INDOOR AIR QUALITY GUIDELINE

FOR NON-INDUSTRIAL WORKPLACES

Environmental Abatement Council of Canada
Canadian Chapter of the EIA

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Foreword

This guideline was prepared to assist employers, building owners, real estate management professionals, constructors, contractors, and workers to better understand typical indoor air quality (IAQ) issues. This includes an overview of industry best practices used in both the assessment of IAQ issues and preventative measures. It is written in the context of non-industrial workplaces, such as offices, schools, and commercial retail areas, and is primarily intended to address issues related to discomfort, irritation, or annoyance rather than health hazards associated with higher risks and potential exposures governed under regulated occupational exposure limits.

The guideline is intended to educate and inform those who need an introductory guide to resolve perceived IAQ concerns, and to prevent them from occurring. This document examines comfort parameters, irritants, typical indoor contaminants, and exposure pathways in such workplaces and provides guidance regarding acceptable airborne concentrations and possible mitigation strategies.

IAQ problems can be very complex, and this guideline is not meant to provide a comprehensive solution for all issues. In many cases, input from a multi-disciplinary team, which may include occupational hygiene professionals, engineers, medical professionals and building ventilation experts may be required.

There are numerous provincial, federal, and international publications available from the private sector, research groups, and various government entities. This guideline is intended to provide a concise overview of practical approaches, rather than restate what is available in greater detail in the referenced literature.

Disclaimer

The Environmental Abatement Council of Canada (EACC) disclaims any liability or risk resulting from the use of the approaches and recommendations discussed in the guideline. It is the user’s responsibility to verify that the recommendations apply to specific workplaces and projects and that they comply with all other applicable federal, provincial, and municipal acts, codes, and regulations. In addition, contaminants and issues discussed may not be comprehensive or applicable to all situations. Users may need to seek professional advice in some situations.

About EACC

The Environmental Abatement Council of Canada (EACC) is a contractor-based organization serving the environmental abatement industry. Our members represent our industry as a whole, including contractors, consultants, engineers, suppliers, government officials, and others interested promoting safe work practices and high standards of work. EACC's purpose is to collect and disseminate information regarding the health effects associated with exposure to asbestos, lead, mould, and other hazardous materials in the construction industry. We achieve this by developing industry standard guidelines that are recognized and utilized by provincial and municipal levels of government.

1.0 GENERAL POINTS AND LIMITATIONS

Sick building syndrome (SBS), building-related illnesses (BRI), and mass psychogenic illnesses (MPI) were first identified in the 1970s when buildings started reducing ventilation rates to focus on energy management. Similar issues have recently resurfaced as the cost of operating buildings increases and designers shift to modern buildings that perform better and are "greener". Modern buildings incorporate significant IAQ components, which have helped raise awareness on the acceptability of the indoor environment for occupants, focusing on sustainability, human health, and wellness.

This guideline intends to educate and inform those who need an introductory guide to manage, prevent, and resolve IAQ issues. This guideline aims to provide consistent information regarding best practices for managing IAQ concerns.

This document is not intended for industrial or residential facilities, but rather non-industrial workplaces, such as offices, schools, and commercial retail areas, nor does it address air quality issues associated with transmission of viruses.

This guideline is intended to accompany existing industry toolkits and reference materials, as well as existing EACC guidelines, including the most recent editions of the following:

- EACC Emerging and Existing Pathogen Cleaning - Best Practices for Environmental Professional Services
- EACC Mould Abatement Guidelines
- EACC Vermiculite Guideline
- EACC Lead Abatement Guideline
- EACC Pre-Construction Guideline

2.0 FACTORS AFFECTING INDOOR AIR QUALITY

2.1 WHAT IS GOOD INDOOR AIR QUALITY?

Indoor air quality (IAQ), also known as IEQ (indoor environmental quality), and maintaining "acceptable" IAQ is a highly complex subject that involves a variety of scientific disciplines and numerous interconnected systems and parameters within the built indoor environment. The quality of indoor air refers to both the composition of common contaminants in indoor air (i.e. the concentration of bioaerosols, gases, vapours, and particulates) and other physical stressors, primarily thermal comfort, noise, lighting, ergonomics, etc.

Definitions of technical terminology and additional information are available in Appendix A.

Several definitions have been proposed for what constitutes "acceptable" IAQ. One of the most widely accepted is that of the American Society for Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), one of the leading authorities on IAQ and building occupant comfort and a primary contributor of quantitative guidelines for IAQ and comfort. ASHRAE defines acceptable IAQ as follows:

> *air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction –*
> *ASHRAE Standard 62.1: Ventilation for Acceptable Indoor Air Quality*

As noted in the ASHRAE definition, the objective of maintaining acceptable IAQ is two-fold:

1. Conditions should be maintained to prevent exposure of building occupants to airborne contaminants at concentrations that could be hazardous to their health
2. The composition and physical properties of indoor air should be maintained such that occupant discomfort or irritation is minimized to the greatest extent possible

While it is possible to achieve the first objective through effective building management, differences in human preferences and physiology mean it may be difficult to maintain the indoor building environment under conditions that will ensure the comfort of every occupant. Therefore, ASHRAE's benchmark is set at ensuring the satisfaction of 80% of more of building occupants.

When building occupants raise concerns regarding their comfort, both facility management and the occupants need to understand the challenges of satisfying the comfort preferences of all building occupants. While facility managers/operators/owners should make every reasonable attempt to maximize occupant comfort, including investigating solutions specific to the given individual expressing the complaint, occupants should be equally aware that not everyone will be satisfied with the indoor environment of the building, and should be prepared to work with management to find solutions acceptable to all individuals.

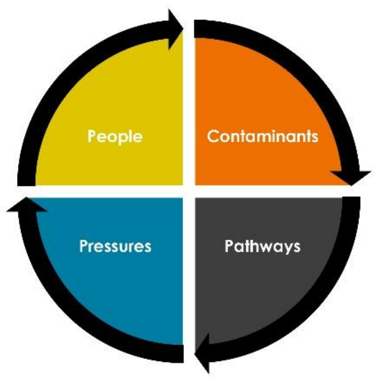
2.2 EXPOSURE PATHWAYS

When building occupants report odours, concerns, or perceived symptoms as a direct result of IAQ conditions, consider the following factors:

- One **contaminant** or more must be present at a concentration high enough to result in a detectable odour or irritant (but not necessarily a hazard)
- A **pathway** by which the contaminant travels from its source
- Air **pressure** differentials that move the contaminant along the pathway
- The **people** affected (i.e. building occupant or receptor)

These IAQ factors are links in an exposure pathway, as shown in Figure 1.

Figure 1: Exposure Pathway Links



In theory, building occupants should only experience potential health effects due to the indoor environment if all factors are present. In fact, to trigger exposure-related complaints, concerns, or symptomatic responses, the contaminant must reach the building occupants, travelling from its source, or generation point, to the areas of a building where people are present. A pathway therefore represents any open trail along which air and consequently the contaminants may travel between a source and a receptor. This can include stairwells, mechanical shafts, openings in ceilings and walls, etc.

In modern buildings, the most dominant pathway is the ductwork of the building's heating, ventilation, and air conditioning (HVAC) system. The HVAC system provides a pathway between different rooms and concealed areas associated with each room. However, an open pathway between a contaminant source and building occupants is not enough for the contaminant to reach the occupants. There must also be a driving force—air pressure—that moves the contaminant from the source to the occupants. Air always moves from areas of higher pressure to areas of lower pressure. Therefore, air (and any contaminants it may carry) will move along pathways from areas of higher pressure to lower pressure.

Air pressure differences in modern buildings are predominantly controlled by the operation of the HVAC system, which uses fans and/or blowers to move air throughout the building. However, mechanical movement in buildings, such as the piston-like movement of an elevator car within an elevator shaft, can also generate strong air pressure differences.

Differences in air pressure between rooms can cause contaminants to move either towards or away from occupants. It is therefore possible to take advantage of these air pressure differences in special use areas like biohazard laboratories and clean rooms to intentionally control known airborne contaminants and to minimize the exposure of building occupants to those contaminants.

2.3 VENTILATION SYSTEMS

The effective design, maintenance, and operation of the building's ventilation system is critical to achieving good IAQ. Ventilation systems are the primary pathway for outdoor air contaminants to enter a building and the mechanism by which indoor contaminants are exhausted from the building. Ventilation can be achieved by mechanical and/or natural means, and must consider the design, operation, and maintenance of the system.

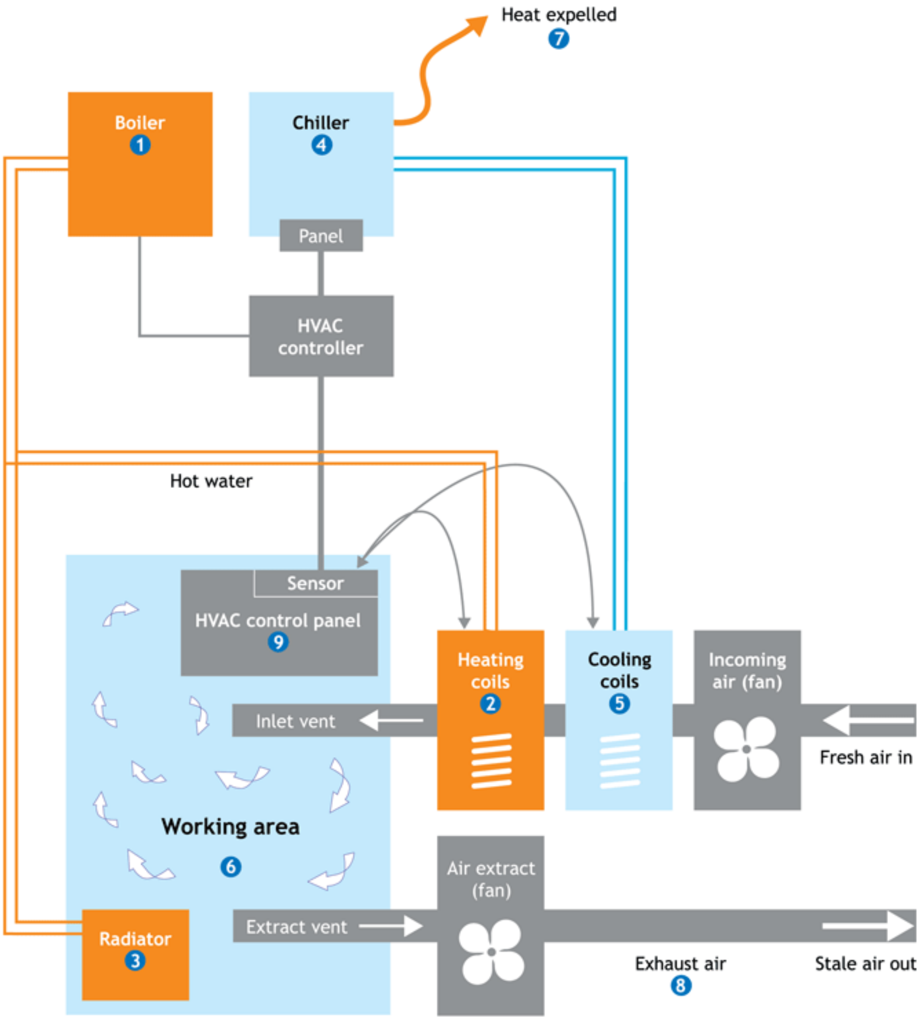
2.3.1 Mechanical Ventilation

Mechanical ventilation systems supply filtered, conditioned outdoor air to the building interior, and exhaust indoor contaminants. These systems range in type and complexity, based on the size of the building, local climate, occupancy, and use. Mechanical ventilation systems are designed to supply the building with adequate outdoor air volumes to dilute indoor contaminants. HVAC systems typically include the following components:

