Guidance on Improving Indoor Air Quality in OFFICE BUILDINGS 2025

Health Canada Santé Canada

Canada

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

Également disponible en français sous le titre :
Document d'orientation sur l'amélioration de la qualité de l'air intérieur dans les immeubles de bureaux 2025

To obtain additional information, please contact:

Health Canada
Address Locator 0900C2
Ottawa, ON K1A 0K9
Tel.: 613-957-2991
Toll free: 1-866-225-0709
Fax: 613-941-5366
TTY: 1-800-465-7735
E-mail: publications-publications@hc-sc.gc.ca

Publication date: September 2025

Cat.: H144-141/2025E-PDF | ISBN: 978-0-660-78983-5 | Pub.: 250228

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This product was developed by Health Canada. Additional consultations and contributions from National Research Council Canada, Public Service and Procurement Canada, and the Public Health Agency of Canada further supported the development of this document.

With acknowledgement of the Canadian Centre for Occupational Health and Safety and the Canadian Committee on Indoor Air Quality in Buildings for the development of supporting background material.

1.0 INTRODUCTION

The purpose of this guidance is to summarize ways to evaluate, improve and maintain indoor air quality in office buildings. This guidance provides practical recommendations to address and respond to potential indoor air quality problems, including:

- guidance for reducing contaminant sources and properly operating ventilation systems,
- sample checklists for evaluating building systems, and
- considerations when hiring a professional to remediate indoor air quality issues.

This guidance is intended for employers, building operators, maintenance staff, urban planners, as well as environmental public health professionals.

The quality of the air in an office building is the result of the complex interactions between the ventilation system (if present), the building (i.e., age, condition, component materials, structure, and envelope), the climate, the quality of the outdoor air, the furnishings and products present, the work processes, and the occupants and their activities. Some factors that contribute to poor indoor air quality may be related to building stewardship activities such as maintenance and housekeeping; inadequate ventilation system design or maintenance; and selection and use of equipment, furnishings, building materials, office supplies and cleaning chemicals.

This guide addresses issues relating to indoor air quality that are common in an office building setting, and promotes best practices. It provides guidance for maintaining good indoor air quality and managing and resolving issues promptly, while encouraging consistency and transparency throughout the assessment, investigation, and resolution process. Good operational practices can prevent many indoor air quality issues. However, when issues do arise, they can be addressed by implementing corrective actions after identifying the potential cause(s). When taking actions to improve indoor air quality, it is important to find appropriate solution(s) that prevent the issue from re-occurring, ensuring that one issue is not being traded for another, or creating new problems.

This guide applies to any size office building in Canada. It applies to non-industrial and non-residential workplace settings which may include buildings with meeting rooms, lunchrooms, and small kitchens.

While this guide provides advice for employers and building operators to help resolve indoor air quality issues, there may be situations that will require the services of a qualified professional, such as a heating, ventilation, and air conditioning (HVAC) professional or an occupational hygienist.

Preventing issues before they arise and addressing issues as soon as they are identified is the best strategy to maintain appropriate indoor air quality. Good practices to maintain indoor air quality include the following:

- Eliminate or reduce sources of contaminants. Sources of contamination may be present indoors (e.g., combustion, cleaning products, furnishings, moisture, or odours from occupants or activities) or outdoors (e.g., smoking areas, vehicle idling, wildfire smoke).
- Maintain protocols to reduce viral and bacterial transmission between building occupants.

- Ensure effective ventilation system design and operation. Ventilation can improve air quality by replacing the indoor air with filtered and conditioned outdoor air, thereby removing and diluting contaminants. Verify ventilation flow rates to match them with any changes in occupant levels, duration of occupancy, renovations, redesigns, and how the space is utilized.
- Develop and implement a preventive maintenance program for the ventilation system. Remove contaminants through appropriate air cleaners or filters.
- Install efficient filtration units or filters as part of the ventilation system and ensure adequate outdoor air ventilation based on applicable standards and outdoor conditions. Select the correct filter efficiency for the contaminants present and the ventilation system. When possible, choose MERV 13 filters or higher.
- Use proactive housekeeping practices, including choosing cleaning products with low volatile organic compounds (VOCs) and using a vacuuming system with a high-efficiency particulate air (HEPA) filter.
- Control moisture and humidity levels and ensure early intervention if mould is suspected. Remediate moisture and damage from flooding, clean mould appropriately, and prevent reoccurrence by determining the source of the moisture and addressing the issue.
- Implement workplace procedures to consider indoor air quality issues throughout procurement and renovations in new and existing buildings. Assess any potential mismatches of the intended space and occupant activities. Where these do not align, the design of the space may affect ventilation distribution and air exchanges.
- Ensure occupants are following workplace policies and procedures, such as the use of scents and cleaning products.
- Conduct indoor air quality training and education for building operators, employers and occupants. Training should be relevant to the audience and can include how to identify a potential indoor air quality issue and how to report concerns. Occupants should also be made aware of issues unrelated to indoor air, such as ergonomic and psychosocial risk factors (e.g., relationships with co-workers, control over workload), as they can affect perceptions of indoor air quality.
- In addition to the guidance on indoor air quality in office buildings provided in this document, indoor air quality professionals seeking technical guidance on the health effects of specific air contaminants and on air sampling and monitoring are also referred to Health Canada's Guidance for Indoor Air Quality Professionals (Health Canada 2025).

2.0 BACKGROUND

Indoor air quality is considered an environmental determinant of health. A healthy indoor environment is one that contributes to productivity and comfort, and protects the health and well-being of occupants. As such, it is an important health and safety consideration for workplaces such as office buildings. Exposure to several contaminants commonly found in indoor air has been associated with adverse health effects. Occupants who work in buildings with adequate ventilation have reported better air quality and health as compared to those working in poorly ventilated spaces (Allen et al., 2015). Higher ventilation flow rates in indoor environments are associated with a reduced prevalence of adverse health effects (Sundell et al., 2010).

Many of the recommended control mechanisms that aim to improve and maintain good indoor air quality also apply to reducing the risk of infectious disease transmission. These mechanisms are often the responsibility of employers, building operators, and maintenance staff. However, other activities undertaken by the building's occupants—such as using printing and photocopying equipment, wearing perfumes and fragrances, blocking vents or improperly using equipment—can generate odours and contaminants that also affect indoor air quality. It is important to recognize that factors that impact indoor air quality can vary over time, and that competing factors can impact air quality goals (e.g., balancing increased ventilation with energy conservation). Management of indoor air quality requires balancing multiple factors to ensure that improvements in one area do not result in significantly reduced efficiency in other areas. Through awareness and education, building operators and occupants can help prevent many indoor air quality issues from developing.

This guidance replaces Health Canada's (1995) Indoor Air Quality in Office Buildings: A Technical Guide.

3.0 INDOOR AIR QUALITY IN OFFICE BUILDINGS

3.1 WHAT IS INDOOR AIR QUALITY?

Indoor air quality refers to the quality of air in an indoor environment, such as inside a building, particularly as it relates to the health and comfort of occupants. Indoor air quality results from the constantly changing complex interactions among building systems, the environment outside the building, activities and items in the building, and occupants that affect the types and levels of contaminants in indoor environments (Canadian Committee on Indoor Air Quality [CCIAQ] 2013a).

3.2 FACTORS AFFECTING INDOOR AIR QUALITY

Indoor air quality results from the interactions between the ventilation system (if present), the building, the climate, the quality of outdoor air, indoor sources of air contaminants, work processes, and occupants.

Elements that impact indoor air include:

- improperly or inadequately designed, maintained or installed heating and ventilation systems, including systems not properly modified after renovations;
- improperly or inadequately designed, maintained or installed building envelope or structure (e.g., water leaks through the roof, windows, walls, penetrations, and flashings as well as air leakages, which can lead to condensation, drafts, rodent or pest infestations, and sanitation issues);
- uses or activities that do not match the original or renovated design of the building or ventilation system (e.g., there are more occupants than planned for in the ventilation system design);
- insufficient intake of outdoor air (such as resulting from an effort to improve energy efficiency) that may allow for a build-up of air contaminants indoors if there is an insufficient exchange rate of the indoor air (e.g., how frequently indoor air is exhausted outdoors and replaced with fresh outdoor air);
- poor quality of outdoor air drawn indoors;
- characteristics of the building or room (e.g., age, design, renovations, dimensions);
- presence of problematic building materials (e.g., asbestos-containing materials, lead, composite wood);
- types of office equipment and furnishings present (e.g., emissions from photocopiers, off-gassing from furnishings, composite wood products containing formaldehyde);
- permeation of contaminants into the building from the ground, such as radon, soil gases or environmental contamination;
- high humidity levels leading to increased odours, stuffiness, and potential for mould growth;
- increased number of building occupants and time spent indoors; or
- occupant activities that impact air quality or circulation (e.g., placement of furnishings, renovations, blocking grilles or vents, cleaning spills, housekeeping, smoking, vaping) or items brought into the building (e.g., food, scented products).

3.3 SOURCES OF INDOOR AIR CONTAMINANTS

Contaminants found in the indoor air of a building can originate from within the buildings, be affected by occupant-related factors, and also be brought in from outdoors. Sources of indoor air contaminants include:

- exhaled air of occupants leading to increased carbon dioxide (CO_2) levels, odours, and stale air;
- dampness and increased moisture leading to mould growth;
- smoking or vaping;
- heating systems and occupant activities (e.g., cooking and reheating food), which can produce combustion-related contaminants s (e.g., carbon monoxide [CO], nitrogen dioxide [NO_2]), particulates and odours;
- attached garages and parking facilities as a source of automotive and fuel-related contaminants (e.g., particulate matter [PM], CO, CO_2, VOCs, and semi-volatile organic compounds [SVOCs]);
- building materials and renovations (e.g., release of VOCs, SVOCs, dusts or fibres from building materials, adhesives, cleaning products, furniture, paints);
- cleaning products, disinfectants, and biocides;
- individuals with airborne infectious diseases, typically spread by infectious respiratory particles; and
- perfumes, fragrances, and air fresheners.

Contaminants may also enter the office through the outdoor air intakes of the ventilation system and open windows and doors, and by infiltration through cracks and openings in the building envelope. Air contaminants that may originate from outdoor sources include:

- vehicle exhaust and other traffic-related pollution (e.g., CO, NO_2, PM), including from vehicles idling near air intakes;
- nearby industrial contaminants;
- microbial contaminants (e.g., bacteria, mould, fungi, viruses, pollen);
- moisture and humidity leading to condensation and mould growth;
- radon gas;
- soil or ground gases (e.g., methane, hydrogen sulfide, alcohols, alkanes, aromatic hydrocarbons);
- wildfire smoke; and
- pollutants arising from emergency events (e.g., fires, chemical spills).

In some situations, contaminants may also originate from ventilation systems which are shared with other businesses (e.g., in a common building or strip mall).

3.4 OCCUPANT COMFORT AND INDOOR AIR QUALITY PERCEPTION

In addition to factors that directly impact the types and concentrations of indoor contaminants, building occupants can be affected by a number of environmental and personal factors, which can affect how they perceive indoor air quality. Some factors affect both the levels of contaminants and perceptions of air quality.

The way in which occupants perceive indoor air quality may also influence their overall comfort, well-being, and productivity. Occupant perceptions are influenced by factors such as air temperature, relative humidity, air movement, and odour as well as non-indoor air quality factors such as noise, lighting, and ergonomics. Employers and building operators should consider both indoor and non-indoor air quality factors when investigating complaints.

3.4.1 Air temperature and relative humidity

Air temperature and relative humidity are the two main factors that determine thermal comfort and are major environmental factors contributing to heat-related illnesses from thermal stress.

3.4.1.1 Thermal comfort

Thermal comfort refers to conditions of feeling neither too hot nor too cold when wearing office-appropriate clothing. Occupants find conditions within a space most comfortable when the air temperature is uniform and the relative humidity between 30% and 50%. Maintaining relative humidity below 50% also prevents mould growth indoors (Health Canada 2016).

Generally, when relative humidity is below 30%, complaints of dry skin, eyes, sinuses, mouth, and throat increase (Jones et al., 2022). When relative humidity is above 50%, complaints of excessive humidity or heat increase. High humidity levels may contribute to condensation, moisture, and mould or fungi growth (Health Canada 2023a).

Personal preferences for temperature may vary greatly. When a space is too warm, occupants may feel lethargic or tire quickly. On the other hand, when a space is too cold, occupants may feel restless or easily distracted. Desired temperatures may vary with the season, clothing worn, and/or activity.

When considering temperature and humidity:

- maintain the building indoor temperature between 20 °C and 23.5 °C in the winter and between 23 °C and 26 °C in the summer (CSA Standard Z412), striving to ensure a thermal environment that a substantial majority (over 80%) of the occupants find acceptable (American Society of Heating, Refrigerating and Air-Conditioning Engineers [ASHRAE] Standard 55);
- maintain the relative humidity of indoor spaces between 30% and 50% (Health Canada 2016), depending on the maximum tolerances of the building envelope, to avoid condensation on interior surfaces;
- perform regular maintenance on the HVAC equipment including economizers, air flow control equipment and fan systems (such as air flow valves, flow control stations, automated pressure control systems);

- confirm airflows meet current applicable ventilation standards (ASHRAE Standard 62.1)) and that the HVAC equipment and thermostats are functioning properly, including humidity control;
- correctly operate and maintain water systems associated with ventilation systems, such as cooling towers, steam systems, and humidifiers;
- adjust ventilation to closely match the persons, activities and equipment in the building;
- confirm that grilles, vents and other ventilation components are not restricted or blocked;
- use portable humidifiers with caution, as they may become a source of mould and bacteria if not maintained; and
- use space heaters with caution, as they are not connected to the building-wide ventilation system.

3.4.1.2 Thermal stress

A further concern with temperatures that should be considered in office buildings is heat-related illnesses. Extreme heat is a serious health risk. Older adults, low-income earners, people experiencing homelessness, and people living with certain underlying medical conditions are among those at greater risk to heat-related illnesses (Health Canada 2024). Vulnerability to heat-related illnesses may also differ between population groups and individuals due to factors such as acclimatization, fitness, and sleep quality (Bergeron et al., 2011; McGarr et al., 2020).

Occupants may be at greater risk of adverse health effects from heat in office buildings when temperatures and humidity levels exceed those recommended in the thermal comfort guidelines described above; however, some occupants that are more susceptible to heat might experience health effects even at temperatures that are within the thermal comfort guidelines. Employers and building operators should seek guidance from local health authorities during extreme heat events.

3.4.2 Odours

Odours (smells) can be indicative of elevated levels of certain contaminants in indoor air, which may lead to potential health risks. Of note, health effects of some indoor contaminants are recognized to occur at levels below the odour threshold. Odours are associated with a perception of poor air quality, regardless of whether or not the source of the odour is a nuisance concern (e.g., food odours) or has the potential to result in direct health effects (e.g., vehicle exhaust). Odours are caused by organic or inorganic gases and vapours that stimulate the olfactory organs. Individual responses can vary with age, experience, time of exposure, and other factors.

Odours may be the result of:

- vehicle exhaust or other traffic pollution infiltrating into the occupied spaces of the building from outdoors or from parking garages;
- body and food odours;
- mould growth;
- moisture (e.g., wet concrete, dampness);

- chemicals and related vapours;
- sewer gases; or
- pest infestation (e.g., rodents, bedbugs, cockroaches).

