely on the passive diffusion of gas across a sensor element.
- Direct-reading tubes: use a hand pump to draw air through a glass tube packed with a specific compound. The length of the stain observed in the tube indicates the concentration of the contaminant it was designed to measure. These are more suited to measuring the high contaminant levels expected in industrial settings.
- Sampling canisters and tubes: collect a defined volume of air passively into an evacuated canister or with a sampling pump into a tube, which enables pulling the sampled air through an adsorbent or reactive material. In both cases, subsequent laboratory and chemical analysis is required. Results are used to calculate concentration over a defined period of time, ranging from minutes to days and months, depending on the parameter and sampling method.

5.5.4 *Particulates*

- Piezoelectric resonance monitors: use a sensor to electrostatically measure particles as air passes through a size-selective inlet. The changes in oscillation frequency relate to the particle mass and produce a measurement value.
- Optical devices: use sensors to measure the air as it passes through a size-selective inlet to an optical cell, where the presence of the particles scatters light. A high degree of scattering correlates with a high concentration of particles.
- Gravimetric methods: use sampling pumps to draw a measured volume of air through pre-weighted filters. Filters are sent to a laboratory for weight analysis. The weight of the particles captured on the filters is measured and correlates with the total concentration of particulates.

5.5.5 *Volatile organic compounds*

- Direct-reading tubes: use a hand pump to draw air through a glass tube packed with a specific compound. The length of the stain observed in the tube indicates the concentration of the contaminant it was designed to measure.
- Passive badges: use charcoal or another medium as an adsorbent. Sampling period may be 8 hours to 1 week. The badge is sent to a laboratory for analysis.
- Active sorption/chemical analysis: uses tubes packed with a sorbent that traps the VOCs when air is pumped through the tubes. Laboratory analysis is required.
- Evacuated canisters: use flow controllers to allow air to slowly enter a stainless steel canister. These canisters are also used to create grab samples (i.e. the technique is not specific to VOCs). The VOCs are subsequently separated by gas chromatography and measured by mass-selective detector or multi-detector techniques.
- Direct-reading instruments: instruments such as photoionization, flame ionization, and infrared detectors provide total VOC concentrations or speciated data depending on the instrument. Portable gas chromatography with mass spectroscopy provides speciated VOC data. Instrumentation may be deployed on-site at the sampling location or grab samples (e.g., Tedlar bags) could be collected on-site and analyzed off-site.

5.5.6 *Microbes*

While measurement methods do exist, neither Health Canada (2016) nor the NIOSH (2022) recommend testing for airborne moulds. The decision to remediate any moisture or mould present in the workplace is based on a thorough building inspection combined with early intervention and remediation—not on mould sampling results, which only reveal a generic classification and concentration in the air at the time of sampling. Sampling may be required in situations where mould is suspected but the source has not been found through a thorough inspection. It may also be proposed as a tool to compare results before and after remediation. The goal of mould sampling would be to determine if there is mould amplification in the building, which would be indicative of a source of mould that requires remediation. The underlying principles to determine if mould is amplifying in a building are outlined in the American Industrial Hygiene Association's (AIHA 2020) publication of the second edition of "Recognition, Evaluation, and Control of Indoor Mold", informally referred to as the Green Book. Correct interpretation of the sampling results requires a combination of proper training and extensive experience.

If microbial sampling is to be carried out, a concurrent outdoor sample is always required, except in winter when the ground is snow-covered, or in situations where a sample is being collected post remediation in a contained area. A sample can also be taken in an area believed to be free of mould contamination (e.g., away from the suspected contaminated area) and then another in the area of concern.

Microbial sampling can consist of the following:

- Viable microbial air sampling: air is sampled to determine the number of colony forming units per cubic meter. Spores are collected on a growth media appropriate for the types of moulds or bacteria of interest, sent to a qualified laboratory, and cultured under the appropriate conditions.
- Non-viable microbial air sampling: air is drawn through a cassette and impacted onto a sticky surface, which is analyzed under a microscope for mould, fibres, and other biological matter, with mould identified to the genus level (AIHA 2019).
- Tape lift sampling: spores are collected and examined by light microscopy for mould, fibres, and other biological matter. This method is only useful for confirming the observed contamination is indeed mould and not other materials.