- Outdoor air intakes: louvres or grilles where outdoor air is drawn into the HVAC system
- Mixing plenums: where outdoor air is mixed with “return” indoor air and reconditioned for energy efficiency
- Filtration systems: media panels, pocket or bag filters, ultraviolet (UV), and/or carbon filters
- Heating and/or cooling equipment: gas-fired heat exchangers, electric heat coils, chilled water cooling coils, and/or refrigerant coils
- Chillers, boilers, and cooling towers
- Humidification/dehumidification equipment: spray, steam, ultrasonic, and/or evaporative humidifiers
- Supply fans
- Air handling unit internals, ductwork, and registers/diffusers
- Terminal units: fan coil units, variable air volume (VAV) units, heat pumps, and/or induction units
- Return air systems
- Exhaust systems
- Controls and sensors

A simplified HVAC system schematic is provided in Figure 2.

Figure 2: Simplified Schematic Diagram of Typical HVAC Components



Adapted from https://www.eex.gov.au/technologies/heating-ventilation-and-air-conditioning/technology-background-heating-ventiliation-and-air-conditioning

Boilers (1) produce hot water or steam that is distributed to heat exchangers in the working space. Distribution is done either by heating coils (2) which heat air as part of the ventilation system, or through hot water pipes to radiators (3). Cooling equipment (4) chills water for pumping to cooling coils (5) or cooling coils can be supplied with refrigerant (i.e. direct expansion, DX cooling, not shown). Treated air is then blown over the chilled water coils into the area (6) to be cooled through the ventilation system. As part of the refrigeration cycle in the chiller, heat must also be expelled (7) from the system via a cooling tower or condenser. Pumps are used to circulate the chilled and hot water to the required areas throughout the building. Stale air is extracted, usually using a fan, via separate ducts (8) and expelled outside. Controls (9) are used to make components work together efficiently.

Some buildings rely on fenestration (i.e. arrangement of windows and doors) to provide ventilation. Natural ventilation is generally perceived to be an air quality asset by building occupants. Some high-performance building certification programs also support natural ventilation in areas where outdoor air quality meets IAQ guidelines and is monitored hourly to verify its suitability. However, IAQ management is difficult in naturally ventilated buildings, particularly in climates with temperature extremes or variable outdoor air quality.

2.3.2 Ventilation Considerations

2.3.2.1 Design

The ability of a ventilation system to adequately dilute indoor contaminants and to supply thermally comfortable air to occupants depends on its design. Design considerations should include placement of outdoor air intakes, filtration efficiency, heating and cooling capacities, condensate removal, humidity control, air flow rates, interior layout, fenestration, and the balancing of air supply, return and exhaust systems. The design of the system should also consider occupancy levels and the varying nature of the work and activities performed in the building.

2.3.2.2 Operation

How ventilation systems are operated, including set points and schedules, also directly impacts IAQ. For example, heating and cooling systems are often operated seasonally, which limits the ability to condition air as needed during the spring/fall seasons when temperatures fluctuate.

Conflicts can arise between the need to save energy and provide adequate ventilation. Efforts toward conserving energy and reducing ventilation rates can lead to IAQ problems. Modern ventilation systems therefore often employ complex building automation and monitoring systems that adjust HVAC operation to achieve both good IAQ and reduce energy use.

2.3.2.3 Maintenance

All buildings should have a site-specific preventative maintenance program that describes the IAQ performance goals for the building, the system design, and the manufacturer’s specifications. Preventative maintenance tasks, such as inspecting air intake areas/plenums, changing filtration media, cleaning heating and cooling coils, calibrating sensors, etc., should be clearly identified and completed regularly to prevent potential air quality issues.

A preventative maintenance program should also include written documentation/record-keeping for work performed on the systems, details of inspections, and logs of occupant complaints regarding air quality. The complaint logs should include details regarding the HVAC system or zone associated with the complaint and any corrective action undertaken.

2.4 IAQ CONTAMINANTS

When IAQ complaints are non-specific, assessing basic IAQ parameters can help identify or rule out a cause. Basic IAQ parameters are easy to measure, therefore a significant quantity of data can be collected quickly. They include thermal comfort factors like temperature and relative humidity, as well as concentrations of carbon dioxide, carbon monoxide, particulates, and volatile organic compounds. As complaints become more specific or significant, involve odours, or result in more serious health complaints, a more detailed assessment of building systems and sources may be required to identify other contaminants.

Contaminants can be non-hazardous substances that are commonly present in indoor air at low concentrations and are therefore not a cause for concern. However, at higher concentrations, these non-hazardous contaminants can affect human health. The concentration at which occupants are exposed to a contaminant, or dose, is a result of the period over which they are exposed to that contaminant, or duration, and how often they are exposed (i.e. daily, weekly, etc.), or frequency. The resulting dose is the primary factor that determines if the substance is likely to present a hazard to the occupants.

Due to the variety of potential contaminants that can affect IAQ, the potential health effects can range widely. These health effects can vary from mild irritation to rare cases of serious disease, such as Legionnaire's disease caused by exposure to *Legionella pneumophila* bacteria. The most common health effects reported to be associated with poor overall IAQ include headaches, sore throat, nasal congestion, watery eyes, and respiratory symptoms.

Individual sensitivity to chemicals and biological agents can also vary substantially. Some individuals may exhibit extreme sensitivity or allergic-type reactions when exposed to chemical or biological substances that cause no adverse reaction in most people. It can therefore be challenging to accommodate the needs of such individuals due to their very low tolerances to specific substances.

Not only can people be affected by exposure to contaminants, but they themselves can be a common source of contaminants in indoor building environments. For example, humans naturally exhale carbon dioxide (CO_2) and release hundreds of thousands to millions of biological particles per hour, including skin cells, bacteria and other microbes, expelled mucous and water into the air when they sneeze. Occupants can also be a source of odours linked to volatile organic compounds, including scents from personal care products and perfumes.

Typical sources of indoor and outdoor contaminants in buildings are shown in the tables provided in **Appendix B**. Further information on how to assess, measure, and monitor each parameter along with comparative standards and guidelines is provided in **Appendix C**.

This section provides a summary of the key potential contaminants and indicators of IAQ.

2.4.1 Carbon Dioxide (CO_2)

Carbon dioxide (CO_2) is an odourless, colourless gas that results from human respiration, combustion processes (e.g. cars, combustion appliances, etc.), and fermentation processes (e.g. winemaking, brewing, etc.). Although not a toxic gas with respect to IAQ, CO_2 can be used as an indicator of the adequacy of the ventilation system and its ability to provide outdoor air to an indoor space. It is also used as a surrogate measure for other contaminants or odours that may build up because of an inadequate supply of outdoor air.

Build-up of CO_2, together with temperature and relative humidity levels beyond recommended ranges, can result in occupant discomfort and possibly negative health effects. Typical indoor CO_2 levels range between 500 and 800 parts per million (ppm) while outdoor levels are commonly measured between 300 and 500 ppm. Carbon dioxide concentrations consistently above 800–1,000 ppm generally results in occupants experiencing symptoms such as itchy or sore eyes, drowsiness, and/or mild headaches. To be of practical use as an IAQ indicator, the CO_2 measurement requires the presence of a “normal” number of occupants in any particular area. Exposure to much higher levels (>5,000 ppm) can cause dizziness, headaches, elevated blood pressure, and increased heart rate. Higher CO_2 levels may also indicate that oxygen in air is being displaced, potentially leading to unconsciousness and death by asphyxiation (due to lack of oxygen); however, this is typically not the focus of CO_2 measurements during an IAQ assessment.

2.4.2 Carbon Monoxide (CO)

Carbon monoxide (CO) is a colourless, odourless, toxic gas that is predominantly a by-product of combustion. Sources of indoor CO include infiltration of vehicle exhaust, cigarette/tobacco smoke, gas/wood/oil-fired (vented and unvented) appliances, and CO in outdoor air.

CO acts as an asphyxiant by blocking uptake of oxygen in the bloodstream. Symptoms of low-level exposure (e.g. low CO dose and short exposure duration) include headaches, dizziness, nausea, weakness, fatigue, and shortness of breath. High-level exposure (e.g. higher CO dose and longer exposure duration) can cause confusion, vomiting, loss of muscle coordination, unconsciousness, and ultimately death due to insufficient blood oxygen level.

2.4.3 Particulate Matter (PM)

Particulate matter (PM) describes the solid and liquid particles that are suspended in air. Particle levels in indoor air are greatly influenced by the presence of people and the intensity of their activity. Health effects depend on the particle size and composition: particles that range between 0.1 and 10 micrometers (µm) are most harmful to occupant health and IAQ. Fine particulate matter ($PM_{2.5}$) is a general term for small particles with an aerodynamic diameter of 2.5 µm or less. Particulate matter (PM_{10}) refers to small particles with an aerodynamic diameter of 10 µm or less. Both particle sizes can enter deep into the lungs when inhaled.

Elevated levels of particulate matter may cause allergic-like reactions such as dry eyes, nose and throat irritation, and respiratory difficulties. Exposure to higher doses may be associated with heart attacks, aggravated asthma, increased respiratory symptoms (e.g. irritation of the airways, coughing, or difficulty breathing), and may even result in premature death for people with heart or lung disease.

2.4.4 Volatile Organic Compounds (VOCs)

Volatile organic compounds (VOCs) are chemicals that easily evaporate indoors, under normal atmospheric conditions of temperature and pressure. Thousands of products typically found in indoor environments emit VOCs. Each individual compound is generally present in concentrations ranging from single parts per billion (ppb) to a few hundred ppb.