Identification and control of the odour's source will help improve indoor air quality. Note that some individuals may have medical conditions, or there may be personal or occupational factors that contribute to odours that are not within their control. For response to environmental sensitivities and medical conditions, see section 6.2—Roles and responsibilities of employers.

3.4.3 Ventilation and comfort

Indoor air contains a mixture of contaminants from both outdoor and indoor sources. A building's ventilation system, when designed and operated properly, exchanges indoor air by replacing or diluting it with outdoor air. This exchange is designed to keep the concentration of biological and chemical contaminants at low enough levels to not cause discomfort for most occupants.

When the rate of replacement of indoor air by outdoor air is too low, the indoor air concentrations of contaminants primarily produced indoors rise, and occupant complaints may become more common. Those complaints typically include exposure-related perceptions (e.g., smells/odours, "stale air," "stuffiness") and potential health effects (e.g., eye, nose, sinus and throat irritation, headaches, fatigue).

It is important to note that the addition of outdoor air into the system may also introduce contaminants into the indoor environment. Outdoor sources of contamination may include smoke, smog, traffic pollution, pollen, and industrial contaminants.

3.4.4 Air velocity and drafts

Air velocity (or speed) refers to the rate of air movement. Lower air velocities may make a space feel "stuffy," while higher air velocities increase skin evaporation and may result in occupants finding the air too cool or "chilly." Air velocity should conform to applicable standards (ASHRAE Standard 55). In most buildings, an air velocity below 0.20 m/s (40 fpm) would be expected.

When there is an issue with the air velocity or leakiness in the building envelope, occupants may report drafts, experienced as an unwanted cooling of the body from air movement. Occupants notice drafts when the air cools the body unevenly, such as at the head, neck or shoulders, or at the foot, ankle or lower leg. Drafts can be related to the air being "thermally stratified," which means there are layers of different air temperatures. Causes often include cold air entering through windows or walls, ventilation that directs cold air towards occupants or floors that are colder than the air. The difference between floor and ceiling temperatures should not be more than 4°C to avoid thermal discomfort (ASHRAE Standard 55).

3.4.5 Non-indoor air quality factors

Concerns about indoor air quality may occur even if all indicators are within acceptable limits. How occupants perceive the general quality of air may depend on organizational and individual factors unrelated to actual air characteristics. For example, noise, lighting, workplace layout, privacy, and workstation design may contribute to how occupants perceive air quality.

3.5 HEALTH EFFECTS OF POOR INDOOR AIR QUALITY

In many cases, the presence of indoor air contaminants, including in situations with poor temperature or humidity control, is known to cause or worsen health effects. Exposure to indoor air contaminants may result in:

- dryness and irritation of the eyes, nose, and throat;
- respiratory symptoms such as wheezing, coughing, and shortness of breath;
- headache, fatigue, dizziness, nausea, and flu-like symptoms; and
- worsening of lung and heart conditions such as asthma, chronic obstructive pulmonary disease, and heart disease.

Recognizing health effects caused or exacerbated by exposure to poor indoor air can be difficult, as many of the symptoms can also be produced by illnesses or exposures unrelated to the air quality indoors. For example, exposure to poor indoor air has been associated with symptoms often experienced by individuals with allergies, the common cold or the flu (influenza), making it difficult to determine the role of indoor air in causing or worsening these symptoms (CCIAQ 2013b). As well, occupants with a respiratory illness may experience symptoms similar to those seen following exposure to other indoor air contaminants, or may find that their symptoms are exacerbated when entering a building. A qualified health professional may be able to help determine whether an individual's symptom is associated with poor indoor air quality.

Poor indoor air quality does not affect everyone in the same way. Certain individuals are generally susceptible to health effects associated with exposure to indoor air contaminants, including children, the elderly, people who are pregnant, and those with pre-existing health conditions such as asthma and cardiovascular diseases. Susceptible individuals may experience a variety of adverse health symptoms resulting from exposure to environmental contaminants, even at very low concentrations.

3.6 KEY STRATEGIES FOR IMPROVING AIR QUALITY IN OFFICE BUILDINGS

Indoor air quality in an office building is the result of complex and constantly changing interactions, and as such, many interacting factors need to be considered when addressing indoor air quality issues. The following are key strategies to address some of these factors, and to maintain and improve indoor air quality:

a. **Reducing or eliminating the sources of air contaminants.** The source(s) of the air contaminants may exist inside and outside the building. Detailed information on specific indoor air contaminants can be found in Guidance for Indoor Air Quality Professionals (Health Canada 2025) and in section 3.3—Sources of indoor air contaminants.

   For indoor sources, contaminants can be eliminated or reduced by practicing good building stewardship, which includes adequate space design, choosing lower emitting products and furnishings, regular housekeeping, and preventive building maintenance as well as open communication between building operators, employers, and building occupants (e.g., education of building staff and employees on indoor air quality).

   The employer or building operator may have little control over contaminant sources outside the building. However, awareness of outdoor air quality conditions, knowledge of the ventilation system, and good operation practices can help prevent or reduce the infiltration of contaminants that may enter the building from outdoors. Infiltration of contaminants can also be reduced or eliminated through activities such as sealing cracks in the building envelope and foundation, and operating remediation systems where required.

b. **Ventilating** can improve air quality by removing and diluting contaminants and by replacing indoor air with filtered air from outdoors. Maintaining the building ventilation system and replacing filters as per the manufacturer's recommendations will help reduce contaminants drawn into the building. Detailed information can be found in section 4—Ventilation.

   In Canada, the national, provincial and territorial building codes require that ventilation flow rates respect, at a minimum, current applicable ventilation standards (ASHRAE Standard 62.1 and 62.2). Beyond that, higher ventilation flow rates have been suggested to help mitigate the risk of airborne infectious disease transmission and to contribute to an improvement of overall indoor air quality (ASHRAE 2023; Centers for Disease Control and Prevention [CDC] 2023; Lancet 2022; Ontario Society of Professional Engineers [OSPE] 2022). While improving indoor air quality, increased ventilation flow rates come at an additional energy cost.

c. **Filtering** the indoor air can reduce some indoor air contaminants and some viral and bacterial respiratory pathogens, depending on the contaminants and filtration equipment used. Although filtering the indoor air may help to improve indoor air quality, it should be combined with reducing contaminants at the source whenever possible and improving ventilation effectiveness. Detailed information can be found in section 4.3.5—Air filtering.

   Indoor contaminants such as dust, fine particles, viruses, bacteria and spores can be removed effectively using indoor air filters. These filters are generally not as effective for gaseous contaminants (e.g., VOCs, CO, CO_2, NO_2). In-duct or portable filtration devices using high efficiency filters can help reduce the levels of airborne particulates.

   A combination of ventilation and filtering can be more cost-effective for reducing particulate levels, including infectious respiratory particles, than increased ventilation alone.

4.0 VENTILATION

Building operators and those responsible for indoor air quality should be knowledgeable about the ventilation system design and operation, which include the outdoor air supply, outdoor air quality, filters and filtration efficiency, space planning (occupant density and activity, as well as duration of occupancy), equipment maintenance, control of other contaminant pathways such as unintended infiltration of pollutants, and when to consult an HVAC professional.

To be effective, a ventilation system must bring in outdoor air and exhaust indoor air—simple air movements (e.g., recirculation) or filtration is not enough. Efficient ventilation helps improve indoor air quality, as it reduces contaminant and moisture levels that may directly or indirectly result in poor occupant comfort or negative health effects (Health Canada 2018).

Outdoor air ventilation may occur naturally or mechanically:

- Natural ventilation describes air flows caused by pressure differences between the inside and the outside of a building, which are primarily driven by weather, wind direction, and pressure and temperature differentials through intentional openings in the building envelope. Occupants generally have little control over natural ventilation, aside from opening and closing external windows and doors. Ventilation that relies only on window opening can lead to excessive energy costs, particularly due to heat loss in the winter or loss of conditioned air in the summer. Window opening can also challenge the management of relative humidity, infiltration of allergens, infiltration of ambient pollution, unintended pressure differences, and entry of pests in the absence of window screens.
- Mechanical ventilation refers to air flows intentionally created through the use of fans, ducting, and designed openings in the building envelope. This includes the operation of a localized, single-path exhaust fan (e.g., bathroom exhausts, range hood fans). In the case of a small building or office, mechanical ventilation will typically be delivered through a central make-up air unit located on the rooftop of the building. In most large office buildings, a central air handling unit will typically be responsible for mechanically ventilating the building.

4.1 OUTDOOR AIR VENTILATION VERSUS INFILTRATION

It is important to be aware of the distinction between outdoor air ventilation and infiltration (Persily 2021). Outdoor air ventilation is intentional and refers to outdoor airflow into a building through intentional openings such as intakes, vents, and open windows. Infiltration refers to uncontrolled and unintentional airflow from the outdoors into the building interior (i.e., entry of air into buildings), and a corresponding exfiltration of air from the building interior to the outdoors (i.e., exit of air from the building). Depending on indoor-outdoor pressure differences, uncontrolled entry and a corresponding exit of air through the building envelope can occur. These pressure differences can be due to weather (e.g., wind and temperature) and the operation of building systems (e.g., exhaust fans and vented combustion equipment). It is important to note that infiltration rates are not controlled, nor is the distribution of infiltrated air within a building. Infiltration can have significant negative impacts on indoor air quality due to transit through spaces with poorer air quality such as wall cavities and

basements. In addition, it can lead to condensation by creating cold surfaces where it enters and inside wall cavities where it exits, leading to issues with indoor moisture management. Proper air sealing and insulating are important strategies for reducing infiltration and associated condensation issues. Ventilation systems, natural or mechanical, that are well designed, installed, operated, and maintained are preferable to infiltration for meeting building ventilation requirements since they can provide the desired ventilation flow rate of higher quality air where it is needed, avoiding both under- and over-ventilation. Ventilation systems also provide opportunities to reduce energy impacts by recovering heat or moisture from the outgoing air. They allow for better humidity control, which has health benefits and can reduce potential for mould issues.

4.2 HVAC SYSTEMS

Heating, ventilating, and air conditioning systems have a significant impact on how air contaminants move through a space, how outdoor air is brought in and indoor air exhausted, and how contaminants are removed from the air. An HVAC system is designed to:

- bring outdoor air into the building;
- clean and filter the air;
- heat or cool the air;
- humidify or dehumidify the air;
- distribute the air throughout the building;
- remove stale air from the occupied space; and
- control the portion of the indoor air recycled vs exhausted outdoors.

The HVAC system typically has many interconnected parts throughout a building, such as intakes, filters, ducts, and fans, that work together to move air into, around, and out of rooms. A well-designed and properly functioning HVAC system will deliver the appropriate amount of air to each zone (e.g., a room or space) to achieve outdoor air ventilation requirements, thermal comfort, proper moisture levels and contaminant control.

4.2.1 Understanding HVAC systems

When functioning properly, an HVAC system will balance the different zones and maintain the desired pressures throughout the occupied space(s). Blocking supply air vents or return air grilles or interrupting air flow with furniture or boxes may unbalance the HVAC system, which may negatively affect the ventilation in other areas of the office or building space.

These systems use filters which can remove PM, including dust, pollen, mould, bacteria and viruses, from the air. Filters must be the appropriate dimensions and rated to match the HVAC system, as improperly sized or rated filters will not function properly. As filter efficiency increases (filter rating), so does the amount of pressure required to move air through the filter. The manufacturer's instructions or an HVAC specialist should be consulted when installing or upgrading filters (increasing the filter rating) to make sure that the mechanical system can handle the increased pressure drop across the filters. Additional information can be found in section 4.3.5—Air filtering.

HVAC systems may also be the source of air contamination if the supply air grilles or air filters are dirty, if there is stagnant water in drip pans, or if there is moisture in air ducts that may promote the growth of moulds or other microbial agents.

4.2.2 Components of HVAC systems

HVAC systems used in office or commercial buildings vary considerably in their size and complexity. These may range from simple make-up air units to large systems that are integrated into the building. Independent of their complexity and size, HVAC systems have the basic components described below (Figure 1). It is important that all components be inspected, cleaned, and maintained to ensure proper function of the equipment and delivery of quality air to the indoor environment. The following figure and associated numbers highlight the major components and functions of an HVAC system.

4.2.3 Heat or energy recovery ventilators

A heat or energy recovery ventilation (HRV/ERV) system (also called economizer) may be used. This equipment is designed to mechanically ventilate the building by replacing indoor air with outdoor air while recovering the heat and/or moisture from the air stream to reduce energy costs. These systems include a sensible or latent heat exchanger core, which both the outdoor and exhaust air streams pass through to recover a percentage of the energy from the conditioned exhaust air within the building. HRVs/ERVs can be grouped into three categories: flat plate, rotary, or regenerative. In office buildings, the most commonly employed HRV/ERV is the rotary type (heat/energy wheel).

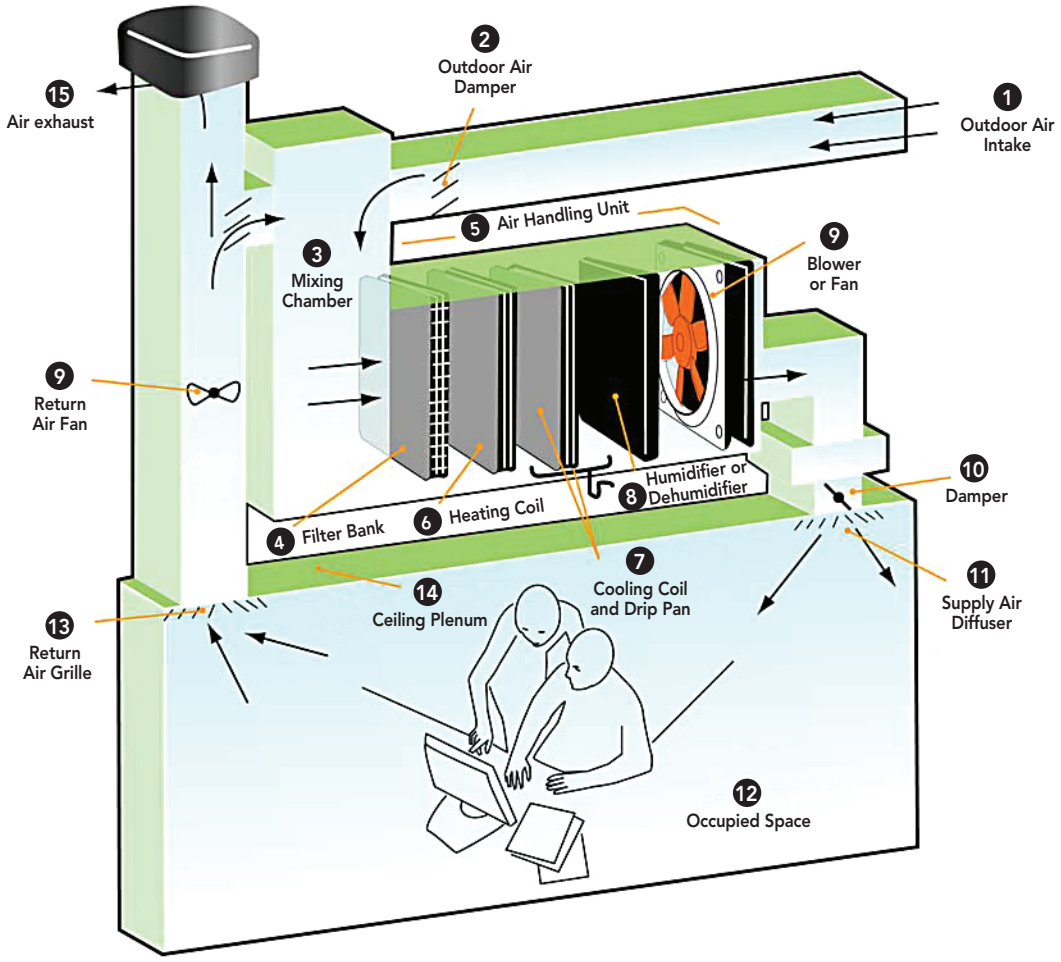
Single room HRV/ERVs are also available, which are mounted on an external wall, independent of the ductwork of the HVAC or other mechanical system. This equipment allows for ventilation of a single room, while transferring the energy from the exhausted air to the incoming air stream, thus reducing the heating and air conditioning load. Installation and operation of single-room HRV/ERVs should be done in consultation with a qualified HVAC technician.