5.6 SAMPLING RESULTS

After receiving the results of chemical sampling from the laboratory, the contaminant's concentration may be compared to health-based exposure limits, when appropriate exposure guidelines exist. It should be noted that many available health-based exposure limits for indoor air contaminants are based on chronic (or lifetime) exposure and thus are not relevant to estimate health risk based on a single sample nor multiple samples collected over a short period of time. Rather, comparing the concentrations to the exposure limits may be useful in determining the existence of a significant source of a contaminant and the potential need for mitigation strategies to reduce exposure. As a best practice, contaminant concentrations should be kept as low as possible.

5.6.1 Volatile organic compound sampling results

Each individual VOC has its own inherent toxicity. Therefore, a total VOC measurement, which does not indicate the individual VOCs included in the measurement nor their respective concentration, cannot be used to directly assess the health risk of exposure to the VOCs present in the indoor air at the time of sampling. While a specific limit of total VOC cannot be supported or applicable in every situation, monitoring spatial or temporal variations in total VOC levels may be helpful. For instance, total VOC monitoring before and after an upgrade to a building's ventilation system or removal of a particular source may show a decrease in total VOCs if the intervention was effective.

Determining if results from monitoring indicate that the exposure level is acceptable will be based on accepted occupational hygiene practices and professional judgment. When guidelines do not exist, other recognized standards and professional judgment will be used to determine at what point hazard controls are required. Recommendations for controls may increase occupant comfort and meet due diligence requirements.

All sampling records and associated data should be provided to the client for their records. This includes the original signed laboratory results, instrumentation calibration records, sampling locations and times, photographs of sampling locations, site observations, any relevant activities during sampling and consultant reports. This information can help inform appropriate follow-up and corrective actions.

6.0 CONTROL MEASURES

Indoor air quality professionals may have to develop or implement mitigation measures to address indoor air quality issues based on up-to-date site-specific information such as sampling results and field observations. Generic mitigation measures implemented without consideration for context can be less effective and may cause additional issues. The control measures selected should eliminate or reduce the indoor air quality issue. Follow-up assessments are important to ensure the corrective action is working as intended and that it did not create a new issue.

Communication with building occupants is important when control measures are being planned and implemented. Occupants can help determine if the control measures are not functioning properly, if a new issue arises, or can express concerns with the timing and scope of the activities. In some cases, sensitive occupants may need to be absent during certain activities or for some time after their completion.

7.0 EVALUATION

Once corrective actions have been implemented, it should be determined whether they have been effective and if the indoor air quality issue has been resolved or mitigated. If not, control measures may need to be added, or existing ones modified.

Methods to ensure control measures are effective include physical inspection, observations, investigation reports, and occupant feedback. Evaluating the effectiveness of control measures may also include periodic, scheduled, or continuous monitoring. This step may include re-sampling or a follow-up walkthrough and assessment.

Indoor air quality professionals should work with their clients to determine what evaluation and follow-up activities are necessary and ensure they are included in the scope of work agreement.

8.0 SUMMARY

Indoor air quality is considered an important environmental determinant of health. Indoor air quality issues occur in buildings where chemical or biological contaminants levels pose a health risk to building occupants. Some building occupants may be more susceptible to health effects from exposure to elevated levels of indoor air contaminants. Preventing issues before they arise and addressing them as soon as they are identified are the best strategies to maintain acceptable indoor air quality.

When issues do arise, those responsible for indoor air quality in a building may need the assistance of qualified professionals or organizations that have the necessary skills, training, and equipment to further investigate and remediate indoor air quality issues. Health Canada's indoor air quality resources for professionals web page contains the most up-to-date information on RIAQGs, IARLs, and guidance documents (Health Canada 2024b, 2024c).

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