VOCs can cause a wide variety of acute and chronic health effects depending on the concentration and duration of exposure. VOCs typically act as a depressant on the central nervous system, leading to nausea, headache, difficulty concentrating, feelings of intoxication, drowsiness, etc. Exposure to some specific VOCs (e.g. benzene, formaldehyde) is linked to cancer in humans. Exposure to other VOCs at high concentrations can also cause damage to liver and kidneys (e.g. organic solvents and heavy metals). These compounds are typically found in industrial environments. To date, toxicity of low dose exposure to many VOCs is unknown and potential interactions are poorly understood.

When assessing IAQ, the sum of the individual concentrations of all VOCs present—total volatile organic compounds (TVOC)—is often used as a screening tool. An IAQ investigator should always attempt to identify what sources are contributing to higher TVOC readings.

2.4.5 Formaldehyde

Formaldehyde is a colourless, flammable gas with a strong odour. It is commonly found in indoor finishes such as adhesives, paints, floor finishes, paper products, and manufactured wood products. Formaldehyde is also a component of smoke (e.g. cigarette and wood burning fireplaces).

Exposure to high concentrations of formaldehyde (or low concentrations for sensitive occupants) can result in respiratory symptoms; eye, nose, and throat irritation; coughing; and wheezing. Formaldehyde exposure is also linked to lung and nasopharyngeal cancer.

2.4.6 Ozone

Ozone is a naturally occurring gas generated from the reaction of oxygen with high-energy electromagnetic radiation, including ultraviolet (UV) light. Examples of ozone-generating equipment include UV disinfection systems, electric motors, electrical discharges, and water treatment equipment. Ozone has a pungent odour that can be detected at low concentrations. Exposure to low ozone concentrations can irritate the respiratory system. Exposure to high ozone concentrations can damage the respiratory system and mucous membrane tissues.

2.4.7 Bioaerosols

Bioaerosols are airborne particles originating from microorganisms such as viruses, fungi (mould), bacteria, and allergens (e.g. nematodes, amoeba, pollen, dander, and mites). The composition of bioaerosols greatly varies depending on their source and from one indoor environment to another. They include viable (living) and non-viable (dead) microorganisms, spores, skin cells, insect parts and fragments, toxins, and particulate waste products.

Sources of bioaerosols include water-damaged materials, high humidity indoor areas, condensation from air handling systems, cooling towers, damp organic material and porous wet surfaces, humidifiers, hot water systems, outdoor excavations, plants, animal excreta, animals and insects, and food products.

Moulds require three things to grow: an appropriate food source, the appropriate temperature, and moisture. In the indoor environment, moisture is the limiting factor for mould growth, and is the only factor that can be effectively controlled to prevent mould growth. The most common symptoms of exposure to moulds are irritation of mucous membranes or allergic responses. However, infection can occur, typically in youth, elderly or the immunocompromised, or due to exposure to moulds from animal droppings.

Legionella is found in fresh or brackish water, coastal waters, lakes, rivers, mud, soil at the banks of water courses, and in potting mixes. *Legionella* and other bacteria can grow in the biofilm in a multitude of warm water sources such as cooling towers, hot tubs, showerheads, faucets, large plumbing systems, and parts of air conditioning systems of large buildings. Legionnaires' disease is contracted when aerosolized mist containing the bacteria is inhaled. The term "Legionnaires' disease" was coined in 1976 after a respiratory disease affected many delegates attending the American Legion convention in Philadelphia. The bacteria responsible for the disease was isolated and named *Legionella pneumophila*.

2.4.8 Radon

Radon is a colourless, odourless, and tasteless radioactive gas that is formed by the natural breakdown of long-lived radioactive elements (e.g. uranium, thorium, actinium) in soil, rock, and water. These materials can break down naturally into other radioactive particles called "radon progeny". Radon-222 is usually the isotope present in high enough concentrations to provide a significant dose. Uranium can be found in granite, black shales, pegmatites, and Paleozoic sandstone.

Radon exposure is linked to greater potential for developing lung cancer. This risk increases with exposure dose and duration, and is greatly increased for smokers at any dose. To maintain radon gas concentrations and workers' exposure as low as reasonably achievable, control measures/options can include sealing major entry routes for radon gas (i.e. open sumps) and maintain or increase mechanical ventilation.

2.5 COMFORT

Building occupants often report complaints regarding discomfort or irritation. Such complaints are often based on individual preferences or sensitivities. A good example of this would be thermal comfort. While addressing an individual concern on a building-wide scale (i.e. adjusting an HVAC system set temperature), others may become uncomfortable and complain of the new temperature setting.

2.5.1 Thermal Comfort

Thermal comfort can substantially affect building occupants' perceptions of IAQ and, therefore, their overall comfort. Most IAQ complaints in office environments are due to perceptions of thermal comfort. Such perceptions are highly subjective and vary from one individual to the next.

Air temperature control ranges and relative humidity (RH) play a significant role in comfort. Clothing, worker activity level, metabolic rates, air movement, cultural norms, seasonal changes, and the temperature of surrounding surfaces can also contribute to perceptions of thermal comfort.

Guidelines developed by the CSA Group recommend that indoor building temperatures range from 20 degrees Celsius (°C) to 23.5°C in the colder (winter) months and between 23°C and 26°C in the warmer (summer) months (CSA 2017). ASHRAE guidelines suggest similar ranges (ASHRAE 2017). The conditions at which most workers feel comfortable differ between winter and summer seasons because of the amount and type of clothing worn as well as worker activity. Most building occupants feel most comfortable at the mid-point of the ranges specified.

The temperature and relative humidity in a workspace should be as uniform as possible. The human body can perceive a temperature differential of as little as 0.5ºC and variations in an indoor work environment as little as 1ºC can create discomfort. Cooler areas in a workspace are typically perceived to be more fresh and pleasant.

Relative humidity refers to the amount of moisture present in the air relative to the maximum amount of moisture possible in the air at the current temperature. Based on ASHRAE (2016) and Health Canada (1995) guidelines, a range of 25% to 60% is generally considered acceptable in occupied spaces. When RH levels exceed 60%, occupants may complain of "muggy" air and may experience breathing difficulties. RH below 25% is associated with increased discomfort due to drying mucous membranes and eyes, associated irritation, and drying skin that can lead to chapping and irritation (ASHRAE 2017). Low RH may also potentially contribute to respiratory illness (AIHA 2016) by weakening the body's defense mechanisms that rely on moist mucous membranes.

2.5.2 Irritants

Building occupants can find some airborne contaminants irritating at concentrations well below the threshold at which the contaminant could present a potential health hazard. Common irritants include perfumes or other scented products, pollen, dust, and VOCs that can off-gas from construction activities or new building finishes. Symptoms of exposure to irritants include headaches, watery eyes, runny nose or congestion, mild nausea, and mild allergic-type reactions. While irritants, by definition, are not expected to cause long-term or serious health effects, they can impact the productivity and morale of the affected occupant and can often be perceived as a health concern.

2.5.3 Odours

Odours in indoor building environments can originate from many different sources, including building materials, building occupants, activities conducted within, or items stored in the building. Common complaints include odours related to roofing work, new building construction or renovations, and entry of sewer gases through (typically dry) plumbing fixtures.

The nature of odours, and their potential impact on IAQ, is often misunderstood.

Odours from various gases, vapours, or fumes can be detected or “smelled” by humans. Detecting an odour can sometimes serve as an effective warning of hazardous conditions, although not every odour indicates a hazard. Many objectionable odours or smells indicate the presence of non-hazardous substances. Objectionable odours can often indicate the presence of potentially hazardous substances, but at concentrations too low to present a hazard.

Due to the sensitivity of the human nose, the odour detection threshold (i.e. the lower concentration limit at which an airborne substance can be detected by approximately 50% of the population) for many potentially hazardous substances is orders of magnitude lower than the concentration at which that substance is known to potentially cause harm to those exposed. Objectionable odours that do not indicate the presence of hazardous concentrations of contaminants can cause irritation or annoyance to building occupants, or may simply trigger occupant concerns when detected. In many cases, odours can be noted at concentrations not detectable on scientific instruments. In other instances, humans cannot detect the odour of hazardous substances until well beyond concentrations at which such substances can cause harm. Therefore, in the context of IAQ, odours should be considered useful indicators of potential IAQ problems, but are not diagnostic of a health hazard without further investigation.

2.6 OTHER CONSIDERATIONS

This guideline provides information on the most common parameters that are encountered (or considered) in IAQ assessments. Further guidance on additional, less common, contaminants can be found in various publications, as referenced in Appendix D and Appendix E.

Other conditions within the indoor environment can contribute to occupants' perception of poor IAQ and can pose challenges to an investigator when determining if an IAQ issue truly exists. Some of these conditions include:

- Excessive noise
- Improper lighting
- Poor workspace ergonomics
- Psychosomatic responses or disorders

Additional information on these physical and psychosocial factors, including causes, solutions, and investigation strategies can be found in the *IAQ Investigator's Guide* (AIHA 2016).

3.0 IAQ MANAGEMENT

Basic management strategies can help prevent IAQ issues and can provide guidance on how to resolve any IAQ concern.

3.1 IAQ MANAGEMENT PROGRAMS

The objective of an IAQ Management Program (IAQMP) is to provide a consistent approach on how to manage, prevent, and resolve IAQ issues to provide all occupants with a safe and comfortable environment. For any program to be successful and effective, the building's senior management must provide adequate support and resources.

3.1.1 Program Components

The following components should be included in an IAQMP:

- Goals and objectives (or purpose)
- Scope and applicable guidelines
- Roles and responsibilities (of building management personnel, tenants, contractors, other stakeholders)
- Procedures and protocols:
  - HVAC assessments
  - Proactive IAQ assessments
  - Procedures to respond to IAQ concerns
  - Preventative maintenance
  - Management of change
  - Water and moisture
- Education and training
- Document control (or record-keeping)
- Program review
- Definitions
- Applicable forms to be used

3.1.1.1 Typical Procedures and Protocols

A key element of the IAQMP is the proactive IAQ assessment, as described in Section 4.2. The proactive IAQ assessment will identify actual and potential IAQ problems, as well as demonstrate the effectiveness of the IAQMP.

The IAQMP should also include procedures or protocols to manage potential contaminant sources. These protocols should be customized to the building function, occupancy type, and geographic locations, and provide step-by-step instructions for those who must carry them out.