4.2.4 System inspection and maintenance

When inspecting the HVAC system of a building, confirm each of the following items and determine if further action is required:

- No potential sources of contaminants (e.g., garages, loading areas, roadways) are near outdoor air intake.
- Outdoor air dampers are open and functioning, noting that these should be open to at least their minimum position during the coldest and hottest outdoor temperature conditions.
- Air supply and exhaust fans are in operable condition.
- Proper fan belts and blades are in operable condition.
- Fan blades are installed properly (correct orientation).
- Ductwork or intakes are free of dust and mould.

FIGURE 1: An example of the components of an HVAC system (Government of Alberta 2009)



1. **Outdoor Air Intake**—Where outdoor air enters the building.
2. **Outdoor Air Damper**—Adjustable barrier that limits the amount of air being brought into the building.
3. **Mixing Chamber**—Area where outdoor air is mixed with air returned from the indoor occupied space and recirculated.
4. **Filter Bank**—May consist of a pre-filter to remove large dust particles, bugs, feathers, and leaves from air before passing through the primary filter. Following filtration, the air is distributed to the occupied spaces.
5. **Air Handling Unit**—Includes the blower or fan, heating and/or cooling coils, and related equipment such as controls, condensate drip pans, and air filters.
6. **Heating Coil**—Heats the air if needed.
7. **Cooling Coil and Drip Pan**—Cools the air if needed; drip pan catches water that is produced during the air-cooling process and drains into the wastewater system.
8. **Humidifier or Dehumidifier**—Adds or removes moisture to and from the air as required to adjust the relative humidity of the building air.
9. **Blower or Fan**—Pushes (supply) or pulls (exhaust) air through the system; controls flow to various parts of the building.
10. **Damper**—Adjustable barrier that limits air flowing into or out of a space.
11. **Supply Air Diffuser**—Distributes the ventilation air into the occupied space.
12. **Occupied Space**—Where people are normally present.
13. **Return Air Grille**—The grille through which air exits the occupied space, being drawn by the return air fan to be returned to the HVAC system for exhausting/recirculation.
14. **Ceiling Plenum**—Space above the suspended ceiling that may be used as a part of the air return system.

- Ducts are dry, clean, intact and well maintained.
- Air handling units (fans, coil units, induction units) are in good repair.
- Air filters with appropriate filtration efficiency ratings are dry, clean, properly sized and well maintained.
- Condensate pans are free of dirty water, slime, rust or mould.
- Drip pans are free of dirty water, slime, rust or mould.
- Humidifier reservoirs are free of dirty water, slime, foam or mould.
- HRV/ERV equipment is maintained as per manufacturer's recommendations (e.g., filter cleaning and replacement, core and cabinet cleaning).

This list is provided as a customizable checklist in Appendix B. Any other information that is pertinent to the specific HVAC unit being inspected can be added. It is always relevant to consult the operator's manual or a qualified HVAC professional for assistance.

A preventive ventilation system maintenance program should be developed and implemented to ensure that the mechanical system is operating correctly, and filters are replaced on a set schedule. This helps reduce contaminants and maintain temperature and moisture levels. All HVAC systems should be inspected and maintained by a qualified professional as per manufacturer's recommendations. If none are available, ASHRAE Standard 62.1 proposes a recommended activity table, along with an inspection frequency, that building operators and employers can reference. As a last resort, a sample checklist (Appendix C) may be used to help inspect and maintain the HVAC system regularly. It is good practice to document and record each inspection and, in some instances, this documentation may be a legal requirement (for example, if the employer is targeted by the Canada Occupational Health and Safety Regulations). It is highly recommended to have the building operator/engineer or an HVAC specialist participate in this inspection.

4.3 VENTILATION OPERATING PRACTICES

As an HVAC system is critical to the overall quality of the indoor air, building operators and those responsible for indoor air quality should follow good operating practices. A well-implemented preventive maintenance program improves the operation of the mechanical systems and can save money over the long term by preventing critical breakdowns.

Good operating practices will:

- reduce indoor sources of contaminants;
- limit outdoor contaminants from entering the space;
- maintain the HVAC system to ensure it is operating correctly;
- provide adequate outdoor air to occupants;
- control temperature, velocity, and relative humidity in the building; and
- dilute, capture, and remove contaminants though ventilation, filtration, and air cleaning.

The following sections address good operating practices.

4.3.1 Outdoor air intake considerations

When considering outdoor air:

- take steps to ensure that the outdoor air intake is free from exterior contaminant sources, including:
  - traffic exhaust (e.g., roadways, parking lots, idling vehicles);
  - birds and other animals, and their droppings; and
  - contaminants from other sources (e.g., other businesses, garbage bins, industries);
- use an air intake screen with sieve openings smaller than 13 mm to help trap debris and prevent it from entering;
- keep the building under a slightly positive pressure, if possible (i.e., drawing slightly more outdoor air into the building than air that escapes or exhausts), as positive pressure limits air infiltration of cold air during heating colder seasons, hot air during warmer seasons, or intake of contaminants; and
- ensure that sufficient outdoor air (expressed as airflow rates of outdoor air) is flowing into the space, with the help of available guidelines and formulas. Airflow rates of outdoor air consider the number of occupants, the area/size, and the activities performed in that space.

Outdoor air captured for indoor use should be of good quality. Depending on the jurisdiction, some buildings may require conformity with national standards and guidelines.

The following minimum distances should separate air intakes from sources of contamination:

TABLE 1: Air intake minimum separation distance. Adapted from ASHRAE (2022b, Table 5-1)

Air Intake Minimum Separation Distance Recommended by ASHRAE Standard 62.1	
Object	**Distance (m)**
Cooling tower exhaust	7.5
Driveway, street or parking place	1.5
Garage entry, automobile loading area, or drive-in queue	5
Garage storage/pick-up area, dumpsters	5
Plumbing vents	1
Truck loading area or dock, bus parking/idling area	7.5
Thoroughfare with high traffic volume	7.5

4.3.2 *Operating schedules*

Reduced operating schedules can help conserve energy during off-peak hours when the building is at a reduced occupancy overnight and on weekends. It is important to make sure that enough air changes occur before regular work hours to remove indoor air contaminants that may have accumulated overnight, and that temperature and humidity are brought to a desired level. The number of air changes depends on the duration of the shutdown period and other factors. These parameters can be determined through consultation with an HVAC specialist. In situations where respiratory infectious diseases are circulating in the community, it is recommended to run the system for two hours at maximum outdoor airflow before and after the building is occupied (Public Health Agency of Canada [PHAC] 2021).

Additionally, adjusting the ventilation system to not operate during the morning rush hour can significantly reduce traffic-related air pollutants within buildings located near major roads (MacNeill et al., 2016). This entails conducting the morning flush-out before morning rush hour, stopping during rush hour, and reactivating once rush hour has passed. This approach allows buildings to be ventilated with cleaner air than if the morning flush-out period was done during morning rush hour. Another important measure that can help reduce the intake of outdoor pollutants into the indoor environment is ensuring that outdoor air intakes are located as far away from traffic and idling vehicles as possible.

4.3.3 *Ventilation flow rates*

The ventilation flow rate can be expressed as an absolute ventilation flow rate (in litres per second [L/s], cubic metres per second [m^3/s], cubic feet per minute [CFM]) or as an air change rate relative to the volume of the space. Non-residential ventilation flow rates are based on number of occupants and room dimensions or are calculated based on the intended dilution of known contaminants (ASHRAE Standard 62.1).

Replacing all the air in a room is called an air change. The number of air changes per hour (i.e., the air change rate) is determined by dividing the amount of air that moves through a room in one hour by the volume of the room (CDC 2023). When there is inadequate mechanical ventilation with minimal infiltration and/or natural ventilation, the air change rate is low and indoor air contaminant levels can increase, resulting in more complaints from occupants.

Canadian building codes reference ASHRAE Standard 62.1 which provides minimal ventilation rates. However, the ventilation flow rates should be determined according to the requirements of the applicable jurisdiction and consider the various zones in a building. Once the appropriate rates are determined, any setting or adjustment of ventilation flow rates and air balancing of the building should be conducted by a qualified HVAC professional.

Building ventilation flow rates should be measured and brought in line with current applicable ventilation standards (ASHRAE Standard 62.1 and 62.2).

Increased air exchange, combined with other measures, has been suggested to help mitigate the risk of airborne infectious disease transmission and to contribute to an improvement of overall indoor air quality (ASHRAE 2023; CDC 2023; Lancet 2022; OSPE 2022). Improved filtration can also be used. These options come at an additional energy cost related to increased energy requirements of HVAC systems due to longer operation, requirements to overcome greater pressure drops across filters and/or the need to condition greater amounts of fresh outdoor air.

4.3.4 Responsive ventilation

Different procedures such as renovation, maintenance and changes in occupancy may result in localized higher concentrations of indoor air contaminants, and it may be necessary to manually control or schedule the mechanical system during these times to provide additional ventilation. At other times, it may be necessary to reduce the amount of ventilation if the outdoor conditions are deemed to be poor (e.g., wildfire smoke, spills), or if work being done in the building requires containment to reduce dissemination of contaminants throughout the building.

Determining when to manually increase or decrease ventilation, and for how long, is the responsibility of the building operator. During wildfire smoke or other air quality events, pay attention to the Air Quality Health Index (AQHI), InfoSmog (Quebec), and air quality warnings (Health Canada 2023b).

4.3.5 Air filtering

Filtration of indoor air is an important part of reducing exposure to small particles including aerosolized virus particles. Air can be filtered by the HVAC or other mechanical systems through the building filtration system. This helps protect the indoor air from contaminants that originate in the outdoor supply air as well as in the building return air. It is recommended to use a filter with a minimum efficiency reporting value (MERV) rating of 13 or higher in buildings with return air, where feasible, in order to reduce viral transmission indoors (Unites States Environmental Protection Agency [US EPA] 2024b; Health Canada 2020a). Indoor air can also be filtered using HEPA-based portable air cleaners (PACs), which can help capture some contaminants (e.g., pollen, dust, viruses) regardless of whether they are produced indoors or outdoors (Health Canada 2022a). Note that filters can help remove particulates but will not be effective against gases, such as CO or CO_2.

4.3.5.1 Filtration system considerations

Increasing the efficiency of filters decreases the chance of particulate material and infectious respiratory particles being spread through the air distribution system. However, even if higher filtration is more effective, it may not be practical because of diminishing returns in improvement of particulate removal and increasing static pressure and cost. For example, while an increase from MERV 13 to MERV 14 enhances the efficacy of capturing particles between 1 and 3 µm from 85% to at least 90%, this improvement may be outweighed by the increased pressure requirements to move air through the filter, which the system may not be able to provide (ASHRAE 2023). Although a filter with a rating of MERV 13 or higher is ideal, the appropriate filtration for a system will depend on the system's capabilities and the manufacturer's recommendations.

Filters must be of appropriate dimensions for installation in the HVAC system, as improperly sized filters will not function as designed. When considering using a higher efficiency filter in an HVAC system, it is important to adjust for the additional air resistance of the higher rated filter.

The gold standard for interior air filtration is a HEPA filter. A HEPA filter is a type of pleated media air filter that is often required for sterile, controlled environments such as hospital operating rooms, laboratories, and micro-electronics manufacturing facilities. HEPA filters remove at least 99.97% of particles at or above 0.3 µm such as dust, pollen, mould, bacteria, viruses and other airborne particles. However, due to the higher pressure drop from HEPA filters, building systems where this rigorous filtering is not required may not be able to accommodate them.

It is important to consult an HVAC or filtration specialist when selecting the type of filters, the MERV rating, and pressure drop of the system.

4.3.5.2 Portable air cleaners

Portable air cleaners (PAC), also known as air purifiers, can also help improve indoor air quality by reducing levels of airborne particulates. This equipment can provide high-efficiency filtration when used alongside building ventilation systems but is not a substitute for whole-building ventilation. However, when mechanical ventilation is not available, PACs can be effective in reducing indoor particulate levels.

Many commercially available PACs are designed to filter the air in a single area or room using HEPA filters. It is important to select a PAC appropriately sized for the space it is used in. The following should be considered when purchasing and installing a PAC (Health Canada 2022a):

- Use a certified PAC with a HEPA filter to help remove particles from the indoor air.
- A PAC is designed to remove particles from the air in a single room. It is not designed to remove particles from an entire building.
- The most reliable way to select a PAC is by looking at the suggested room size and the clean air delivery rate (CADR). The CADR describes how well the machine reduces particles with sizes equivalent to those of tobacco smoke (the smallest particles), dust, and pollen.
- For an overall reduction in fine particles, consider choosing a PAC with the highest tobacco smoke CADR that is properly sized to fit the room in which it will be operated. The higher the number, the more fine particles the PAC can remove.
- Calculate the minimum CADR required for a room: as a general guideline, the CADR of a PAC should be equal to at least two-thirds of the room's area.
- Follow the manufacturer's instructions for placement and operation to ensure good airflow. Generally, higher fan speeds and longer run times will increase the amount of air filtered. Be aware that some PACs can be noisier than others.
- Clean or replace filters as recommended by the manufacturer. Consider increasing the frequency of filter cleaning or replacement depending on use and conditions.

In general, a PAC will work best when operating at the highest fan speed setting; however, noise may become an issue. The CADR reflects the effectiveness of a PAC and assumes that the PAC is operated at full speed.

Devices that use ions, such as photocatalytic oxidizers, ion generators, electrostatic precipitators, and others, to purify air may produce ozone. If selecting these devices, they should have an Underwriters Laboratory (UL) 2998 (zero ozone emissions) certificate (UL 2022b). If the device is not certified, it should be avoided, as ozone can impact human health. The California Air Regulatory Board lists units that have passed testing for ozone emissions (Health Canada 2022a).

4.3.5.3 Stand-alone filtration units

In addition to portable filtration units, larger filtration systems are available that can be affixed to walls and ceilings to allow air cleaning in defined areas. Where available, building operators should seek equipment with independent stages of filtration that can be replaced at different times. Filtration systems may contain at least the following three layers:

1. A pre-filter to trap larger particles in the air.
2. A layer of carbon filtration to capture odours.
3. A HEPA filter to capture fine particles, smoke, bacteria, viruses, etc.

These systems will allow for the replacement of individual filters at different times and of the prefilter on a regular basis to prolong the useful life of the expensive HEPA filter.

4.3.5.4 Do-it-yourself air cleaners

If a ventilation system or certified portable air cleaner is not available, an option to consider is to use a do-it-yourself (DIY) air cleaner (Health Canada 2023b; National Collaborating Centre for Environmental Health [NCCEH] 2023). There is some evidence that DIY air cleaners can be an effective option in short-term emergency situations, such as during a wildfire smoke event. It is important to understand the limitations and safety risks associated with DIY air cleaners. If choosing to use DIY air cleaners, remember to use a clean, recent (2012 or later) box fan with a safety fuse and ideally certified to UL 507 (UL 2022a). Never leave the fan running unattended and keep it away from walls, furniture and curtains. Do not use an extension cord, do not use a damaged or malfunctioning fan, and be sure to change the filters regularly during smoke events as clogged filters are ineffective and may cause the fan to overheat and lead to fires.

4.3.6 Carbon dioxide as an indicator of ventilation

The primary source of CO_2 in indoor air is occupant respiration, with lesser sources such as improperly vented combustion appliances and cigarette smoke also potentially contributing to indoor CO_2 levels (Health Canada 2021b). Common situations leading to elevated CO_2 concentrations indoors include excess building occupancy (overcrowding), or when occupants are spending prolonged periods of time indoors. As such, CO_2 can serve as a proxy for occupant-emitted contaminants and pathogens and as a means to assess the ventilation

rate (Morawska et al. 2024). With increased public awareness of the importance of ventilation, alongside commercially-available inexpensive CO_2 monitors, there is a renewed interest in using CO_2 monitoring as a method for quantifying ventilation efficiency.

Indoor CO_2 concentrations have long been used to control outdoor air intake rates of building HVAC systems, using demand-controlled ventilation. This control strategy reduces the energy use associated with overventilation during periods of low occupancy and helps to ensure that spaces are adequately ventilated based on their actual occupancy (ASHRAE 2022). When CO_2 monitors are integrated into an HVAC system, it is important for those investigating indoor air quality to confirm that the system has been properly maintained, calibrated, and monitored; that false readings are not common; and that system reports are available for review (National Education Association 2022).

Guidance provided by ASHRAE (2022) acknowledges that indoor CO_2 concentrations can be a useful tool in indoor air quality assessments if users understand its limitations. Sensor accuracy, location, frequency of monitoring, and calibration, as well as building occupancy, among other issues, are all critical for drawing meaningful inferences from measured indoor CO_2 concentrations. See Guidance for Indoor Air Quality Professionals (Health Canada 2025) for more information.

The importance of ventilation as a method for reducing transmission of the SARS-CoV-2 virus was highlighted during the COVID-19 pandemic (PHAC 2021). However, indoor CO_2 levels should not be interpreted as a proxy for risk of infection from airborne infectious diseases, as transmission depends on multiple factors, of which ventilation is only one (US EPA 2024a; NCCEH 2021). There are numerous scenarios in which reliance on indoor CO_2 levels may cause occupants to under- or over-estimate the risk of transmission.

4.3.7 Thermostats and monitors

Thermostats must be functioning, calibrated, correctly located, and not obstructed or enclosed in a way that limits air flow to them. To be correctly located, a thermostat should be placed on an interior wall that is in the centre of the room and away from direct sunlight or other heat sources. Placing a thermostat in the path of direct sunlight can have implications on the operation of the HVAC system and an associated energy penalty (Berquist and O'Brien 2018). In addition, personal heaters or humidifiers can disrupt or interfere with thermostats and humidity sensors, and may lead to inaccurate adjustments of the temperature or humidity in an area.

If CO_2 or any other indoor air quality monitoring is part of the ventilation system design, an HVAC professional should be consulted to determine proper locations for mounting any sensors or monitors.

4.3.8 Special areas

Special areas include photocopy rooms, bathrooms, kitchens, parking garages, loading docks, print shops, janitorial closets, and some storage areas (e.g., for paint, cleaning chemicals or other hazardous products). These areas require additional consideration for exhausting air and may require increased ventilation flow rates, as there may be higher contaminant levels present. Section 8 (Exposure controls/Personal protection) of the safety data sheet for any hazardous

products provides additional guidance for exposure controls and personal protection. To avoid recirculating contaminants into the main air supply, these areas should be designed to exhaust air directly outdoors if they contain hazardous products.

4.3.9 Balanced systems

A balanced ventilation system introduces outdoor air and exhausts inside air to achieve the target pressure balance (Health Canada 2018). Outdoor air is conditioned prior to being supplied to offices and meeting rooms where occupants spend most of their time, and air is specifically exhausted from areas where there may be extra moisture and contaminants, such as in lunchrooms and washrooms. A portion of the return air may also be exhausted depending on system design and operation. Office areas and meeting rooms have supply air diffusers and return air grilles to ensure proper air movement. Installation, calibration, and inspection of a balanced system will be the responsibility of an HVAC professional or other appropriately trained individual.

Blocking air supply diffusers or return air grilles may cause the system to overcompensate, leading to balancing issues. The correct volume of air should be delivered to all locations in a building to provide adequate air quality. It may be beneficial in the HVAC system design and operation to use zone controls to help manage changing temperature and humidity needs. For example, a south-facing sunny location may need more cool air while a north-facing location may need more heated air. Induction heating or cooling units on the building perimeter can be used for this purpose.

4.4 REDUCING AIRBORNE INFECTIOUS AEROSOL EXPOSURE

Many of the control mechanisms recommended to improve and maintain good indoor air quality also reduce the risk of airborne infectious diseases. Ensuring proper ventilation by introducing outdoor air can reduce the concentration of contaminants—including virus- and bacteria-laden particles—in indoor air through dilution or exhausting to the outdoors. Use of localized ventilation (e.g., exhaust fans typically found in bathrooms, kitchenettes) can also help reduce the transmission of infectious diseases. Proper ventilation can reduce surface contamination by removing some virus- and/or bacteria-laden particles before they can deposit on surfaces.

In addition to increasing outdoor air ventilation as a mechanism for reducing infectious disease transmission, ASHRAE Standard 241 provides guidance on using filtration and disinfection to deliver equivalent clean air. Equivalent clean air is calculated by considering dilution ventilation using outdoor air and the impact of different kinds of air cleaners, filters, and ultraviolet (UV) germicidal irradiation disinfection systems. A filter or air disinfection unit can be added to the ventilation system instead of increasing outdoor air intake above the minimum outdoor air ventilation requirements, thus providing energy savings and flexibility in how a building delivers clean air.

In Canada, UV radiation-emitting devices designed to kill or control human pathogens on surfaces and in air are regulated under the *Pest Control Products Act* and must be registered prior to use

and installation (Health Canada 2022c). Selection, installation, and maintenance of UV disinfection equipment should be done by a trained professional in accordance with the manufacturer's instructions to prevent unintended exposure of room occupants to UV energy. These devices are not permitted to produce ozone or other harmful substances.

When used alongside other personal protective measures (e.g., staying home when ill, wearing a well-fitting respirator or mask, practicing hand hygiene, covering coughs and sneezes, and cleaning and disinfecting high-touch surfaces and objects), improving ventilation and air filtration can be part of a plan to reduce the spread of infectious diseases indoors (PHAC 2021, 2022a, 2023a, 2023b, 2023c). For additional information on controlling exposure to infectious diseases, consult PHAC.

4.4.1 Other air cleaning technologies

Beyond removal of fine particulate material from the indoor air by mechanically trapping them on filter material, additive air cleaning or alternative methodologies exist that are meant to clean or disinfect the air. ASHRAE (2021a) recommends to "only use air cleaners for which evidence of effectiveness and safety is clear." Also, these technologies have the potential to degrade the quality of the air through the generation of ozone and other harmful secondary by-products.

ASHRAE Standard 241 provides a procedure for testing the effectiveness and safety of air cleaning systems. This guidance establishes testing methods and reporting requirements for in-room and in-duct air cleaning system effectiveness against microorganisms and sets limits for the release of UV radiation and degradation by-products.

4.5 POOR OUTDOOR AIR QUALITY EVENTS

As outdoor air pollution can be an important determinant of indoor air quality, strategies to prevent infiltration of outdoor air pollutants are essential to maintain and improve indoor air. General recommendations for maintaining and protecting indoor air when outdoor air quality is poor include (Health Canada 2020b):

- Reducing infiltration of outdoor air pollutants.
  - Installing the highest quality filter that the ventilation system will allow in accordance with the manufacturer's instructions to filter incoming air. Additional information can be found in section 4.3.5—Air filtering.
  - Switching off any HRV/ERV to limit the intake of outdoor air.
  - Properly sealing windows and doors and keep them closed.
- Using a PAC with a HEPA filter to help remove fine particles from the indoor air.

4.5.1 Wildfire smoke

Communities across Canada regularly experience wildfire smoke events, with wildfire season typically running from early April to late October. The indoor air quality in office buildings may be impacted by such pollution events. As wildfires burn, they produce dense smoke and a variety of air pollutants that can have an impact on human health.

Proactive planning by building managers will allow procedures to be initiated during wildfire events to help protect office building occupants. Planning frameworks developed by ASHRAE (2021b, 2024) and the US EPA (US EPA 2025) focus on reducing exposure to $PM_{2.5}$. These frameworks provide recommendations and processes for developing a Smoke Readiness Plan for commercial buildings and similar building types that can be implemented when smoke is forecasted and during smoky days. The advice closely aligns with guidance developed for community-based cleaner air spaces for use during wildfire events (Health Canada 2020a).

The framework emphasises that a Smoke Readiness Plan needs to be specific to a building. According to ASHRAE's Smoke Readiness Plan (2021b, 2024), building managers should consider the following:

1. Purchase smoke preparation supplies prior to the wildfire season to ensure that enough extra filters and PACs are available for use, as supplies may be limited during a smoke event.
2. Upgrade HVAC system recirculation filters to MERV 13 after ensuring that the system has been deemed capable of handling the upgraded filters. Note that high efficiency filters will likely require more frequent changes than usual due to their greater particulate retention and the increased outdoor smoke levels.
3. Repair broken dampers, actuators, and HVAC controls prior to wildfire season and ensure they will allow the reduction in outdoor air flow, if required.
4. Optimize airflows such that they are protective of human health while controlling odour, temperature, and indoor contaminant levels and maintaining a positive building pressure consistent with the building and HVAC system design.
5. Add air intake filtration during a smoke event, where possible. Installing MERV 13 filters on air intakes will capture a large fraction of $PM_{2.5}$ prior to entering the HVAC system.
6. Routinely monitor filter conditions and add a pressure gauge to measure the pressure drop on air handling units. This will help determine when to replace filters.
7. Limit smoke intrusion by weatherizing the building envelope to reduce infiltration—seal and caulk cracks, and keep doors and windows closed.
8. Monitor indoor $PM_{2.5}$ by obtaining one or more air monitors equipped with a $PM_{2.5}$ sensor. Even low-cost monitors can provide important information to building operators on the $PM_{2.5}$ levels in the building. Level trends can indicate if interventions are needed and if existing practices are effectively reducing indoor $PM_{2.5}$. For example, an upward trend can indicate that doors are open, air filters are degrading, or HEPA PACs should be turned on.
9. Determine how to create temporary cleaner air spaces within the building prior to fire season. Select and operate properly-sized HEPA portable air cleaners. It may be helpful to use an air monitor to determine whether the air is being cleaned and to verify that the air is in fact cleaner than other spaces in the building.
10. Anticipate other sources of $PM_{2.5}$ in the building such as cooking, vacuum cleaning, use of printers or copiers, and smoking. Awareness of potential sources can assist in reduction of these sources during wildfire events and beyond.

4.6 VENTILATION STANDARDS

4.6.1 Standards

Standards are produced by non-profit organizations, such as the CSA Group, the American National Standards Institute, ASHRAE, and the International Organization for Standardization. Specific standards are often incorporated into building codes, regulations, and certifications. Examples of standards relevant to indoor air quality include the following:

- American Conference of Governmental and Industrial Hygienists—Threshold Limit Values
- ASHRAE 55—Thermal Environmental Conditions for Human Occupancy
- ASHRAE 62.1—Ventilation and Acceptable Indoor Air Quality
- ASHRAE 62.2—Ventilation and Acceptable Indoor Air Quality in Residential Buildings
- ASHRAE 170—Ventilation of Health Care Facilities
- ASHRAE 180—Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems
- ASHRAE 241—Control of Infectious Aerosols
- CAN/CSA-F326-M91—Residential Mechanical Ventilation Systems
- CAN/CSA-Z317.2—Special Requirements for Heating, Ventilation, and Air-Conditioning (HVAC) Systems in Health Care Facilities
- Canada Labour Code—Canada Occupational Health and Safety Regulations
- MD 15000—Mechanical Environmental Standard for Federal Office Buildings—Public Works and Government Services Canada
- MD 15161—Control of *Legionella* in Mechanical Systems—Public Works and Government Services Canada

4.6.2 Building codes

Building codes outline the requirements for air exchanges, thermal comfort, and occupancy limits in a building, structure or facility. Heating, ventilation, storage facilities, renovations, CO alarms, smoke alarms, and maintenance are typically covered and are enforced by the provinces, territories, and municipalities. Certain premises are under federal jurisdiction. Always refer to the building code(s) that apply to your building.

Their objectives are to ensure that:

- the building is structurally adequate for its intended use;
- the structure and materials can withstand temperature extremes, wind, seismic activity, and ice and snow loads;
- the building design meets the fire code, electrical safety code, ventilation requirements, and other regulatory requirements; and
- the building is suitable for the planned occupancy.

4.7 HVAC SAFEGUARDING

Building operators should consider the possibility of deliberate attempts to tamper with or damage HVAC systems and/or introduce chemical, biological or radiological contaminants into the building through outdoor air intakes or from within the building, and plan accordingly. Additionally, depending on the HVAC system, cybersecurity incidents such as malware and ransomware attacks on the controls could disable and damage system components. Prevention of tampering or damage requires an assessment of the access points, operating conditions, and controls of the HVAC system.

Conducting a risk assessment of the building's mechanical ventilation system is an important component of protecting the building and its occupants. Using up-to-date drawings (e.g., mechanical, electrical) and the written operational procedures for the existing HVAC system, building operators should consider the following:

- Determine the location of outdoor air intakes and outdoor mechanical components. Design or modify the location of air intakes and mechanical components so they are not readily accessible and are less noticeable. If this is not possible, incorporate barriers such as fences and locked gates and/or surveillance and monitoring to limit access as much as possible.
- Determine the location of the filtration and distribution systems as well as the ventilation system controls. Secure areas where equipment is located, restrict access to these areas to authorized personnel, and screen and supervise personnel and contractors that have access to these systems.
- Establish a procedure for rapidly and safely shutting down the system should it be required. Ensure staff are trained and available.
- Determine if the system has the capacity to zone off, isolate or independently control ventilation of specific sections of the building. If so and if the HVAC system is damaged, operators can continue to provide ventilation to unaffected parts of the building while damaged sections are undergoing repairs. If contaminants are deliberately introduced into the system (from inside or outside), this capability combined with the operators' quick response can prevent or limit the exposure of occupants. This capability can also aid in evacuation planning.
- Determine the location and types of filters used in the system to aid operators with regular maintenance and help inform whether filters can mitigate the entrance of certain contaminants.
- Assess whether the system has adequate cybersecurity protection. Software used to automate and/or control these systems can be subject to cyber-attacks disabling or harming system components, which can in turn cause issues with indoor air quality, heating, and cooling. This can impact business operations through disruption of occupant activities and cause damage to equipment or materials stored in the building. Additionally, if the system controls are not adequately protected from intrusion, they can provide a gateway to access other networks and information, including financial and personal data.