Typical procedures or protocols can include the following:

- Preventative Maintenance:
  - Review building mechanical systems and components at specified intervals to check that all systems are operating at peak performance and according to manufacturer's specifications.
- Housekeeping Program:
  - Since particulates and contaminants can enter the indoor environment through internal sources or by external pathways, an adequate housekeeping program can provide essential controls to limit indoor contaminants.
- Remodelling and Renovation (Management of Change):
  - Construction activities associated with remodelling and renovations can introduce several contaminants into interior spaces without protocols to control their migration.
- Pest Control:
  - Strategies for pest prevention and non-pesticide controls can eliminate or reduce the need for pesticide application.
- Shipping and Receiving:
  - A significant external pathway for contaminants can include the vehicle traffic in shipping and receiving areas.
- Moisture and Mould Growth:
  - Inspections, inventory of past water leaks/infiltration, and source sampling are the primary means of determining whether mould contamination exists.
- Occupant Complaint System:
  - This allows the end user to participate in the IAQMP and communicate concerns that will be documented and addressed.
- Program Review:
  - Ensure the elements of the program are implemented, effective, and regularly evaluated/updated as needed.

3.2 MITIGATION STRATEGIES

3.2.1 Source Control

How a building functions and is managed can affect the quality of the indoor air. By implementing an effective IAQMP, most issues and possible sources of contaminants can be mitigated or managed before occupant complaints and/or symptoms arise.

However, IAQ concerns still occur, even in the best managed facilities. When this occurs, and a specific source can be identified through the investigative process, the most effective solution will always be eliminating the source or substituting with a non-hazardous equivalent. A secondary strategy may involve isolating the source, which is optimally achieved using both physical separation and ventilation isolation from occupied areas.

In situations where sources are not well defined, or are variable and periodic, improving comfort, odour, and IAQ perception factors may also be effective in improving occupant perceptions.

Administrative or policy-based changes may be implemented to improve IAQ. These changes may include:

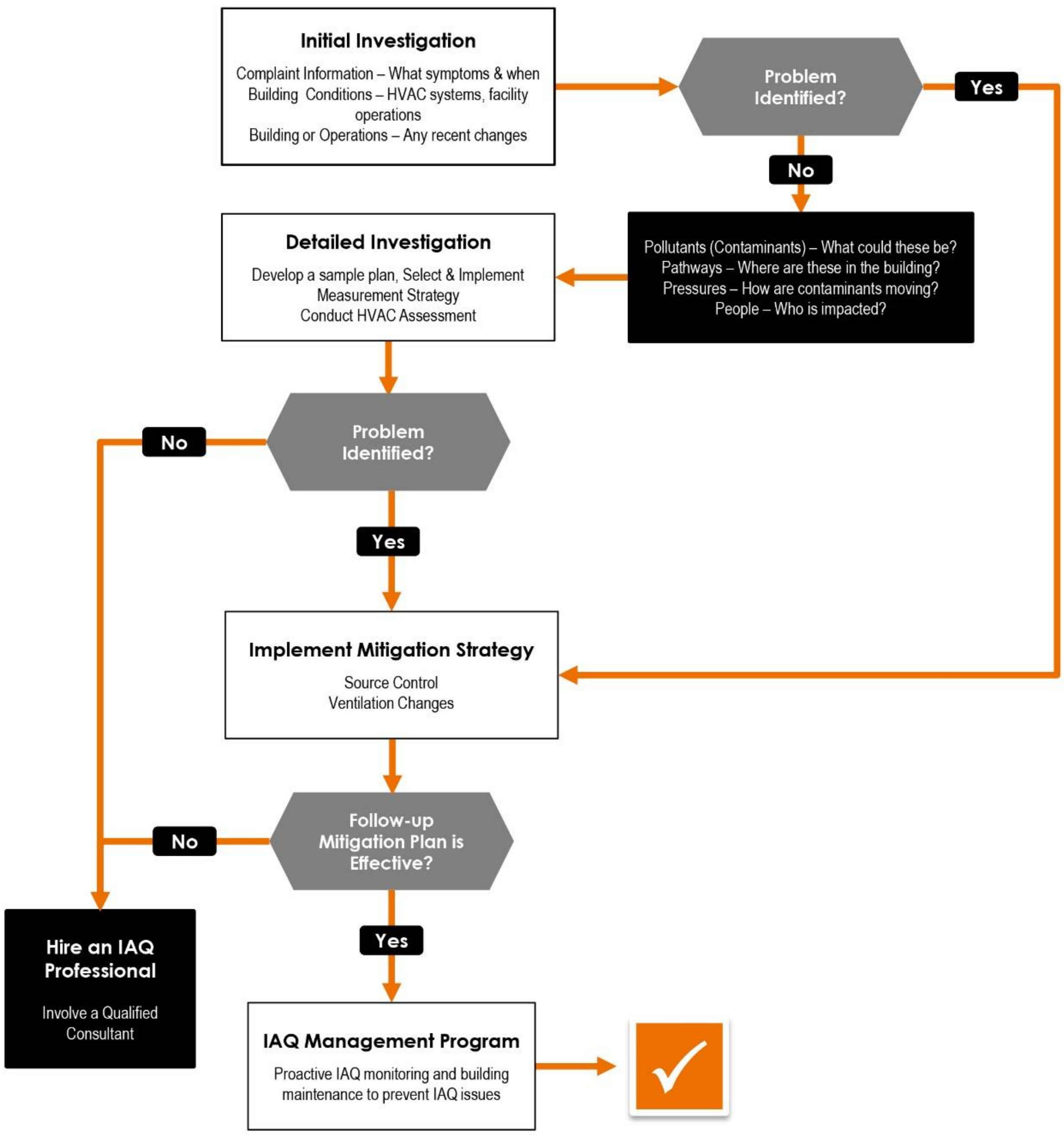
- Procuring new furnishings, cleaning products, etc.
- Using “green” cleaning products
- Creating fragrance-free areas
- Expanding no smoking areas at entrances or designating the entire property as smoke-free

4.0 CONDUCTING AN IAQ ASSESSMENT

An IAQ assessment should follow a systematic approach to ensure that the common IAQ factors or parameters are considered. IAQ assessments can be **proactive** (i.e. regularly scheduled for due diligence or certification purposes) or **reactive** (i.e. in response to an occupant concern).

Figure 3 provides an overview of the IAQ assessment process. The process is further described in the following sections.

Figure 3: Key Steps to Conduct an IAQ Assessment



4.1 HVAC ASSESSMENTS

Whether the assessment is proactive or reactive, an inspection or review of a building's HVAC system is integral to understanding the air quality of an indoor environment.

The goal of an HVAC assessment is to confirm that HVAC components are functioning as intended, the system is adequate for the current use and occupancy of the space, and the system is free of internal contamination which would potentially impact IAQ.

For proactive assessments, all main air handling equipment and a representative number of supplemental and terminal systems should be inspected. Reactive assessments should include any air handling equipment which serves the area of concern.

The following HVAC system elements should be reviewed as part of any IAQ assessment. Detailed checklists for HVAC equipment and components are available from several sources outlined in Appendix D and Appendix E and can also be developed or customized to be building specific, as needed.

Ventilation Component	Assessment Considerations
Outdoor Air Intakes	• Proximity to contaminant sources, such as building exhausts cooling towers, stagnant water and/or biofilms, vehicular exhaust sources, cigarette smoke, sanitary and storm sewer manholes, or vents • Blockages from nesting of birds or other pests in or near the air intake • Cleanliness of intake louvres, grilles, or screens • Damper settings (% open)
Unit Internals/Plenums	• Cleanliness • Presence of standing water inside the condensate pans of the cooling coil condensate drainage system • Condition of internal insulation • Mould
Filtration Systems	• Type of filtration (e.g. media, carbon, UV) • Efficiency • Integrity of fit to prevent air bypass • Particulate loading • Adequate schedule for filter changes
Heating/Cooling Equipment	• Type of system (e.g. gas, water, refrigerant) • Cleanliness and condition of coils/exchangers • Condensate removal • System temperature • Seasonal operation
Humidifiers	• Type of system (e.g. evaporative, spray, steam, ultrasonic) • Cleanliness and condition of bars/nozzles/evaporative media • Presence of standing water • Water source (steam from domestic cold water, treated boiler water, etc.)

Ventilation Component	Assessment Considerations
Supply Fans	• Capacity is sufficient for application • Constant or variable volume • Cleanliness and condition of fan inlet, housing, and frame • Static pressure
Ductwork, Registers, Diffusers	• Cleanliness of ductwork internals • Dust accumulation on diffusers, registers, and grilles • Condition of internal insulation (if present) • Blockages (fire dampers, fallen insulation) • Leakage • Mould
Terminal Units	• Cleanliness • Filters
Return Air Systems (including open ceiling void return)	• Cleanliness of return air plenums and ductwork • Damper settings (% open)
Exhaust Systems	• Operating to reduce contaminant sources such as washrooms, cooking facilities, parking areas, etc. • Damper settings (% open)
Controls and Sensors	• Set points for temperature/humidity • Carbon dioxide or VOC-based demand ventilation sensors and set points • Calibration of sensors • Thermostats • Confirm any seasonal adjustments to settings

4.2 PROACTIVE ASSESSMENTS

The objective of a proactive IAQ assessment is to assess indoor environmental conditions in the building and to identify potential problems or risks that may exist with respect to indoor air quality. Assessments help identify any variations in air quality with time and provide confirmation that the quality of the air being supplied by the air handling units is satisfactory.

Proactive IAQ assessments are often undertaken on an annual or semi-annual basis, depending on the building's requirements. The assessments provide a record of site conditions for the property manager or tenant to reference in the event of subsequent occupant concerns. The assessments include a review of conditions of HVAC equipment and measurements collected within occupied areas of the building to identify issues that may affect air quality. This routine check can help avoid serious IAQ problems.

The following are the recommended steps for conducting a proactive IAQ assessment.

Conducting an IAQ Assessment

1. Interview with building management, and where possible, with building occupants and/or workplace joint health and safety committee representatives to gather information regarding:
   a. Building construction age
   b. HVAC design, maintenance, operations, and settings
   c. Recent or current renovation work or re-configuring of tenant spaces
   d. Occupancy levels
   e. IAQ complaints or concerns reported
   f. Historical leaks or mould remediation work completed
   g. Cleaning practices and products used
2. A walkthrough visual inspection of each floor to identify any of the following that may potentially affect IAQ:
   a. Any noticeable odours
   b. Evidence of any renovation work or re-configuring of tenant spaces
   c. Indications of occupant discomfort (e.g. fans, heaters, humidifiers)
   d. Evidence of leaks or mould growth (e.g. stained ceiling tiles, carpet staining)
   e. Housekeeping items (e.g. dust accumulation on surfaces, or dust accumulation or staining on air supply and return vents, unusual waste accumulation, presence of plants, aquariums)
   f. Indications of pests
   g. Chemical storage areas
   h. Presence of floor drains
   i. Operational shading for windows
   j. Operational windows
   k. Location of air supply and return vents relative to occupants
   l. Location of loading docks (e.g. vehicle traffic)
3. A walkthrough visual inspection of mechanical spaces to identify HVAC components that may potentially affect IAQ (see Section 4.1)
4. A review of the building exterior to determine adjacent contaminant sources and pathways for contaminants to affect the indoor environment:
   a. Location of outdoor air intakes
   b. Smoking areas near building entrances
   c. Adjacent construction activities
   d. High vehicle traffic areas
   e. Neighbouring facilities
5. Collection of IAQ samples (using approved passive or active air sampling methodologies) or instantaneous “spot” measurements (using direct-reading instruments):
   a. Refer to Section 2.4 for a preliminary list of potential parameters to sample or measure
   b. Select representative locations on each occupied floor (i.e. open office areas, private offices, meeting spaces within each ventilation zone)
   c. Where instantaneous measurements are elevated or outside of the recommended ranges, further investigation of the area should be conducted to identify a potential source of the measurement
   d. Collection of outdoor reference IAQ measurements

4.3 REACTIVE ASSESSMENTS

The objective of a reactive IAQ assessment is to address a specific issue or concern, often as a result of an occupant complaint. Occupant concerns may range from non-specific symptoms such as headaches, fatigue, and odours, to potentially serious health and safety concerns. In any case, building occupants should request an investigation into the nature and origin of the concern.