The above list includes a few examples of the many mitigation measures that may be implemented to protect the HVAC system and the indoor air quality of an office building. A building-specific risk assessment is necessary to determine specific risks and help identify additional mitigation measures that may be implemented.

Undertaking a comprehensive risk assessment and implementing changes to help protect the HVAC system will help reduce but not necessarily prevent intentional disruption of the building operations. Monitoring and surveillance, comprehensive operational procedures for which staff are adequately trained, and communication with building occupants are all necessary to lessen the adverse impact to the mechanical ventilation system, the indoor air quality, and the health of the building occupants should an incident occur.

For additional information, refer to Protecting HVAC Systems from Cybersecurity Threats (ASHRAE 2021c) and Guidance for Protecting Building Environments from Airborne Chemical, Biological or Radiological Attacks (National Institute for Occupational Safety and Health 2002). All design, maintenance, and risk assessment activities should be conducted with the assistance of an HVAC professional.

5.0 BUILDING STEWARDSHIP

Good indoor air quality management includes building stewardship and communication.

Stewardship refers to the oversight of and responsibility for the care and maintenance of property. Building operators and employers are often able to directly and positively impact indoor air quality through building stewardship. By understanding indoor air and the interactions between products, furnishings, occupants, processes, and air quality, building managers and employers can develop policies and procedures or implement changes with air quality in mind.

Stewardship includes the day-to-day proactive upkeep and maintenance of the building and building envelope. By promptly identifying and addressing issues, operators or employers will be able to eliminate or reduce the causes of poor air quality, ideally before the issue becomes serious. Building stewardship includes building maintenance, space design and renovations, procurement, and housekeeping. Building operators should develop and maintain good communication with occupants, and educate employers, custodians, maintenance staff, and occupants about the importance of air quality and good practices to follow. Good communication between building operators and occupants can be facilitated through the development of a formal reporting process. A standardized procedure will ensure that communication regarding building issues is handled consistently over time.

5.1 BUILDING MAINTENANCE

Similar to good maintenance practices required for ventilation systems, measures should be taken to upkeep a building's indoor air quality or address potential causes of poor air quality before they become a problem. It is important to schedule routine cleaning and maintenance and to conduct regular inspections of the building.

Maintenance personnel or the health and safety committee should carry out regular inspections and monitor the building systems as required to look for indicators of moisture issues and to ensure that contaminants are not introduced into the building.

During inspection of the building and building envelope, particular attention should be given to:

- decay, leaks or damage in exterior walls, masonry work, roofs, eaves, soffits, foundations (e.g., cracks, openings, missing shingles, deteriorated caulking, separating flashings, missing eavestroughs, etc.);
- erosion, cracks or damage between doors or windows and the building itself that may let air or water enter the building;
- the soil grading around the building (i.e., the ground surface should slope downward to divert water away from the building);
- damage from plants, trees or shrubs, and their roots (e.g., roots lifting and cracking concrete, roots accumulating in drainage pipes);
- water or sewage leaks from plumbing (e.g., safety showers, emergency eyewash stations, fire suppression sprinkler systems, washrooms, drinking fountains, kitchens, roof drains);

- damage or discolouration in ceiling tiles, floors, and walls;
- condensate (water) forming on surfaces such as windows, windowsills, window frames, exterior walls, water pipes, etc.; and
- efflorescence, a crystalline salt deposit on brick or concrete that can serve as a sign of past water intrusion after the material has dried.

It is good practice to inspect the building after storms or heavy precipitations, when temperatures rise quickly causing snow to melt, or during extreme heat events to determine if moisture has entered the building or condensation is present on cool surfaces.

Identifying and addressing these issues early can help maintain good air quality and, in some cases, avoid expensive or extensive repairs or remediation.

5.2 SPACE DESIGN AND RENOVATIONS

When renovating spaces or reorganizing occupancy within a building, there are many factors to be considered before starting the work. Repairs and renovations should include isolation of work areas if normal occupant activities are still ongoing in other parts of the building and to limit the spread of any contamination. The appropriate jurisdiction (for example, the municipality) should be consulted to determine if permits are required for new installation or renovation of HVAC systems.

Recommendations for mitigating indoor air quality impacts during renovations include:

- Schedule activities such as cleaning, disinfecting, repairs or renovations that may generate contaminants to be completed at times that will minimize exposure to occupants. Certain renovation projects, including the removal of asbestos-containing materials, have a number of regulatory requirements, which, depending on the size of the removal, can include isolating the work area, disabling the ventilation system, and sealing ducts.
- Consult with an HVAC professional before performing any renovations or remodelling activities to identify controls for reducing exposure or activities that may impact indoor air quality.
- Plan for changes in air flow patterns when installing partitions, walls or other barriers.
- Be aware of the use of each space. If a space was designed for one or two people but is later used as a meeting room for several people, the HVAC system may require adjustment or modification. The same goes for changes in space usage (e.g., an office is converted into a photocopying room).
- Be aware of the position of air inlets and outlets within a room or space, ensuring that the location of inlets and outlets is conducive to cross ventilation.
- Off-gas (i.e., air out) new materials that may introduce contaminants into the air before bringing them into the workplace.
- Use products formulated to have low emissions.
- Allow sufficient time for off-gassing and ventilation when using products that are known to emit contaminants .
- Use barriers to limit the entry of dust from work areas into the air handling system.

Before reoccupying a repaired or renovated space:

- remove all construction materials and debris, and adequately clean the area in a manner appropriate to any contaminants that may be present;
- return all systems to a functional state (e.g., fire, lighting, electrical, mechanical); and
- confirm air handling systems are clean, balanced, and operational.

5.3 PROCUREMENT

Employers can include indoor air quality considerations in their purchasing decisions by taking steps to reduce exposure to contaminants from cleaning products, new furnishings, building materials, etc.

- Consider sustainable procurement policies to identify and reduce environmental impacts of supply chains when choosing suppliers of goods and services.
- Consider long- and short-term maintenance requirements when selecting flooring.
- Choose low-emitting furnishings and products, where available.
- Consider selecting low-emission cleaning and disinfecting products.

5.4 HOUSEKEEPING

Effective housekeeping includes more than just cleanliness. It also requires paying attention to the layout of the space and the use of storage facilities. Building managers should consider the following when planning housekeeping:

- Schedule routine cleaning of the building to prevent dust from accumulating on surfaces. Reduce the amount of dust that is generated when cleaning by damp wiping, carefully using lint-free cloths, or using wet methods for dusting and mopping (CCIAQ 2013a).
- Use vacuums equipped with HEPA filters, whenever possible.
- Empty or replace vacuum bags and filters as required.
- Keep entry ways (including areas outdoors) clear of water or snow to reduce the amount of moisture that may enter the building. Clean and dry mats to reduce debris and moisture.
- Select non-toxic products whenever possible and follow manufacturer's instructions and, where applicable, the safety data sheet for its safe use.
- Promptly clean areas to prevent a worsening of issues.
- When cleaning carpets:
  - schedule cleaning when there are no or a limited number of occupants;
  - follow the manufacturer's instructions for safe operation of any equipment and products used;
  - maximize the amount of water extracted from the carpet;
  - increase ventilation or open windows to help carpets dry faster (within 24 hours);
  - if possible, do carpet cleaning in winter when relative humidity is lower; and
  - dispose of cleaning solutions and contaminated water properly.

- Keep areas such as food preparation rooms and washrooms clean to minimize microbes and pests. Properly clean dishes and utensils and store food in designated spaces. Refer to cleaning and disinfection guidance for reducing spread of infectious diseases (Health Canada 2022b; PHAC 2022b, 2023a, 2023b, 2023c).
- When buying disinfecting products, ensure that they are approved by Health Canada and labelled with a drug identification number. If an approved disinfectant is not available, use a diluted bleach solution.
- Water plants appropriately to prevent excess moisture or spills. Plants placed on carpets should have a stand or other means to prevent moisture from entering the carpet. Strive to ensure plants are pest-free prior to introducing them into the building.
- Store paints, solvents, and cleaning products as required by the manufacturer. Storage areas should be dry, clean, and well ventilated. Keep containers properly sealed when not in use and, whenever possible, stored in a location not connected to the return air portion of the building ventilation system. For hazardous materials, consult section 7 (Handling and Storage) of the safety data sheet for more specific storage instructions.
- Discard products no longer used and expired cleaning products in accordance with the manufacturer's instructions and local waste requirements. For hazardous materials, consult section 13 (Disposal Considerations) of the safety data sheet.

6.0 ROLES AND RESPONSIBILITIES

Everyone has a role to play in maintaining good indoor air quality in the workplace from building operators and employers to the health and safety committee and employees.

Factors that contribute to poor indoor air quality may be related to inadequate ventilation system design, maintenance or operation. These factors are generally under the control of the building operator. Poor building stewardship practices such as inadequate housekeeping and cleaning by maintenance and janitorial staff can also have an important impact on indoor air quality, as can office occupants through activities such as wearing fragrances, blocking air return vents or opening/closing doors.

6.1 BUILDING OPERATORS

The building owner and property managers are ultimately responsible for building operations. There may be instances where the building operator is also an employer of the occupants.

Building operators maintain indoor air quality through preventive maintenance and investigation into issues or reported complaints of poor air quality. Building operators and employers should work collaboratively to prevent, reduce, and eliminate sources of indoor air contaminants through good building stewardship practices, and appropriately maintain the ventilation system.

As a best practice, it is recommended that building operators:

- ensure that the HVAC system is configured correctly—this responsibility may include consulting a qualified professional;
- have adequate knowledge of the ventilation system's operation (i.e., knowing intake and exhaust locations, timing of any scheduled air exchanges);
- use appropriate air filters and replace them when required;
- have scheduled preventive maintenance activities conducted on the ventilation system by a qualified professional, as required by the manufacturer;
- maintain the building to prevent and repair damage, cracks, water leaks, air infiltration, etc.;
- update plans, including building floor plans, as required;
- have procedures in place to follow when investigating issues or concerns regarding indoor air quality; and
- conduct a risk assessment before changing office layouts, floor plans or parking areas as it relates to the ventilation system and implement findings, as warranted.

6.2 EMPLOYERS

Employers have an overall responsibility to maintain a healthy and safe workplace, taking every reasonable precaution to prevent injuries, incidents or illness in the workplace. To help adequately maintain indoor air quality in the workplace, it is recommended that employers:

- develop and implement a formal reporting process to consistently communicate building issues;
- make sure that building systems and controls are in place, functioning, and maintained appropriately;

- have procedures in place for investigating issues or concerns regarding indoor air quality;
- implement, in collaboration with the building operator, any controls that may be necessary to maintain or improve indoor air quality;
- provide, in collaboration with the building operator, the necessary resources to maintain or improve indoor air quality; and
- provide communication to employees relating to indoor air quality or investigations.

Employers will benefit from implementing an indoor air quality management program that outlines:

- the roles and responsibilities of all parties;
- contact information for reporting indoor air quality concerns and issues;
- the methods for cataloguing indoor air quality concerns and issues, and recording how they were addressed;
- the required education and training;
- operation and maintenance of the building and ventilation system; and
- how to manage air contaminants and sources.

6.3 HEALTH AND SAFETY COMMITTEE OR REPRESENTATIVE

In Canada, the health and safety committee or representative is fundamental to supporting health and safety activities in the workplace. For areas under federal jurisdiction, the *Canada Labour Code* outlines the responsibilities of the health and safety committee as follows: "A workplace committee, in respect of the workplace for which it is established, shall consider and expeditiously dispose of complaints relating to the health and safety of employees" (Canada Labour Code 2024b). As it relates to indoor air quality, the health and safety committee or representative has the right and responsibility to:

- participate in workplace investigations and inspections;
- inquire into and monitor the status of ongoing investigations;
- receive reports related to health and safety activities;
- monitor the effectiveness of the health and safety program by cataloguing incidents and effectiveness of interventions over time; and
- provide recommendations to the employer.

6.4 EMPLOYEES

Under occupational health and safety legislation, employees have a duty to report any workplace hazard that causes or may cause an injury or illness. Concerns or potential issues can be discussed with a supervisor, the health and safety committee or representative (if present), the union (if present) or the employer.

Employees should also follow workplace policies regarding the use of products (e.g., cleaning products, scented products) and safe work procedures (e.g., housekeeping, handling and storing chemicals) to help maintain good indoor air quality.

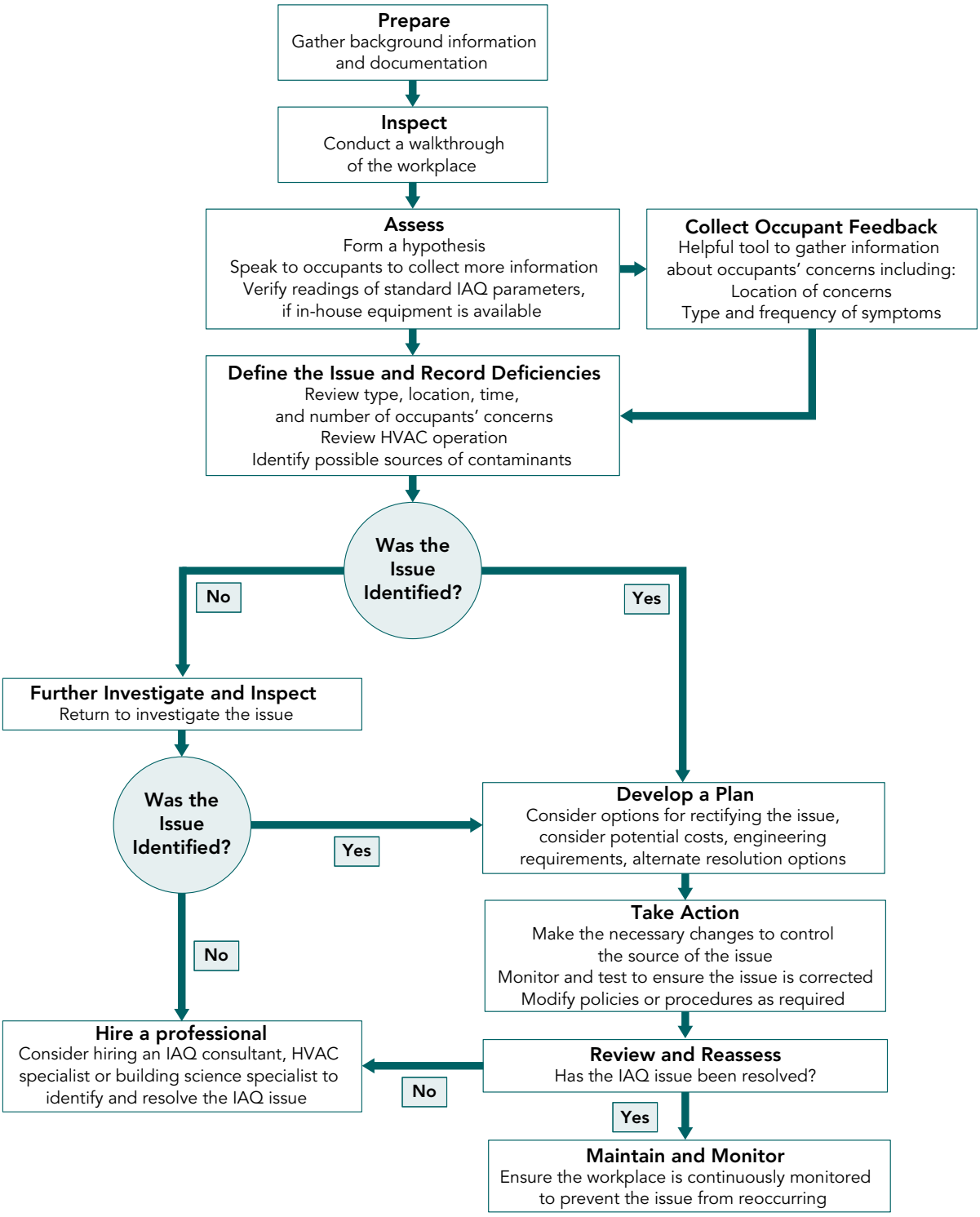
7.0 GUIDANCE FOR DEVELOPING AN INDOOR AIR QUALITY RESOLUTION PROCESS

The indoor air quality resolution process will often involve responding to a reported air quality issue while continuing to focus on preventive maintenance and continuous improvement. Thus far, guidance provided in this document has focused primarily on preventing indoor air quality issues through strategies such as source control, ventilation, and building stewardship. If issues do arise, the resolution process can assist in determining the causes of these issues and addressing them.

The process for diagnosing an indoor air quality issue begins when a complaint is received or an issue is discovered. Occupants may report concerns through the supervisor or manager, the health and safety committee or representative, the union, or the employer. As a best practice, it is recommended that the employer has a formal reporting process in place for recording and investigating indoor air quality concerns. When a concern is reported, the workplace should investigate to determine if an issue exists. It is important that each workplace party understands their respective roles and responsibilities as it relates to the indoor air quality management and resolution process.

The goal of diagnosing an indoor air quality issue is to discover the cause of the problem and to find solutions that will solve the problem and prevent the issue from re-occurring without creating new problems. Often, there may be more than one issue, requiring more than one solution. The causes of many of these issues may be easily determined and remediated by persons with a general knowledge of indoor air quality. Resolving some issues may, however, require more attention and effort. In some situations, the cause of an issue may not be easily determined, the investigation of the issue may be complex, or the strategies and mitigation measures needed to address the suspected issue may not be straightforward. For any indoor air quality investigation, whether simple or complex, following a resolution process may be useful. After identifying an issue, for example, through a formal reporting process, this issue can be resolved by following the indoor air quality resolution process presented in Figure 2. This process can vary from workplace to workplace and, depending on the situation, may or may not include all these steps. The process begins with the creation of an indoor air quality resolution team, and ends with the resolution of the issue. Full resolution may require further assessment and the help of a professional.

FIGURE 2: Indoor air quality concern resolution flowchart. Adapted from the Canadian Centre for Occupational Health and Safety (CCOHS 2021).



7.1 CREATION OF AN INDOOR AIR QUALITY RESOLUTION TEAM

Many individuals can help resolve an indoor air quality issue, including the building operator, employer, facility or building maintenance personnel, occupants, unions, and outdoor professionals. Selecting who conducts the investigation will depend on the organization of the workplace.

In most situations, there will be more than one person involved in investigating and resolving an indoor air quality issue. The resolution team may include a person designated as the leader and a representative from the health and safety committee or the union, where appropriate. The expertise of others such as health and safety professionals, building maintenance personnel or HVAC professionals can help determine the primary cause of the issue. These individuals may be part of the team or be asked to contribute their expertise as needed. The steps outlined in this document can be followed by any individual who is part of a team or not.

The role of the resolution team is to understand the air quality issue and determine the primary causes. As these causes may vary, it will often be necessary to seek the assistance of other individuals or groups during this process. The employer may also consider providing education and training about indoor air to the resolution team members for them to fulfill their roles.

The team, in consultation with the health and safety committee and the employer, can help develop an indoor air quality management program to:

- establish procedures for responding to issues;
- describe methods of communication to be used before and after a situation develops;
- outline how occupants can raise their complaints;
- explain the steps that will be taken to investigate the issue; and
- outline how issues will be resolved.

It is important to communicate to the occupants the purpose and scope of any investigation. If the investigation will take time, updates of any progress should be posted. Occupants should also be encouraged to participate in the process.

The findings from this team should be reported to the employer and the health and safety committee, if any. The health and safety committee can assist the team and employer in developing and prioritizing recommendations for action. The results should be made available to all occupants and feedback encouraged.

If the resolution team feels that they are lacking the experience or knowledge to adequately address issues discovered during the walkthrough and assessment process or that they cannot properly assess the situation, it is recommended to seek the assistance of a consultant or qualified professional as described in section 8.

7.2 PREPARATION

Communication, cooperation, and early action can lead to a successful outcome. Without open communication, an indoor air quality issue can become complicated by frustration and distrust, which may delay its resolution. It is recommended that the building operator or employer respond promptly and take all issues about the indoor environment seriously.

To be prepared to resolve indoor air quality concerns, it is recommended the building operator or employer:

- identify key people and form a resolution team;
- identify and communicate to the occupants who is responsible for receiving concerns (e.g., supervisor, resolution team lead, employer);
- encourage occupants to report issues using the formal reporting process of the building;
- establish a system to document the time and location at which effects or concerns have occurred—this system may include an indoor air quality log or occupant surveys—and encourage occupants to record issues as they occur to reduce recall bias;
- develop systems to notify occupants of the scope and purpose of any investigation, and post, distribute or address the information using communication channels (e.g., emails, bulletin boards) or through the health and safety committee;
- determine whether the team requires permission or access to inspect the ventilation system and if a professional is required for this task; and
- decide how the results of the investigation, corrective actions, and the proposed implementation plan will be made available to occupants for review and feedback.

7.3 INSPECTION

It is highly recommended that the building operator be present as part of the resolution team during the walkthrough inspection by the supervisor and resolution team to attempt to identify any immediate causes of the issue. Occupants may have more details beyond what was reported. Often, those working in the same area have similar issues but may not have reported them or may have useful information, especially related to any past incidents or issues with the area (i.e., flooding incidents or odours).

Typically, the inspection will seek to identify and possibly resolve any straightforward issues, such as:

- adjusting building temperature;
- closing or opening windows or doors;
- confirming that ventilation ducts or air intakes are not closed or blocked;
- ensuring occupants are following workplace policies and procedures (e.g., for the use of scents or cleaning products);
- addressing odour issues from activities such as cooking; and
- considering issues that can exacerbate disease transmission when there is a reportable disease circulating in the community. Examples include:

- ensuring suitable cleaning and disinfecting procedures are in place;
- identifying high-risk areas such as enclosed areas or places where large numbers of people congregate; and
- reducing the use of enclosed or poorly ventilated spaces.

If the team identifies a specific cause and proposes a solution, the investigation may be paused until the changes are implemented and the results evaluated.

If there is no clear solution or the resolution team identifies other issues, it may be necessary to proceed with an assessment.

7.4 ASSESSMENT

The assessment will gather more details and facts and examine potential issues more closely than during the walkthrough. During the assessment, the resolution team will attempt to define the issues more clearly and should consider:

- meeting with the occupants of the affected area and collecting information about the issues;
- physically inspecting the building to become familiar with the layout, activities in each area, and the ventilation system, and recording any observations directly onto a copy of the floor plan;
- reviewing issues and looking for patterns in the type of conditions reported, including the duration and frequency of complaints, and locations of those reporting issues, including commonalities of areas of complaint locations and HVAC units that serve them;
- being aware of the factors that influence indoor air quality perception (section 3.4);
- checking the ventilation system with the assistance of the building operator or a qualified professional, particularly if the resolution team does not have adequate information or knowledge regarding the ventilation system and its operation; and
- reviewing any available documents about the building history, particularly recent modifications and past incidents.

Similar to the walkthrough, the team will likely perform the following in more detail during the assessment:

- Check temperature and humidity to see if the area is within the comfort range for the season.
- Confirm if the air has odours, feels stuffy, or is drafty.
- Check for dampness in walls or carpets, visible mould, elevated humidity levels or water leaks.
- Check for presence of dust, dirt, or signs of pests.
- Check for obvious sources of internal or external contaminants.
- Confirm if regular maintenance has been conducted on the ventilation system (e.g., look for dirt or mould, check records and status of air filters).
- Compare the original uses of the area and the surrounding rooms with their present uses. Has occupant density increased? Have work areas been rearranged or repurposed? Has new equipment been added, such as furniture, computers, printers, photocopiers or humidifiers?

- Identify areas where renovations, repairs or redecorating activities are in progress or have recently been completed, and ensure appropriate/increased cleaning and ventilation, if necessary.

As many, if not most, indoor air quality assessments can be completed without air sampling, it is not recommended as a first step. Air sampling uses specialized equipment to determine the level of a contaminant or particle in the air. In some cases, particularly for federally owned buildings, air sampling may be needed to ensure regulatory or legal compliance, or to help further define the issue. Refer to Sampling or Monitoring Indoor Air Contaminants in Guidance for Indoor Air Quality Professionals (Health Canada 2025) for more information.

The resolution team can use a checklist or form to help make sure their review is thorough and consistent when performing the assessment. A blank sample assessment form can be found in Appendix D. It is important to record the date and location of the assessment to properly document the issue. Recording the item and area inspected, along with observations of what was inspected, will help the resolution team determine whether the item inspected appears to be satisfactory or unsatisfactory, or if additional information or follow-up is required. The resolution team can then focus their efforts on those items to help them define the issue. Additionally, the recording of the investigation activities in a checklist or form can make the information gathered be more easily analyzed.

Furthermore, keeping records of these assessments will be useful for repeated issues in the same area or similar issues in other parts of the building. These records, which may be kept by the owner, employer, maintenance staff or health and safety committee, can be reviewed as part of the information gathering phase of the next resolution process.

The goal is to provide a structured approach to indoor air quality assessments to ensure that all areas that often contribute to poor air quality have been examined.

7.5 COLLECTION OF OCCUPANT FEEDBACK

When conducting the assessment, it is important to speak to the occupants, especially those that have reported an issue, if possible. Information on symptoms or discomfort, timing of onset and relief, and patterns (such as spaces occupied) and specifics related to the types of any symptoms experienced can be useful to better define the issue.

It is important to remember the following when speaking to occupants:

- Health effects associated with poor indoor air may be similar to those of other health conditions. Where individuals are experiencing adverse health effects that may be related to indoor air quality, an assessment by their health care provider may be warranted.
- Providing information on symptoms or diagnosed health conditions is at the discretion of the employee, and information should be kept confidential.
- Not everyone is equally susceptible to issues with indoor air quality. Even if one person or only a few people report symptoms, the possibility of an issue should not be ignored. If air quality worsens, more people may be affected.
- If workplace exposures are suspected to be causing an adverse health outcome, applicable workers' compensation legislation may require reporting.

This information can also be gathered from occupants who work in the same area but who have not reported their issues or related their health concerns to indoor air quality. As mentioned, occupants should be encouraged to record health symptoms or concerns as they happen, as well as throughout the investigation period, to ensure accurate information is captured.

See Appendix E for a blank health effects reporting form.

7.6 DEFINING THE ISSUE AND RECORDING DEFICIENCIES

After collecting the completed reports, the resolution team should consider summarizing these findings in combination with other details gathered. This summary will provide an overview of the assessment and help identify patterns and potential causes of the occupants' issues as well as possible solutions. Appendix F shows a method for summarizing findings and assisting with transparency throughout the process.

7.7 FURTHER INVESTIGATION AND INSPECTION

If there are no clear corrective actions or solutions after completing the walkthrough and the assessment, a more detailed investigation may be necessary.

During this detailed investigation, the team may work with other individuals, such as health and safety or building maintenance personnel, who may have a better understanding of the area to conduct a more thorough review.

If no further possible causes or solutions are identified after this second investigation, the team should consider consulting or hiring a professional with experience in ventilation systems, building engineering and/or indoor air quality.

7.8 DEVELOPING A PLAN AND TAKING ACTION

Based on the information collected, recommendations may range from straightforward solutions (e.g., adjusting the temperature, changing air filters, installing a dehumidifier) to more complex ones (e.g., remediating leaks or mould growth or rebalancing the HVAC system). Often, depending on the situation, a combination of multiple actions or controls may be appropriate to resolve the issue. If several issues are identified, the relative importance of each issue to the situation that prompted the investigation may not be clear.

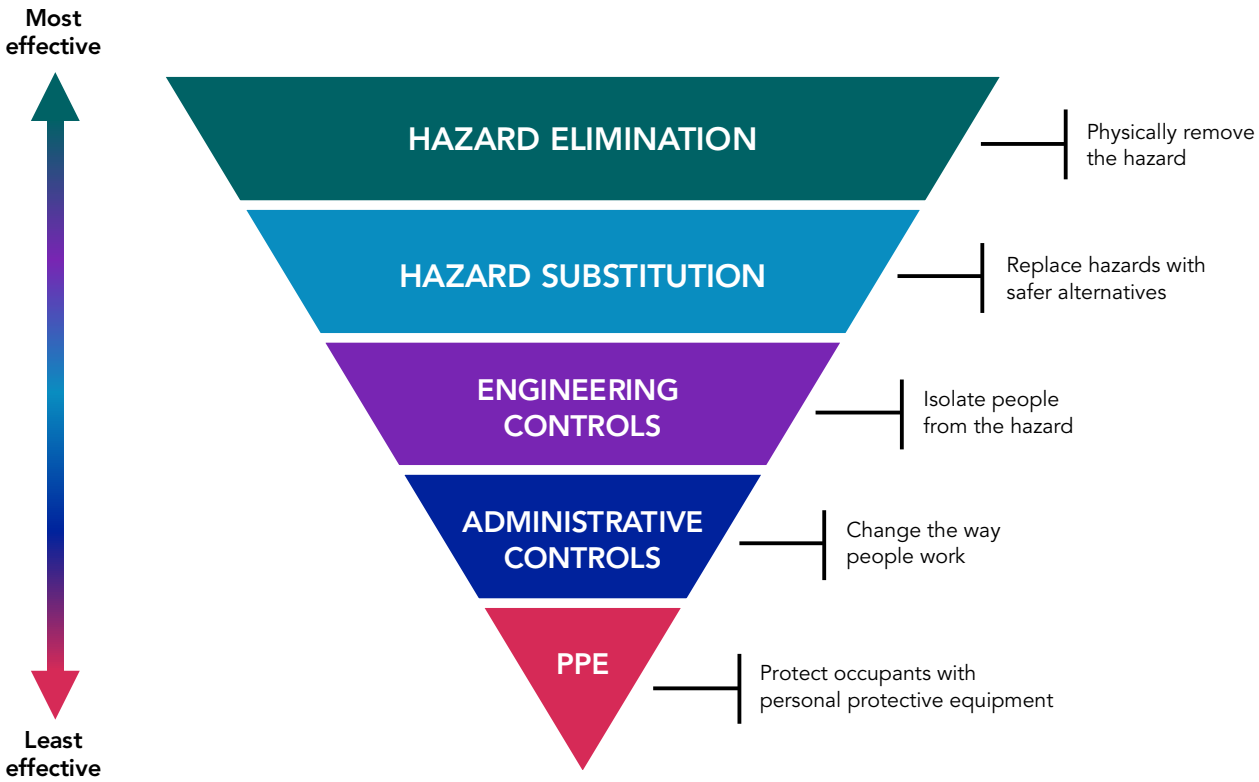
A hierarchy of controls is useful when considering potential solutions (Figure 3). Where there is a chemical or biological exposure in the workplace, the hierarchy of controls refers to the order in which different types of control measures should be implemented based on their effectiveness and ease of eliminating hazards and controlling risks. The most effective control measures are those that eliminate or reduce the hazard, such as replacing a hazardous cleaning product with a less hazardous one. If these controls are not possible or if there is a remaining risk, engineering controls should be considered next, such as storing or mixing chemicals in a room with exhaust ventilation. Only in cases

where administrative and engineering controls are not sufficient would personal protective equipment (PPE) be used. For example, PPE may be used to minimize the hazard in an interim period until administrative controls can be implemented to complement other controls, such as using these products after occupants have left for the day (Canada Labour Code 2024a; CCOHS 2018).