Like proactive assessments, the reactive assessment includes a review of conditions of HVAC equipment and measurements collected within occupied areas of the building but are specific to the type and area of concern. If occupants are experiencing acute symptoms, or for more immediate concerns, follow the applicable emergency procedures.

The following are the general recommended steps for conducting a reactive IAQ assessment in **non-emergency situations**. Once information has been gathered regarding the concern, this process can be further refined so it is applicable to the specific situation:

1. Interview with knowledgeable stakeholders including, but not necessarily limited to, building facility management, tenants, and joint health and safety committee representatives to gather information regarding:
   a. The nature and timing of the IAQ concerns
   b. Any symptoms reported by occupants
   c. The timing and the duration of the symptoms (are they experienced only when in the building)
   d. Existing water leaks or mould concerns
   e. Historical leaks or mould remediation work completed
   f. Cleaning practices and products used
   g. Occupancy levels at the time of the IAQ concern
   h. Any changes in occupancy levels
   i. HVAC design, maintenance, operations, and settings

2. Review existing records that could supplement the investigation, including:
   a. Construction and design drawings
   b. Any previous IAQ reports
   c. Incident reports

3. A walkthrough visual inspection of the area of concern to gather additional insight into the nature of the concern or to identify any of the following that may potentially impact IAQ:
   a. Any noticeable odours
   b. Evidence of any renovation work or re-configuring of tenant spaces
   c. Indications of occupant discomfort (e.g. fans, heaters, humidifiers)
   d. Evidence of leaks or mould growth (e.g. stained ceiling tiles, carpet staining)
   e. Housekeeping items (e.g. dust accumulation on surfaces, or dust accumulation or staining on air supply and return vents, unusual waste accumulation, presence of plants, aquariums)
   f. Indications of pests
   g. Chemical storage areas

   h. Presence of floor drains
   i. Operational shading for windows
   j. Operational windows
   k. Location of air supply and return vents relative to occupants
   l. Location of loading docks (e.g. vehicle traffic)

4. A walkthrough visual inspection of HVAC system servicing the area(s) of concern to gather additional insight into the nature of the concern or to identify any component that may potentially affect IAQ (see Section 4.1)

5. To supplement the gathered information and visual observations, a sampling plan may be required.

4.4 DEVELOPING A SAMPLING PLAN

An air sampling or monitoring plan may be required to allow for a qualitative and quantitative perspective of the concern. The objective of any air sampling plan is to identify contaminants suspected to be present and their respective concentrations, which may reveal useful patterns for determining potential causes.

When selecting a sampling methodology, consider the following:

- Most applicable guideline limit
- Available sampling methodologies (and their minimum detection limit)
- Ease of use
- Costs

At a minimum, the sampling plan should include the chosen methodology and the published guideline, standard, or regulation to which the results will be compared. This will determine how the samples will be collected and analyzed.

Additionally, site-specific factors should be considered when developing a sampling plan:

1. Physical sample locations:
   a. Pre-determined “affected” and “unaffected” areas
   b. Include samples at outdoor air intakes
   c. Target worst-case conditions or conditions for typical occupancy

2. Time of sample collection:
   a. Morning and/or afternoon to provide comparative data
   b. Continuous monitoring to determine patterns and temporal variations

3. Receptor or source measurement:
   a. Sampling at the breathing zone of occupants (standing or sitting)
   b. At locations where there may be potential emissions from a specific process or piece of equipment

4.5 MEASUREMENT STRATEGIES

Most general IAQ assessments adopt a standard set of core parameters to sample which are related to common potential sources of contamination. These include carbon dioxide, carbon monoxide, particulate matter, VOCs, formaldehyde as well as temperature and relative humidity. However, these may not be appropriate in every situation. An initial inspection and professional judgment must be exercised to determine potential sources and contaminants.

When developing the sampling strategy for an IAQ investigation, multiple sampling methodologies are available for the potential parameters. The viability or practicality of the chosen method of sampling and analysis must consider factors such as cost, time, availability of resources, and the limitations of the equipment and analysis.

4.5.1 Active

Active sampling involves drawing a known volume of air through a sampling media/collector by means of a pump over a known period of time, such that the contaminants are trapped in the media that is then analyzed by a specified analytical method. Results are then provided with a unit of air contaminants per volume of air.

4.5.2 Passive

Passive air sampling involves the diffusion of gases or vapours (only) through a device with a static air space or permeable membrane. The contaminants are trapped in the sampling media then analyzed by a specified analytical method. Results provide a unit of air contaminants per unit volume of air, based on the amount of time the device is unsealed and a set sampling rate provided by the manufacturer of the device.

4.5.3 Direct-Reading Instruments

The goal of the investigation can determine how direct-reading instruments will be used in the overall sampling plan. In cases where the sampling is being conducted to meet the requirements of a prescriptive guideline, occupational exposure limit, sustainability certification, internal procedure or project specification, the sampling methodology may have specific requirements that limit the use of direct-reading instruments.

However, if the contaminant of concern and the potential source(s) are unknown, a direct-reading instrument can be a valuable screening tool to identify elevated concentrations of a specific contaminant or group of contaminants. If a specific airborne contaminant is known, a direct-reading instrument can also be useful for a preliminary or limited investigation. If an investigation requires real-time data to identify the source of a contaminant or how concentrations are distributed over a geographical area at the time of the investigation, the direct-reading instrument will be most appropriate. These instruments can also provide data on contaminant spikes or peaks with reference to the time and location they occurred.

Direct-reading instruments require precise application and maintenance for the results to be meaningful and reliable. The equipment will require calibration annually and/or prior to each use, in accordance with the manufacturer’s specifications and may have specific selectivity, interferences, or sensitivity to environmental factors, such as temperature and humidity.

5.0 HIRING AN IAQ PROFESSIONAL

For situations where the source cannot be identified, and the occupant complaint cannot be resolved or is more serious, hiring an IAQ professional or consultant may be necessary.

A third-party often provides an independent and objective evaluation and allows for the involvement of a professional with the necessary technical expertise and experience to provide a solution.

For most issues, mechanical engineers and industrial/occupational hygienists will provide the appropriate body of knowledge to do a thorough assessment. Additional experience or certification may be required for specific investigations involving asbestos, mould, radon, sustainability certification, soil vapours, lighting, acoustic design, etc.

When evaluating the qualifications of a third-party IAQ professional, consider the following:

1. Will the project be conducted by a Professional Engineer, Registered Occupational Hygienist (ROH), or Certified Industrial Hygienist (CIH)?
2. Does the consultant team have prior experience with work of a similar type and scale?
3. Do the technicians who will perform the assessment have experience and training?
4. Does the consultant have insurance? This includes errors and omissions, professional liability, and personal injury insurance.
5. Does the consultant have a written planned assessment approach?
6. Can the consultant provide client references for past work?

Additional factors to consider verifying the consultant’s experience and subject matter expertise include:

- Purpose of proposed sampling for the specific parameters listed in the proposal
- How the results will be compared against the specific limits
- Approved sampling method (“validated”) method (e.g. OSHA or NIOSH method) to be used
- Use of accredited laboratories, such as American Industrial Hygiene Association (AIHA), Industrial Hygiene Laboratory Accreditation Program (IHLAP), Canadian Association for Laboratory Accreditation (CALA), Canadian National Radon Proficiency Program (C-NRPP), etc.
- Type of equipment that will be used for the sampling and air monitoring

There are currently no provincial or federal requirements for consultants providing professional IAQ services. However, several professional associations publish consultant’s directories. The following resources are provided to assist in selecting qualified consultants. It remains the responsibility of the individual using these directories to verify a consultant’s competencies and qualifications.

American Industrial Hygiene Association: *https://www.aiha.org/publications-and-resources/Pages/Consultants-Listing.aspx*

Canadian National Radon Proficiency Program: *https://c-nrpp.ca/find-a-professional/*

Canadian Registration Board of Occupational Hygienists: *http://www.crboh.ca/*

Occupational Hygiene Association of Ontario: *https://www.ohao.org/index.php/consultantsdirectory*

Environmental Abatement Council of Canda: *http://www.eaccanda.ca*

Professional Engineers of Ontario: *http://www.peo.on.ca/index.php?ci_id=1798&la_id=1*

APPENDICES

Appendix A DEFINITIONS

American Conference of Governmental Industrial Hygienists (ACGIH): A professional association of industrial hygienists and practitioners of related professions whose goal is to advance worker protection by providing timely, objective, scientific information to occupational and environmental health professionals.

American Nation Standards Institute (ANSI): A US-based organization that oversees the creation, promulgation, and use of thousands of norms and guidelines that directly affect businesses in nearly every sector. ANSI is actively engaged in accreditation, assessing the competence of organizations determining conformance to standards.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): A global professional association seeking to advance heating, ventilation, air conditioning and refrigeration systems design and construction.

Allergens: A substance that causes an allergic reaction.

BOMA BEST: A national green building certification program launched by BOMA Canada in 2005 to address an industry need for realistic standards for energy and environmental performance of existing buildings based on accurate, independently verified information.

Building-Related Illnesses: Disorders or illnesses that affect an occupant and are suspected to be caused by exposure to substances in modern, airtight buildings.

Bioaerosols: Biological particles that are airborne, such as:

- **Viruses:** An infective agent that typically consists of a nucleic acid molecule in a protein coat. Viruses are too small to be seen by light microscopy and can only multiply inside the living cells of a host.
- **Fungi:** Unicellular, multicellular, or syncytial spore-producing organisms that feed on organic matter. Fungi include moulds, yeast, mushrooms, and toadstools.
- **Bacteria:** Unicellular microorganisms that lack a membrane-bound nucleus, mitochondria, or any other membrane-bound organelles. Bacteria are typically a few micrometres in length and have several shapes, ranging from spheres to rods and spirals.
- **Nematodes:** Also known as roundworms, nematodes are a diverse animal phylum inhabiting a broad range of environments.
- **Amoeba:** A type of cell or organism that can alter its shape.
- **Pollen:** A fine to coarse powdery substance comprising pollen grains, which are the male portion of seed plants that produce male gametes (sperm cells).
- **Dander:** Material shed from the body of humans and various animals that have fur, hair, or feathers.

- **Mites:** Tiny arthropods, less than 1 mm in length, that have a simple, unsegmented body plan. Mites have adapted to many different environments: some species live in water, many live in soil as decomposers, and others live on plants, sometimes creating galls (abnormal growths). Some mite species are predators or parasites.

Canada Green Building Council (CaGBC): A not-for-profit, national organization that has been working since 2002 to advance green building and sustainable community development practices in Canada. The CaGBC is the licence holder for the LEED green building rating system in Canada and supports the WELL Building Standard and GRESB (Global Real Estate Sustainability Benchmark) in Canada.

Canadian Standards Association (CSA) Group: A global organization dedicated to safety, social good, and sustainability. The CSA Group is a leader in developing standards and in testing, inspection, and certification around the world including Canada, the U.S., Europe, and Asia.

Certified Industrial Hygienist (CIH): An industrial hygiene practitioner who has become certified through the American Board of Industrial Hygienists (ABIH). A CIH maintains workplace health and safety by identifying, evaluating, and controlling exposure to chemical, physical, ergonomic, and biological hazards.

Contaminant: A polluting or poisonous substance that makes something impure. Contaminants can be present in various forms, such as:

- **Fumes:** Solid particles formed by condensation from the gaseous state (e.g. lead fume).
- **Gases:** Formless fluids usually produced by chemical processes involving combustion or by the interaction of chemical substances. Gases will completely fill the space into which it is released (e.g. carbon monoxide, nitrogen dioxide).
- **Mists:** State of matter with definite volume but no definite shape, like water. The routes of entry for liquids could be ingestion and skin contact. If finely dispersed, liquids become a mist and can be inhaled.
- **Particulate Matter:** Solid or liquid particles in the air with a diameter of 10 micrometers (µm) or less. Displayed as PM_{10}, where the subscript number indicates the diameter of the particle.
- **Smoke:** A substance made up of small particles of carbonaceous matter in the air, resulting mainly from the burning of organic material, such as wood or coal.
- **Vapours:** Gaseous form of a material normally encountered in a liquid or solid state at normal room temperature and pressure (e.g. paint thinners, acetone).

Diesel Particulate Matter: Gaseous exhaust produced by a diesel type of internal combustion engine, plus any contained particulates. Its composition may vary with the fuel type or rate of consumption, or speed of engine operation and type of engine. Diesel particulate matter primarily consists of carbon dioxide, water, and nitrogen.

Ergonomics: Application of psychological and physiological principles to the engineering and design of products, processes, and systems.

Filtration Efficiency: A measure of how efficiently a filter removes airborne particles from the air stream as the particles pass through the filter. The most common rating system for comparing air filters is the

MERV Rating (Minimum Efficiency Reporting Value), developed by ASHRAE. This rating is recognized as an industry standard, both domestically and internationally.

Heating, Ventilation and Air Conditioning (HVAC): The technology of indoor and vehicular environmental comfort. Its goal is to provide thermal comfort and acceptable indoor air quality. HVAC system design is a subdiscipline of mechanical engineering, based on the principles of thermodynamics, fluid mechanics, and heat transfer. Source: https://en.wikipedia.org/wiki/HVAC.

Irritant: A substance that causes slight inflammation or other discomfort to the body.

Leadership in Energy and Environmental Design (LEED): The most widely used green building rating system in the world. LEED includes a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighbourhoods that aims to help building owners and operators be environmentally responsible and use resources efficiently.

Mass Psychogenic Illness (MPI): Also known as mass sociogenic illness, MPI is the spread of illness signs and symptoms affecting members of a group, originating from a nervous system disturbance involving excitation, loss, or alteration of function, whereby physical complaints that are exhibited unconsciously have no corresponding cause (e.g. reports of headaches, nausea, and fainting triggered by an odour).

Metabolic Rates: The rate of energy expenditure per unit time by humans at rest.

Negative Pressure: Generated and maintained by a ventilation system that removes more exhaust air from the room than air is allowed into the room.

Occupational Exposure Limit (OEL): A restriction on the amount and length of time a worker is exposed to airborne concentrations of hazardous biological or chemical agents. Three types of OELs have been defined:

- 8-hr occupational exposure limit (**TWA**): the time-weighted average airborne concentration of a biological or chemical agent to which a worker may be exposed in a standard work day.
- 15-minute or short-term exposure limit (**STEL**): the maximum airborne concentration of a biological or chemical agent to which a worker may be exposed in any 15-minute period.
- Ceiling limit (**C**): the maximum/peak airborne concentration of a biological or chemical agent to which a worker may be exposed at any time.

Odour Detection Threshold: The lower concentration limit at which an airborne substance can be detected or “smelled” by approximately 50% of the population.

Polycyclic Aromatic Hydrocarbons (PAH): Organic compounds containing only carbon and hydrogen, composed of multiple aromatic rings.

Professional Engineer: An individual who has fulfilled education and experience requirements and passed rigorous exams, allowing them to offer engineering services directly to the public, including: any act of planning, designing, composing, evaluating, advising, reporting, directing, or supervising (or the managing of any such act) that requires the application of engineering principles and concerns the safeguarding of life, health, property, economic interests, the public welfare or the environment, or the managing of any such act.

Psychosomatic Responses or Disorders: A disease or disorder that involves both mind and body. Some physical diseases may be particularly prone to be made worse by mental factors such as stress and anxiety.

Registered Occupational Hygienist (ROH): An occupational hygiene practitioner who has become certified through the Canadian Registration Board of Occupational Hygienists (CRBOH). An ROH maintains workplace health and safety by identifying, evaluating, and controlling exposure to chemical, physical, ergonomic, and biological hazards.

Sick Building Syndrome (SBS): A condition affecting office workers, typically marked by feeling generally unwell or with flu-like symptoms, headaches, irritation of eyes, nose and throat, and respiratory problems, attributed to unhealthy or stressful factors in the working environment such as poor ventilation.

Total Volatile Organic Compound (TVOC): A grouping of a wide range of organic chemical compounds. Using TVOC simplifies reporting when these compounds are present in ambient air or emissions.

Units of Measurement:

- Parts per billion (ppb): the number of units of mass of a contaminant per 1,000 million units of total mass.
- Parts per million (ppm): the number of units of mass of a contaminant per million units of total mass.
- Milligram per cubic meter of air (mg/m^3)
- Microgram per cubic meter of air ($\mu g/m^3$)

Ventilation: The act or process of ventilating; circulation of air in a room with good ventilation; a system or means of providing outdoor air.

Volatile Organic Compound (VOC): Organic chemicals that have a high vapour pressure at standard room temperature. Their high vapour pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublimate from the liquid or solid form of the compound and enter the surrounding air, a trait known as volatility.

WELL Building Standard: The first rating system to focus exclusively on the ways that buildings, and everything in them, can improve our comfort, drive better choices, and generally enhance, not compromise, our health and wellness. This rating system is delivered by the International WELL Building Institute™ (IWBI™).

Appendix B SUMMARY OF TYPICAL INDOOR AND OUTDOOR SOURCES

Appendix B Summary of Typical Indoor and Outdoor Sources

Table 1: Common Indoor Sources of IAQ Issues in Buildings

Source	Typical Contaminants of Concern	Key Contributing Factors	Possible Preventative/Control Measures
Parking Garages	CO, CO_2, soot, particulates, vehicle emissions including diesel exhaust	• Insufficient ventilation • Poor CO controls	• Increase exhaust and outdoor air ventilation rates • Calibrate CO sensors
Loading Docks / Shipping and Receiving	Diesel exhaust, CO, CO_2	• Insufficient ventilation • Air intakes located near vehicles	• Increase outdoor air ventilation in area • Require engine shut-off during unloading • Relocate building air intakes away from source • Pressurize building relative to outdoor environment
Mechanical Areas with Combustion Appliances (e.g. fossil fuel fired boilers/heaters, portable generators)	CO	• Damaged or improper/insufficient exhaust ventilation for appliances	• Perform regular visual inspections of combustion appliances • Perform regular monitoring for CO concentrations (or install fixed CO monitors) • Remove from service and perform immediate repairs if issues found
Indoor Construction / Renovation Areas	Formaldehyde, VOCs, objectionable odours, particulates, diesel particulate matter	• Off-gassing of VOCs from newly-installed building finishes (e.g. paint, furniture, carpeting, wall and floor coverings, etc.) • Cutting, drilling, grinding, etc. of building materials without sufficient dust suppression/control/ isolation measures • Use of diesel-powered lifts or other construction equipment indoors • Exfiltration of construction generated contaminants to occupied areas	• Ensure qualified person reviews safety data sheets for paints and finishes prior to use • Depressurize work area relative to rest of building during work • Use fast-drying, low-VOC emitting paints and finishes • Conduct work during unoccupied hours • Minimize spray-application of paints and finishes • Increase outdoor air ventilation to entire building during and after work • Use walk-off "sticky" mats • Isolate work areas where dust (particulates) will be generated and place under negative pressure during work, or use cutting or grinding tools with purpose-built, HEPA-filtered exhaust ventilation at working surface of tool • Use electrically powered construction equipment indoors
Office Areas – Humidifiers and Aquariums	Bioaerosols (airborne mould, bacteria), high relative humidity	• Insufficient cleaning/ sterilization of interior surfaces	• Restrict/ban use of personal humidifiers • Implement requirements for regular inspection and cleaning