For indoor air quality issues in office buildings, this process begins with eliminating the issue (hazard) at the source. If this is not possible, then steps to minimize the issue should be taken to the greatest extent possible, such as substituting products that are believed to be the main source of the issue. However, indoor air quality issues are often due to problems with the ventilation system. When it comes to indoor air quality, after addressing any maintenance-related issues, the next step would be to investigate system balancing to see if it is suitable for current occupancy and design requirements. In some cases, this can mean rebalancing it to align with the original design requirements. In other cases, new requirements may require engineering controls, such as adding exhaust to a printer room, or modifications to the ventilation system for increased occupancy or changes to room partitioning (adding or removing walls). While PPE is a form of protection, outside of the context of an infectious disease, it is not normally used to solve problematic indoor air quality. It is expected that the office environment should have suitable indoor air quality without the need for PPE.

Examples of actions related to good indoor air quality and the hierarchy of controls are discussed below.

FIGURE 3: Hierarchy of controls (CCOHS 2024)



7.8.1 Implementing corrective actions

When an identified indoor air quality hazard cannot be easily addressed, it may be necessary to implement additional corrective actions. Controls should be implemented in order of effectiveness according to the hierarchy of controls and, where necessary, using multiple controls to reduce risk to acceptable levels or, where this is not possible, to levels as low as reasonably achievable.

Throughout the resolution process, communication between the building operator or employer and affected individuals is very important. There may be situations where a corrective action will take time to implement. In other situations, corrective actions may not be initially identified because the source of the issue cannot be determined, or no reasonable corrective action exist. Collaboration should continue with the occupants to determine other options (e.g., relocating work, reducing exposure time).

7.8.1.1 Hazard elimination

Eliminating the source of the contamination is the most effective solution to indoor air quality issues. The following should be considered:

- Remove or control sources of odours from the workplace (e.g., garbage, strong-smelling cleaning products, fragrances, and deodorizers).
- Remove sources of contaminants (e.g., ozone-generating equipment, gas-powered heaters).
- Correct issues related to high humidity or where water gains access to the building and may cause mould growth.
- Reduce or eliminate aerosolized sprays.
- Encourage policies that eliminate potential sources of respiratory infectious diseases (e.g., encourage employees to stay home when ill and promote remote work when symptomatic) (PHAC 2023c).
- Change or eliminate the activity causing the original hazard.

7.8.1.2 Hazard reduction

If the hazard cannot be eliminated, control measures to reduce it can be implemented through techniques that diminish the intensity of the hazard should it occur or prevent the hazardous situation from occurring. These can include hazard substitution and engineering controls, as described in the next sections.

7.8.1.2.1 Hazard substitution

If eliminating the source of the contamination is not possible, it may be possible to substitute products for less hazardous ones, such as ones with lower emissions, low odour, or unscented ingredients. Care must be taken to make sure that one hazard is not being replaced with another that is just as or more harmful. Before deciding on a new product, all the implications and potential hazards of each alternative product should be considered. For hazardous products, consult Section 2 (Hazard Identification) of the safety data sheet to understand these hazards.

7.8.1.2.2 Engineering controls

Hazard reduction can also be addressed by engineering controls built into the design and operation of the building, equipment or process. Engineering controls are reliable when they are designed, installed, and maintained properly.

The primary example of engineering controls for air quality is the ventilation system, which may be natural or mechanical. In some situations, a separate or portable HEPA filtration unit may be appropriate to remove contaminants. Consider controls to reduce risk of transmission of infectious diseases (i.e., ventilation, filtration, use of PACs).

Isolation is another control approach and includes the following:

- Keep tasks or processes generating air contaminants separate from where the occupants work. Make sure that any equipment or processes that produce contaminants are used under negative pressure to exhaust odours or contaminants from the area through exhaust ventilation that conveys the contaminants directly outdoors.
- Place new materials and furnishings away from the work area to off-gas (air out) before introducing them to the workplace.
- Install barriers or containment during dust-producing activities to limit or prevent dust from entering the workplace and ventilation system.

7.8.1.3 Administrative controls

Administrative controls include implementing procedures related to how and where the work is done and providing education and training to increase awareness of indoor air issues. While administrative controls may not reduce the hazard, they can limit exposure to it. Administrative controls should be implemented only after all hazard-reduction measures have been considered. Ideally, they should be used in combination with other methods of control.

Indoor air quality administrative controls include:

- Implementing an indoor air quality management program.
- Establishing preventive maintenance schedules for all mechanical ventilation equipment and for the building as a whole. Proactively addressing issues that may contribute to poor indoor air quality.
- Scheduling maintenance and other operations that may impact the indoor air (e.g., renovations, large-scale or significant cleaning activities) for times during lower occupancy or when employees are not present. Allow enough time to ventilate the workplace before occupants return.
- Inspecting the workplace with health and safety committee members or representatives regularly to identify potential indoor air quality issues.
- Establishing and maintaining good housekeeping practices.
- Providing education and training on hazardous products in the workplace (e.g., Workplace Hazardous Materials Information System [WHMIS 2015]).

- Including indoor air quality considerations in the procurement procedures.
- Creating and enforcing a scent-free workplace policy (CCOHS 2019).
- Consider encouraging staff to self-screen and stay home when ill, and promote remote work options, particularly when infectious diseases are circulating in the community.

7.8.1.4 Personal protective equipment

There may be situations where wearing a mask or respirator (e.g., N95) is necessary or appropriate, such as when investigating or cleaning a very dusty or mouldy space, or when there is suspected animal or bird feces present (Health Canada 2023a). This kind of inspection or remediation should be carried out by a trained professional. Note that specific training and fit testing are often required before wearing a mandatory respirator. Any PPE program should follow legislation requirements of the local jurisdiction (CCOHS 2017). In these situations, care must be taken to ensure building occupants are not exposed to the hazard (established or suspected).

7.9 REVIEW AND REASSESSMENT

Once all corrective actions have been implemented, the resolution team can determine if the actions resolved the issue. While this decision will be managed case by case, the team should ideally seek a mutual agreement that an acceptable resolution has been reached. The review of the indoor air quality issue resolution may be qualitative (descriptive) or quantitative (measurable):

1. **Qualitative:** occupants no longer report health effects or issues. No or fewer reports may be an indication that the issue has been addressed adequately.
2. **Quantitative:** properties of the air before and after the corrective actions indicate acceptable improvements in the desired parameters (e.g., temperature, humidity, air flow).

Methods to ensure actions are effective include physical inspection, observations, measurements, health effect and issue tracking, investigation reports, and employee feedback. Reassessment can determine the answers to the following questions, as applicable:

- Did the actions resolve the issue that prompted the initial investigation?
- Is the hazard eliminated or the risk controlled?
- Have the actions been implemented in a way that does not create a new (worse) hazard?
- Are any new hazards appropriately controlled?
- Are monitoring processes in place and adequate?
- Have employees been informed about the hazards and the controls?
- Has there been sufficient communication throughout the process?
- Has education and training been provided to reflect the current hazards and required controls?

If the answer to all of the above questions is yes and if no further issues have been raised about indoor air quality, it is likely that control measures are successful. Monitoring and seeking employee feedback should continue to ensure the air quality remains adequate. If any answers to the above questions are no, further action may be required.

Conditions may change over time. Some issues, such as those involving odours, may be due to seasonal differences in air infiltration related to temperature differences indoors and outdoors. It is important to include discussion of indoor air quality issues in workplace inspections when seeking employee feedback and when performing building or ventilation system maintenance.

7.10 MAINTENANCE AND MONITORING

A preventative ventilation system maintenance program, in combination with systems to control temperature, moisture and airflow will contribute to maintaining and improving indoor air quality. Proactive monitoring can aid in identification of worsening indoor air quality, allowing for prompt action to remediate it.

8.0 WHEN AND HOW TO HIRE A PROFESSIONAL

In some situations, it may not be apparent what the issues are and how to address them, or the skills needed may not be available in-house.

Building operators or employers may need to hire the services of a qualified professional or organization that has the necessary skills, training, and equipment to further investigate and remediate the issue.

The activities of the indoor air quality resolution team (i.e., walkthrough, assessment, and occupant surveys), which take into consideration the building, its ventilation system, its occupants, and their interactions, generate information that may be valuable when consulting with a professional. It may provide the professional with important details to help them determine what actions need to be taken and whether specialized equipment or additional information is needed to further investigate and address the issue.

8.1 PROFESSIONAL SERVICES

Professionals may be qualified individuals, technicians or consultants who can offer a wide range of services.

While the resolution team can identify the potential issue, qualified professionals may be required to install, maintain, repair or adjust the ventilation system when building operators cannot. In addition, licensed or specifically trained professionals are required in certain situations where the cause of the problem is not readily apparent and with specialized cases such as asbestos abatement or large mould area remediation.

Careful documentation of the professional's competencies, work carried out and project communications is important, especially when an indoor air quality complaint escalates to litigation or mediation.

8.1.1 Choosing a professional

When choosing a professional, that individual's or organization's competency to perform the required tasks should be considered. In general, for individuals to be competent, they should have a combination of:

- qualifications to do the work based on their knowledge, skills, training, and experience;
- knowledge about the hazards and risks associated with the job or task to be performed (e.g., know what hazards and risks are likely present and how to safely and effectively address them);
- knowledge to recognize, assess, and control these hazards and risks (e.g., know what precautions to take, what controls to use, or what needs to be in place for the different hazards or risks); and
- knowledge to work in compliance with all applicable laws, codes, and standards.

Depending on the issues to be resolved, professionals should be:

- able to address the specific issues of the workplace;
- familiar with any applicable legal requirements, codes, standards, and guidelines (e.g., the building code for that jurisdiction and the ventilation requirements prescribed therein);
- qualified to assess thermal comfort, ventilation, building envelope issues, and air contaminants;
- experienced with HVAC system performance, operation, and maintenance;
- experienced in indoor air quality investigations;
- able to provide guidance, updates, and interpretation of results;
- able to provide actionable recommendations related to their area of specialization (e.g., HVAC, building envelope, indoor air quality investigations, and remediation);
- accredited (e.g., the laboratory used to analyze samples) or credentialed (e.g., licensed in occupational hygiene or HVAC design and installation), where needed; and
- able to provide references.

8.1.2 Verifying experience, credentials, and qualifications

Before hiring a professional, it is important to always confirm their experience, request samples of their work, and check references. Contacting previous clients and verifying that individual's or organization's competence, professionalism, and ability to deliver timely results for a comparable scope of work can provide reassurance in selecting the right service provider. Accreditation bodies may also provide a list of certified professionals on their website.

It is good practice, and sometimes required, to verify qualifications, including licences, degrees, certificates, liability insurance, and employee's compensation coverage of the professional for hire. To acting on their behalf in this capacity is adequately qualified or competent. Therefore, it is important to request and keep documentation of the person's qualifications, resume, and verified references. A professional should not be offended by this request and should willingly provide the documentation supporting their experience or credentials.

8.2 SCOPE OF WORK AGREEMENT

The information gathered during the walkthrough, assessment, and occupant surveys will help plan the work that needs to be completed by the professional (known as the "scope of work"). Establishing an agreement that covers the scope of the work the professional will complete and the cost of the services is important.

The agreement should include a description of the following:

- the methods that will be used;
- the schedule, costs, and deliverables, such as air sampling, reports, and training for building staff;
- who will complete which tasks (e.g., some tasks may be able to be completed by building staff); and

- the type and frequency of communications between the professional and the building operator or employer.

For example, the following should be included if the professional is conducting air sampling:

- contaminants measured;
- sampling and analysis methods used;
- sampling location and time;
- the laboratory analyzing the samples and whether they are certified/qualified;
- any direct reading instruments appropriate for the work with confirmation their calibrations are documented and within manufacturers' specifications;
- use and interpretation of the results (e.g., comparing them to standards or guidelines, or to levels from an area without issues raised); and
- the costs for the various tasks, including costs for laboratory analysis and the schedule for completing the work.

See Guidance for Indoor Air Quality Professionals (Health Canada 2025) for more information.

A written agreement is valuable because it describes how the professional will achieve the expected outcomes (deliverables), in what timeframe and for what cost. In addition to the agreement elements listed above, the scope of work may also:

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

While many actions can be taken by the building operator or employer to resolve indoor air quality issues, there will be situations where hiring qualified professionals is necessary. As with any business activity, due diligence should be conducted when engaging the services of a qualified professional or organization that has the necessary skills, training, and equipment to further investigate and remediate the issue.

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

9.0 SUMMARY

Poor indoor air quality can affect your health. The most effective way to improve your indoor air is to identify activities that can contribute to poor indoor air quality and remove or reduce the sources of indoor air pollutants. Indoor air quality issues may occur in buildings when chemical or biological contaminants exist at levels that may pose a health risk to building occupants. It is also important to note that some building occupants may be considered more susceptible to health effects from exposure to elevated levels of indoor air contaminants. Thermal comfort can also be a highly relevant indoor air quality issue.

Preventing indoor air quality issues before they arise and addressing issues as soon as they are identified are the best strategy for building operators and employers. Good practices to maintain indoor air quality include strategies to:

- Eliminate or reduce sources of contaminants. Sources of contamination may be present indoors (e.g., combustion, cleaning products, furnishings, moisture, or odours from occupants or activities) or outdoors (e.g., smoking areas, vehicle idling, wildfire smoke).
- Maintain protocols to reduce viral and bacterial transmission between building occupants.
- Ensure effective ventilation system design and operation. Ventilation can improve air quality by replacing the indoor air with filtered and conditioned outdoor air, thereby removing and diluting contaminants. Verify ventilation flow rates to match them with any changes in occupant levels, duration of occupancy, renovations, redesigns, and how the space is utilized.
- Develop and implement a preventive maintenance program for the ventilation system. Remove contaminants through appropriate air cleaners or filters.
- Install efficient filtration units or filters as part of the ventilation system and ensure adequate outdoor air ventilation based on applicable standards and outdoor conditions. Select the correct filter efficiency for the contaminants present and the ventilation system. When possible, choose MERV 13 filters or higher.
- Use proactive housekeeping practices, including choosing cleaning products with low VOCs and using a vacuuming system with a HEPA filter.
- Control moisture and humidity levels and ensure early intervention if mould is suspected. Remediate moisture and damage from flooding, clean mould appropriately, and prevent reoccurrence by determining the source of the moisture and addressing the issue.
- Implement workplace procedures to consider indoor air quality issues throughout procurement and renovations in new and existing buildings. Assess any potential mismatches of the intended space and occupant activities. Where these do not align, the design of the space may affect ventilation distribution and air exchanges.
- Ensure occupants are following workplace policies and procedures, such as use of scents and cleaning products.
- Conduct indoor air quality training and education for building operators, employers, and occupants. Training should be relevant to the audience and can include how to identify a

potential indoor air quality issue and how to report concerns. Occupants should also be aware of issues unrelated to indoor air, such as ergonomic and psychosocial risk factors (e.g., relationships with co-workers, control over workload), as they can affect perceptions of indoor air quality.