Appendix B Summary of Typical Indoor and Outdoor Sources

Source	Typical Contaminants of Concern	Key Contributing Factors	Possible Preventative/Control Measures
Office Areas – Windows that Open	Temperature and relative humidity fluctuations	• Occupant-adjustable windows can circumvent building ventilation system design and contribute to existing occupant comfort issues or create new ones	• Consider preventing windows from being opened by non-mechanical staff
Office Areas – People-Related Sources	Objectionable odours, VOCs	• Insufficient outdoor air ventilation for number of occupants • Use of scented products including perfumes, lotions, etc.	• Ensure outdoor air ventilation meets recommended parameters based on occupancy (CO_2 levels commonly a proxy) • Restrict use of scented products within the workplace
Office Areas – Plants	Airborne mould, bacteria	• Large numbers of indoor plants	• Implement regular maintenance on plants and potting soil
Office Areas – Air Cleaners	Ozone	• High localized levels of ozone can result from use of certain types of electrostatic cleaners	• Ensure adequate ventilation in the area
Food Preparation Areas	Objectionable odours, high temperatures and relative humidity	• Insufficient isolation of cooking areas from rest of building	• Negatively pressurize kitchen areas relative to other areas of the building while ensuring sufficient volume of makeup air is provided • Increase outdoor air ventilation to areas affected by food odours
Pools	High relative humidity	• Insufficient isolation from rest of building	• Negatively pressurize pool areas relative to other areas of the building while ensuring sufficient volume of makeup air is still provided • Increase outdoor air ventilation rates
Water-Impacted Areas	Mould	• Leaks from mechanical systems, indoor pools or water features or building envelope including roof • Failure to rapidly identify leaks and remove or dry damaged materials	• Maintain mechanical systems and building envelope to prevent leaks from occurring • Dry materials that become wet as soon as possible to reduce potential for mould growth • Obtain professional assistance if mould is visually identified • Use water-resistant building materials in construction

Source	Typical Contaminants of Concern	Key Contributing Factors	Possible Preventative/Control Measures
Animal Nested / Roosted Areas	Pathogenic microorganisms (bacteria/ fungi/viruses), allergens	• Unsealed entry points into building • Build-up of fecal matter, skin, hair, fur, etc.	• Identify and seal potential animal entry points • Retain a professional to assess and clean animal-related materials upon discovery in order to minimize disturbance / potential for contaminants to enter building • Establish an integrated pest management program
Janitorial Areas	VOCs, objectionable odours	• Application of janitorial products (e.g. cleaners, floor polishes) that emit high concentrations of VOCs	• Use low-VOC emitting janitorial products where possible • Select low-VOC emitting products with low-VOC certifications intended for indoor usage (not those intended for prevention of environmental damage)
Trash Storage Areas	Objectionable odours	• Build-up of trash due to insufficient frequency of removal • Trash storage areas insufficiently ventilated or not sufficiently isolated from rest of facility	• Provide dedicated exhaust for trash storage areas • Place trash storage areas under negative pressure relative to rest of building • Maintain a cooler temperature in the area
Other Specific Generation Sources within Buildings (e.g. laboratories, restaurants, repair shops, etc.)	Source-specific contaminants (often including objectionable odours and VOCs)	• Use of various products in area within inadequate ventilation	• Control measures will vary depending on source • Obtain professional assistance when establishing controls

Table 2: Common Outdoor Sources of IAQ Issues

Source	Typical Contaminants of Concern	Key Contributing Factors	Possible Control Measures
Construction Work Activities	Particulates, CO, CO_2	• Work conducted close to building perimeter, including: • Cutting, grinding, refinishing, etc. of concrete, brickwork or other finishes generating large quantities of airborne particulates • Use of heavy construction equipment near building perimeter	• Pressurize building relative to outdoors • Install more effective filtration at air handling units • Increase frequency of filter replacement as needed • Temporarily shut down and seal air intakes nearest work, or relocate air intake point further from work area • Minimize use of heavy equipment near building perimeter
Contaminated Soils, Underground Storage Tanks (USTs)	Source-specific soil gases/vapours (e.g. hydrocarbons, other VOCs, etc.)	• Soil gases/vapours may enter building through penetrations	• Maintain inventory of known USTs and replace when beyond manufacturer-specified service lifespan • Relocate any air ducts running through soil beneath building • Depressurize soil relative to building, seal foundation and penetrations in foundation • Coordinate with a qualified professional to assess and remediate suspected soil gas/vapour intrusion issues or leaking USTs
Weather	Temperature and relative humidity fluctuations	• Seasonal weather changes	• Consider installing/updating building automation system and temperature/RH sensors to automatically respond to changes in outdoor temperature and RH conditions
Forest Fires	Smoke (particulates, PAHs, soot)	• Entry of smoke into the building during an event	• Pressurize building relative to outdoors, install better filtration at air handling units, consider installing revolving doors or airlock doors near source if necessary, replace filters more frequently

Appendix B Summary of Typical Indoor and Outdoor Sources

Source	Typical Contaminants of Concern	Key Contributing Factors	Possible Control Measures
Vehicle Emissions	CO, CO_2, soot	• High levels of nearby vehicle traffic (including on roadways/highways) • Idling vehicles near building	• Enforce “no idling” policies near building • Design parking lots and roadways to keep vehicles away from doors, windows, and air intakes • Install devices to prevent opening of windows near sources of vehicle emissions • Pressurize building relative to outdoors, install better filtration at air handling units, consider installing revolving doors or airlock doors near source if necessary
Smoking	Formaldehyde, CO, VOCs	• Smoking near building	• Ban smoking on property or within a given radius of entry doors and air intakes • Pressurize building relative to outdoors • Consider installing revolving doors or airlock doors near source if necessary
Animal Nested / Roosted Areas	Pathogenic microorganisms (bacteria/ fungi/viruses), allergens	• Unsealed entry points into building • Build-up of fecal matter, skin, hair, fur, etc.	• Retain a professional to assess and clean animal-related materials upon discovery in order to minimize disturbance / potential for contaminants to enter building • Discourage animals from occupying locations on building exterior (e.g. install spikes on possible roosting areas) • Establish integrated pest management program
Location of Building Air Intake	Objectionable odours, VOCs	• Exhaust from heavy commercial tenants (e.g. drycleaners, photo processing, laundry) or food preparation areas / tenants (e.g. kitchens, restaurants) in multi-unit commercial or residential / commercial buildings may re-enter the building if air exhausts and intakes are not properly designed	• Generally, a professional will be required to assess and develop a strategy for resolving the issue • Relocate air intakes/exhausts away from source
Standing Water on Roof Near Air Intakes	Objectionable odours, microorganisms (e.g. mould, bacteria)	• Poor roof drainage can result in ponding that can encourages microorganism growth, and subsequent entry of microbial contamination into building	• Design/re-design roof to prevent ponding • Regularly inspect roof

Appendix B Summary of Typical Indoor and Outdoor Sources

Source	Typical Contaminants of Concern	Key Contributing Factors	Possible Control Measures
Aerosolization of Building Water (e.g. at cooling towers)	*Legionella* bacteria	• Insufficient control of water quality, combined with aerosolization at cooling towers, and potential entry into building via air intakes	• Complete a risk assessment of building system • Inspect and maintain building systems as recommended • Conduct sampling as required
Nearby Facilities	Objectionable odours, VOCs, CO, particulates	• Emissions from nearby industrial/manufacturing, public works (e.g. incinerator, utility, water treatment) or commercial (e.g. dry cleaning, auto body shop, gas station, restaurant) facilities or agricultural lands can affect quality of air entering building	• Pressurize building relative to outdoors, install better filtration at air handling units, increase frequency of filter replacement, locate air intakes as far from source as possible

Appendix C IAQ INDICATOR AND CONTAMINANT SUMMARY TABLE

Appendix C IAQ Indicator and Contaminant Summary Table

This table is not a comprehensive or complete list of IAQ contaminants, standards, and guidelines. EACC provides available information to assist the reader in making decisions when evaluating a space. The reader should consult the appropriate source of the suggested limits for applicability.

IAQ Indicator or Contaminant	Suggested Limits	Reference Source(s)	Common Sampling/Monitoring Strategies	Other Notes
Carbon Dioxide (CO_2)	**Outdoor concentration + (x) ppm** *Value of x depends on specific type of indoor environment as well as size and occupancy, and can be determined as per ASHRAE 62.1* *As a general guideline, x = 700 ppm will dilute odours from human bioeffluents to a level that will satisfy a substantial majority of unadapted, sedentary occupants of a space.*	ANSI/ASHRAE Standard 62.1-2016 *Ventilation for Acceptable Indoor Air Quality*	• Direct-reading instrument (handheld or fixed to structure), with 1 ppm resolution	• Typical indoor CO_2 concentrations: 500–800 ppm • Tasteless, odourless, colourless gas • Used as a surrogate measure of other contaminants in indoor air • Outdoor concentration + 700 ppm represents a general guideline for unadapted sedentary workers • ASHRAE Standard 62.1 provides equations for calculating ideal CO_2 limits for specific environments, where warranted. Refer to Table and Section 6.2.2.1 of ASHRAE 62.1 for further details. • Levels exceeding suggested limits may indicate a problem with overcrowding or inadequate outdoor air ventilation rates • Common sources of CO_2 include human respiration, combustion processes (e.g. cars, combustion appliances, etc.), and fermentation processes (winemaking, brewing, etc.)
	As CO_2 concentrations increase, occupant satisfaction decreases and perception of poor air quality and incidence of reported physical effects increases. At 650 ppm, the number of complaints is relatively limited. Complaints occur much more frequently > 1,000 ppm.	National Research Council of Canada - Construction Technology Update No. 64, Indoor Air Quality and Thermal Comfort in Open-Plan Offices, 2005		
Carbon Monoxide (CO)	**25 ppm** (1 hour average [hr avg.]) **10 ppm** (24 hr avg.)	Health Canada Residential Indoor Air Quality Guidelines	• Direct-reading instrument (handheld or fixed to structure), with 0.1 ppm resolution	• Typical indoor CO concentrations are < 2 ppm • Tasteless, odourless, colourless gas • High concentrations can result from poorly located air intakes, migration of air from adjacent spaces with combustion sources, smoking, vehicle exhaust entering building, poorly vented combustion appliances • Levels above 5 ppm suggest the presence of unvented combustion source or vehicle exhaust indoors. Source(s) should be identified and rectified
	11 ppm (8 hr avg.)	Health Canada Exposure Guidelines for Residential Indoor Air Quality		
	9 ppm or no greater than 2 ppm above outdoor concentration	Canada Green Building Council: LEED ID+C: Commercial Interiors, Credit 3.2: Indoor Air Quality Assessment		
	< 9 ppm	International Well Building Institute: WELL Building Standard v1 – Air Quality Standards		
	Values **>5 ppm suggest presence of poorly vented combustion sources**	Health Canada: Indoor Air Quality in Office Buildings, A Technical Guide		
Particulate Matter Fine Suspended ($PM_{2.5}$)	Maintain **concentrations as low as possible, and lower indoors than outdoors**	Health Canada Residential Indoor Air Quality Guidelines	• Direct-reading instrument with particle size section capability • Active air sampling via pre-weighted polyvinyl chloride (PVC) filters using size-selective impactor/cyclone (e.g. US EPA Method IP-10)	• Typical indoor $PM_{2.5}$ concentrations are 5–10 µg/m³ • Indoor levels exceeding outdoor levels indicate indoor activities or systems are a source of $PM_{2.5}$
	15 µg/m³	Canada Green Building Council: LEED ID+C: Commercial Interiors, Credit 3.2: Indoor Air Quality Assessment, International Well Building Institute: WELL Building Standard – Air Quality Standards		

Appendix C IAQ Indicator and Contaminant Summary Table

IAQ Indicator or Contaminant	Suggested Limits	Reference Source(s)	Common Sampling/Monitoring Strategies	Other Notes
Particulate Matter Respirable (~PM_{10})	**50 µg/m³**	ASHRAE 62.1	• Direct-reading instrument providing PM_{10} values (as proxy for respirable PM) • Active air sampling via pre-weighed PVC filters using size-selective impactor / cyclone (e.g. US EPA Method IP-10)	• Typical indoor PM_{10} concentrations are 5–30 µg/m³ • ACGIH (2019) offers a 3 mg/m³ guideline limit. This limit is not appropriate for non-industrial applications and should only be applied to types of particulate matter that (per ACGIH 2019 TLVs and BEIs): o Lack a published OEL or ACGIH TLV o Are insoluble or poorly soluble o Have low toxicity **TLV = Threshold limit value* *BEI = Biological exposure indices*
	50 µg/m³	Canada Green Building Council: LEED ID+C: Commercial Interiors, Credit 3.2: Indoor Air Quality Assessment International Well Building Institute: WELL Building Standard – Air Quality Standards		
Total Volatile Organic Compounds (TVOCs)	**1 mg/m³** (target level) or approx. 440 ppb **5 mg/m³** (action level) or approx. 2200 ppb	Health Canada: Indoor Air Quality in Office Buildings, a Technical Guide	• Direct-reading instrument (photoionization detectors [PID] with detection limit in the ppb range for TVOCs) • Active air sampling via sorbent tube (analysis via EPA Method TO-17, for a specific list of VOCs) • Air sampling via Summa ® canister (analysis via EPA Method TO-15, for a specific list of VOCs) • Open characterization via sorbent tube or Summa® canister (includes any VOC the lab can detect and identify)	• Typical TVOC concentrations are 50–350 ppb • Thousands of products typically found in indoor environments emit VOCs • An IAQ Investigator should always attempt to identify what sources are contributing to TVOC readings. If sources could present a hazard at levels below TVOC reading, consider additional substance-specific testing • TO-15 and TO-17 methods test for a specific list of VOCs, whereas open characterization includes any VOC the lab can detect and identify
	500 µg/m³	Canada Green Building Council: LEED ID+C: Commercial Interiors, Credit 3.2: Indoor Air Quality Assessment International Well Building Institute: WELL Building Standard – Air Quality Standards		
Formaldehyde	**40 ppb** (8 hr. avg.) **100 ppb** (1 hr. avg.)	Health Canada Residential Indoor Air Quality Guidelines	• Direct-reading instrument equipped with passive electrochemical sensor • Passive sampling badges/dosimeters (US EPA Method TO-11 and ASTM D5197, US EPA Method TO-11, ASTM D5197, OSHA 52, OSHA 1007) • Active air sampling with silica gel cartridges (NIOSH 2016, EPA IP-6, ASTM D 5197, NIOSH 2016, NIOSH 2541)	• Typical formaldehyde concentrations are 10-40 ppb • Colourless, flammable gas with strong odour • Should be kept at concentrations as low as possible due to carcinogenic nature
	27 ppb	Canada Green Building Council: LEED ID+C: Commercial Interiors, Credit 3.2: Indoor Air Quality Assessment, International Well Building Institute: WELL Building Standard – Air Quality Standards		
Mould	Identifiable promoters of fungal growth require correction, and any visible fungi require removal	Health Canada Fungal Contamination in Public Buildings: A Guide to Recognition and Management	• Active air sampling via spore trap sampling (for non-viable airborne spores) • Active air sampling via Andersen/N-16 or RCS (Reuter Centrifugal Sampler) (for culturable viable airborne spores) • Tape-lift sampling or bulk sample collection (for microscopic identification of fungal elements to determine surface growth)	• Moulds are a large group of microorganisms forming a subset of the Kingdom Fungi of living matter • In the indoor environment, moisture is the limiting factor for mould growth, and is the only factor that can be effectively controlled to prevent mould growth • Acceptability of airborne spore levels is based on comparison to outdoor (and sometimes indoor) reference samples. Although exceptions often apply, spore types should generally be similar to reference samples, concentrations should be lower than in reference samples, and overall sample makeup should be similar to reference samples • Retain a skilled and experienced IAQ professional to interpret mould air sampling results
	Address any water damage to building materials within 48 hrs to prevent mould growth; remove any visible or concealed mould	Health Canada Residential Indoor Air Quality Guidelines		

Appendix C IAQ Indicator and Contaminant Summary Table

IAQ Indicator or Contaminant	Suggested Limits	Reference Source(s)	Common Sampling/Monitoring Strategies	Other Notes
				• Remediation of mould should be carried out by a qualified contractor, typically supervised by a qualified third-party mould consultant, following the **EACC Mould Abatement Guidelines**
Radon	**<200 Bq/m^3** (annual average, in lowest occupied level of building)	Health Canada – • Guide for Radon Measurements in Public Buildings • Guide for Radon Measurements in Residential Dwellings (Homes) Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM)	• Alpha-track radon detectors • Electret Ion Chambers • Continuous (real-time) radon monitors • Measurements for comparison against Health Canada standard should be of at least 91 days, and are recommended to be completed during the heating season (fall-winter)	• Typical radon concentrations are <200 Bq/m^3 • Tasteless, odourless, colourless gas • Measurements for comparison against Health Canada standard should be of at least 91 days, and are recommended to be completed during the heating season (fall-winter) • Radon measurement and mitigation professionals are certified by the Canadian National Radon Proficiency Program (C-NRPP)
	4 pCi/L (148 Bq/m^3) (in lowest occupied level of project)	WBI's WELL Building Standard v1 Air Quality Standards (adopted from US EPA radon standard)		
	Exposures as low as reasonably achievable (ALARA)	General principle of radiation management. *Radon is a form of radiation and therefore no threshold exists at which harm cannot occur from exposure. Efforts should be made to maintain exposure to radon at levels as low as reasonably achievable (ALARA).*		
Temperature	Summer: **23°C -26°C*** Winter: **20°C -23.5°C*** **at 50% RH*	CSA Standard Z412 – Office Ergonomics	• Direct-reading instrument	• Humans can perceive temperature differences of as little as one degree Celsius
	ASHRAE Standard 55 provides multiple additional methods for determining appropriate temperature limits	ASHRAE Standard 55		
Relative Humidity (%RH)	**>25%**	Health Canada – Indoor Air Quality in Office Buildings: A Technical Guide	• Direct reading instrument	• High humidity can result in condensation on surfaces, and possible mould growth
	<60%	ASHRAE Standard 62.1		

Appendix C IAQ Indicator and Contaminant Summary Table

IAQ Indicator or Contaminant	Suggested Limits	Reference Source(s)	Common Sampling/Monitoring Strategies	Other Notes
Legionella	Goal is zero detectable *Legionella* Cooling tower: <10 CFU/mL Potable: <10 CFU/mL Humidifiers: <1 CFU/mL Open Water systems: <10 CFU/mL Humidifiers: <1 CFU/mL	OSHA *Legionella* guidelines PWGSC MD 15161-2013 Control of *Legionella* in Mechanical Systems ASHRAE Standard 188 AIHA *Legionella* Guidelines WHO *Legionella* Guidelines OSHA Technical Manul	Water sampling and subsequent laboratory analysis of samples, either by culturing or qPCR analysis The WHO recommends that swabs be taken in conjunction with water samples from sites where biofilms are likely to form International Organization for Standardization (ISO) 11731:"Detection and Enumeration of Legionella" CDC "Procedures for the Recovery of *Legionella* from the Environment"	• A bacterium that can grow in stagnant and low-flow hot, cold and process water systems if not properly maintained/treated • Temperature significantly influences bacterial growth: can survive and multiply between 25-45 degrees Celsius • Human exposure typically occurs when bacteria aerosolized via showers, fountains, cooling towers, etc. • Can cause severe flu-like/pneumonia-like symptoms, can cause death • Generally, most dangerous to elderly, young or immunocompromised individuals
Ozone	20 ppb (8 hr. avg.)	Health Canada - Residential Indoor Air Quality Guidelines	• Direct reading monitor with metal oxide semiconductor sensor • Passive sampling badges/dosimeters • Active air sampling with treated glass-fibre filters	• Typical ozone concentrations are <100 ppb • Colourless gas with characteristic odour • Common indoor sources include electric motors, photocopiers, portable and fixed "air cleaning devices" • Can be transported into building from outdoor sources via HVAC (e.g. during thunderstorms)
	120 ppb (1 hr. avg)	Health Canada - Residential Indoor Air Quality Guidelines		
	0.075 ppm (75 ppb)	Canada Green Building Council: LEED ID+C: Commercial Interiors, Credit 3.2: Indoor Air Quality Assessment		
	51 ppb	International Well Building Institute: WELL Building Standard – Air Quality Standards		

Appendix D ADDITIONAL RESOURCES

American Industrial Hygiene Association *Consultants Listing*	https://www.aiha.org
Canadian Construction Association *Mould Guidelines for the Canadian Construction Industry*	http://www.cca-acc.com/
CSA Group *Office Ergonomics – An application standard for workplace ergonomics (CAN/CSA-Z412-17).*	https://store.csagroup.org/
EACC *Mould Abatement Guidelines*	http://www.eaccanada.ca
EACC *Members - Consultants*	http://www.eaccanada.ca
Health Canada *Guide for Radon Measurements in Public Buildings: Workplaces, Schools, Day Cares, Hospitals, Care Facilities, Correctional Centres*	https://www.canada.ca/en/services/health/publications.html
Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) *Guide for the prevention of microbial growth in ventilation systems*	https://www.irsst.qc.ca/en/institute/organization
New York City Department of Health and Mental Hygiene *Guidelines on Assessment and Remediation of Fungi in Indoor Environments*	https://www1.nyc.gov/
Occupational Health Clinics for Ontario Workers (OHCOW) *Office Ergonomics Handbook*	https://www.ohcow.on.ca/
Occupational Hygiene Association of Ontario *Consultants Directory*	https://www.ohao.org

US EPA *Text Modules for the Indoor Air Quality Building Education and Assessment Model*	https://www.epa.gov/indoor-air-quality-iaq
Well Building Institute (WBI) *WELL Building Standard Air Quality Standards*	https://standard.wellcertified.com/air/air-quality-standards
WorkSafe BC *Indoor Air Quality: A Guide for Building Owners, Managers, and Occupants*	https://www.worksafebc.com/en
World Health Organization (WHO) *WHO guidelines for indoor air quality: selected pollutants*	http://www.euro.who.int/en/health-topics/environment-and-health

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