When building occupants report indoor air quality concerns, the building operator or employer should assemble a resolution team to perform a walkthrough and assessment. The goal of the walkthrough and assessment is to identify the issue and potential causes. Speaking with the building occupants of the affected area will assist throughout the investigation process. By understanding the potential causes of an issue, the building operator or employer can implement corrective actions to remediate the situation. It is important to take all indoor air quality issues seriously and communicate with building occupants throughout all activities and corrective actions.

The control measures used should eliminate or reduce the issue. Follow-up assessments are important to ensure the corrective action is working as intended and that it did not create a new issue. There may be instances where additional resources, such as an external qualified professional, are required to either determine the cause of the issue or to modify the ventilation system.

By following good prevention practices and addressing concerns promptly, building operators and employers can prevent and reduce indoor air quality issues.

10.0 REFERENCES

Allen, J.G., MacNaughton, P., Laurent, J.G.C., Flanigan, S.S., Eitland, E.S. and Spengler, J.D. 2015. Green buildings and health. Current Environmental Health Reports. 2(3):250–258.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 2021a. Core recommendations for reducing airborne infections aerosol exposure.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 2021b. Planning framework for protecting commercial building occupants from smoke during wildfire events.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 2021c. Protecting HVAC systems from cybersecurity threats.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 2022. ASHRAE position document on indoor carbon dioxide.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 2023. Design guidance for education facilities: Prioritization for advanced indoor air quality.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 2024. Guideline 44-2024—Protecting building occupants from smoke during wildfire and prescribed burn events.

Bergeron, M.F., Devore, C.D. and Rice, S.G. 2011. Climatic heat stress and exercising children and adolescents. Pediatrics. 12(3):e741–e747.

Berquist, J. and Obrien, L. 2018. A quantitative model-based fault detection and diagnostics (FDD) system for zone-level inefficiencies (HO-18-015). ASHRAE Transactions, 2018 ASHRAE Annual Conference. 124:133–152.

Canada Labour Code. 2024a. Canada occupational health and safety regulations, SOR/86-304—Preventative measures—Section 19.5(1).

Canada Labour Code. 2024b. R.S.C., 1985, c. L-22.—Duties of committee—Section 135(7).

Canadian Centre for Occupational Health and Safety (CCOHS). 2017. Designing an effective PPE program.

Canadian Centre for Occupational Health and Safety (CCOHS). 2018. Hazard control program.

Canadian Centre for Occupational Health and Safety (CCOHS). 2019. Scent-free policy for the workplace.

Canadian Centre for Occupational Health and Safety (CCOHS). 2021. Indoor air quality—General.

Canadian Centre for Occupational Health and Safety (CCOHS). 2024. Reducing risks in the workplace—Going beyond a generic policy.

Canadian Committee on Indoor Air Quality (CCIAQ). 2013a. Guide for indoor air quality. Module 3 Custodial activities, maintenance, repair and renovation.

Canadian Committee on Indoor Air Quality (CCIAQ). 2013b. Guide for indoor air quality. Module 4 Recognizing and addressing indoor air quality problems.

Centres for Disease Control and Prevention (CDC). 2023. Ventilation in buildings.

Government of Alberta. 2009. Indoor air quality tool kit.

Health Canada. 1995. Indoor air quality in office buildings: A technical guide.

Health Canada. 2014. Flood cleanup: keep in mind indoor air quality.

Health Canada. 2016. Relative humidity indoors: Fact sheet.

Health Canada. 2018. Ventilation and the indoor environment.

Health Canada. 2020a. Guidance for cleaner air spaces during wildfire smoke events.

Health Canada. 2020b. Infographic: Protecting your indoor air from outdoor pollutants.

Health Canada. 2021a. Flood cleanup and indoor air quality.

Health Canada. 2021b. Residential indoor air quality guideline: Carbon dioxide.

Health Canada. 2022a. Choosing a portable air purifier.

Health Canada. 2022b. COVID-19: Cleaning and disinfecting.

Health Canada. 2022c. Regulating certain ultraviolet radiation-emitting and ozone-generating devices under the Pest Control Products Act: Devices subject to the Act.

Health Canada. 2023a. Guide to addressing moisture and mould indoors.

Health Canada. 2023b. Wildfire smoke, air quality and your health.

Health Canada. 2024. Extreme heat events: Health risks and who is at risk of extreme heat events.

Health Canada. 2025. Guidance for indoor air quality professionals. (pending)

Jones, E.R., Laurent, J.G.C., Young, A.S., Couli, B.A., Spengler, J.D. and Allen, J.G. 2022. Indoor humidity levels and associations with reported symptoms in office buildings. Indoor Air. 32(1):e12961.

Lancet COVID-19 Commission Task Force on Safe Work, Safe School and Safe Travel (Lancet). 2022. Proposed non-infectious air delivery rates (NADR) for reducing exposure to airborne respiratory infectious diseases.

MacNeill, M., Dobbin, N., St-Jean, M., Wallace, L., Marro, L., Shin, T., You, H., Kulka, R., Allen, R.W. and Wheeler, A.J. 2016. Can changing the timing of outdoor air intake reduce indoor concentrations of traffic-related pollutants in schools? Indoor Air. 26(5):687–701.

McGarr, G.W., Saci, S., King, K.E., Topshee, S., Richards, B.J., Gemae, M.R., McCourt, E.R. and Kenny, G.P. 2020. Heat strain in children during unstructured outdoor physical activity in a continental summer climate. Temperature. 8(1):80–89.

Morawska, L., Allen, J., Bahnfleth, W., Bennett, B., Bluyssen, P.M., Boerstra, A., Buonanno, G., Cao, J., Dancer, S.J., Floto, A., Franchimon, F., Greenhalgh, T., Haworth, C., Hogeling, J., Isaxon, C., Jimenez, J.L., Kennedy, A., Kumar, P., Kurnitski, J., Li, Y., Loomans, M., Marks, G., Marr, L.C., Mazzarella, L., Melikov, A.K., Miller, S.L., Milton, D.K., Monty, J., Nielsen, P.V., Noakes, C., Peccia, J., Prather, K.A., Querol, X., Salthammer, T., Sekhar, C., Seppänen, O., Tanabe, S-I, Tang, J.W., Tellier, R., Tham, K.W., Wargocki, P., Wierzbicka, A., and Yao, M. 2024. Mandating indoor air quality for public buildings. Science. 383(6690):1418–1420.

National Collaborating Centre for Environmental Health (NCCEH). 2021. Indoor CO_2 sensors for COVID-19 risk mitigation: Current guidance and limitations.

National Collaborating Centre for Environmental Health (NCCEH). 2023. Do-it-yourself (DIY) air cleaners: Evidence on effectiveness and considerations for safe operation.

National Education Association (NEA). 2022. How to evaluate building ventilation using carbon dioxide monitors.

National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention. 2002. Guidance for protecting building environments from airborne chemical, biological or radiological attacks.

Ontario Society of Professional Engineers (OSPE). 2022. Core recommendations for safer indoor air.

Persily, A.K. 2021. Evaluating ventilation performance. Chapter 20-1. Handbook of indoor air quality. Pages 1–39.

Public Health Agency of Canada (PHAC). 2021. COVID-19: Guidance on indoor ventilation during the pandemic.

Public Health Agency of Canada (PHAC). 2022a. COVID-19: Improving indoor ventilation.

Public Health Agency of Canada (PHAC). 2022b. Respiratory syncytial virus (RSV): Prevention and risks.

Public Health Agency of Canada (PHAC). 2023a. COVID-19: Prevention and risks.

Public Health Agency of Canada (PHAC). 2023b. Flu (influenza): Prevention and risks.

Public Health Agency of Canada (PHAC). 2023c. Reduce the spread of respiratory viruses.

Sundell, J., Levin, H., Nazaroff, W.W., Cain, W.S., Fisk, W.J., Grimsrud, D.T., Gyntelberg, F., Li, Y., Persily, A.K., Pickering, A.C., Samet, J.M., Spengler, J.D., Taylor, S.T. and Weschler, C.J. 2010. Ventilation rates and health: Multidisciplinary review of the scientific literature. Indoor Air. 21(3):191–204.

Underwriters Laboratory (UL). 2022a. UL 507—Electric fans.

Underwriters Laboratory (UL). 2022b. UL 2998—Zero ozone emissions validation.

United States Environmental Protection Agency (US EPA). 2024a. Preventing the spread of respiratory viruses in public indoor spaces.

United States Environmental Protection Agency (US EPA). 2024b. What kind of filter should I use in my home HVAC system to help protect my family from COVID-19?.

United States Environmental Protection Agency (US EPA). 2025. Best practices guide for improving indoor air quality in commercial/public buildings during wildland fire smoke events.

APPENDIX A: GLOSSARY

Air changes per hour Number of times air is theoretically replaced in a space during one hour.

Air conditioning Process of treating air to meet the requirements of a conditioned space by controlling its temperature, humidity, and purity.

Air filter Air cleaning device that passively traps particulate matter when air passes through.

Air handling unit Ventilation equipment in an HVAC system *(see HVAC system)*.

Air intake Part of the ventilation system through which outdoor air is drawn into the air handling unit.

Air velocity The speed of the air flow. In ducts, it is the volumetric flow rate of the air (in litres per second) divided by the cross-sectional area of the duct.

ASHRAE American Society of Heating, Refrigerating and Air-Conditioning Engineers—the primary association involved in developing indoor air quality guidelines and standards in North America. The society is organized for the sole purpose of advancing the arts and sciences of heating, ventilation, air conditioning, and refrigeration for the public's benefit through research, standards, continuing education, and publications.

Bio effluents The pollutants produced during the metabolic processes that take place within the human body.

Building envelope All the building components that separate the indoors from the outdoors, including exterior walls, foundations, roof, windows, and doors.

CCOHS Canadian Centre for Occupational Health and Safety—Canada's national organization for promoting workplace health and safety through information, advice, training, and research.

CADR Clean air delivery rate—indicates the volume of filtered air delivered by an air cleaner, with separate scores for tobacco smoke, pollen, and dust. The higher the CADR number for each contaminant, the faster the unit filters the air. As a rule of thumb, the CADR of an air cleaner should be equal to at least two-thirds of the room's area measured in square feet.

Condensate Water resulting from the process of condensation in HVAC systems.

CSA Group A global organization that develops standards around the world.

Dilution ventilation The introduction of clean air into potentially contaminated air to reduce the concentration of airborne contaminants.

Drug identification number Eight-digit number located on the label of prescription and over-the-counter drug products that have been evaluated by the Health Products and Food Branch and approved for sale in Canada.

Duct Conduits or passages used in HVAC systems for conveying air.

US EPA United States Environmental Protection Agency—Agency of the United States government whose mandate is to protect people and the environment from significant health risks, sponsor and conduct research, and develop and enforce environmental regulations.

Exhaust ventilation Removal of air, usually by mechanical means, from any space. Typically designed to be near the source of air contaminants.

Fungus Moulds, dusts, mildews, smuts, and mushrooms that grow in humid spots and can impact indoor air quality in buildings.

HVAC system Heating, ventilating, and air conditioning system—Common term for the equipment that controls the temperature, humidity and purity of the air for comfort, safety, and health.

HEPA Filter High efficiency particulate air filter that is rated to be at least 99.97% efficient in removing particles 0.3 μm in size. HEPA filter effectiveness can be verified using thermallygenerated monodisperse dioctyl phthalate smoke (DOP test).

Indoor air quality Purity of air in an indoor environment, such as inside a building, particularly as it relates to the health and comfort of occupants. Acceptable indoor air quality has been defined as air in which there are no known contaminants at harmful levels and with which 80% or more of the people do not express dissatisfaction (ASHRAE 2020).

Mechanical ventilation Refers to air flows intentionally created through the use of fans, ducting, and designed openings in the building envelope. It includes HVAC components such as intake and exhaust fans, as well as components such as clothes dryer exhausts, range hoods, and heat or energy recovery ventilators.

MERV Minimum Efficiency Reporting Value—which is a rating system that measures how well an air filter traps particles and ranges from MERV 1 to MERV 16. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) developed the MERV rating system in 1987.

Mould Growth of fungi on building materials and surfaces.

Natural ventilation Movement of outdoor air into a space through intentional openings, such as windows and doors, non-powered ventilators or infiltration.

NIOSH National Institute for Occupational Safety and Health—Research agency established by the United States Congress through the *Occupational Safety and Health Act of 1970* focusing on the study of worker safety and health.

Odours Often caused by gases or organic vapours that stimulate the olfactory organs. Response varies with person, age, experience, time of exposure, and other factors.

Off-gassing Gradual release of vapours and gases trapped in materials into the atmosphere, usually from new furnishings, carpets, and building materials.

Outdoor air Fresh air brought into a building and not previously circulated through the system.

Recirculated air Air removed from the occupied space and reused as supply air.

Relative humidity Measure of the relative amount of water vapour in air compared to how much moisture the air can contain (in %).

Return air Air going to the HVAC system from the occupied space for recirculation as supply air.

Safety data sheet Summary documents that provide information about the hazards of a product and advice about safety precautions. Safety data sheets are usually written by the manufacturer or supplier of the product.

Ventilation The process by which 'clean' air (normally outdoor air) is intentionally provided to a space and stale air is removed. This may be accomplished by either natural or mechanical means.

VOCs Volatile organic compounds—Chemical compounds containing carbon linked to other elements and that evaporate readily at room temperature. These include aromatic and halogenated hydrocarbons, alcohols, ketones, aldehydes, ethers, and esters. Several hundred VOCs have been identified in indoor air, with formaldehyde being the most commonly identified.

APPENDIX B: SAMPLE HVAC OVERVIEW CHECKLIST

The following is a sample checklist. Always adapt any checklist to the needs of the workplace.

OK	Not OK	Parameter to inspect
☐	☐	Outdoor air intake is clean and not located near building air exhausts.
☐	☐	Outdoor air dampers are open and functioning.
☐	☐	No potential sources of contaminants (e.g., garages, loading areas) are near outdoor air intake.
☐	☐	Air supply and exhaust fans are in good repair.
☐	☐	Proper fan belts and blades are in good repair.
☐	☐	Fan blades are installed properly (correct orientation).
☐	☐	Ductwork or intakes are free of dust and mould.
☐	☐	Ducts are dry, clean, and well maintained.
☐	☐	Air handling units (fans, coil units, induction units) are in good repair.
☐	☐	Air filters with appropriate filtration efficiency ratings are dry, clean, and well maintained.
☐	☐	Condensate pans are free of dirty water, slime, rust or mould.
☐	☐	Drip pans are free of dirty water, slime, rust or mould.
☐	☐	Humidifier reservoirs are free of dirty water, slime, foam or mould.
☐	☐	HRV/ERV equipment are maintained as per manufacturer's recommendations (e.g., filter cleaning/replacement, core/cabinet cleaning).
☐	☐	[… any other information pertinent to the workplace]

APPENDIX C: SAMPLE HVAC INSPECTION CHECKLIST

All HVAC systems should be inspected and maintained by a qualified professional. In some cases, building operators may perform inspections themselves. The following sample checklist may be useful in these cases. Always adapt any checklist to the needs of the workplace.

Parameter to inspect	Completed	Requires Action
Document the preventive maintenance program and all maintenance or repairs to make sure that no steps are missed and to serve as a reference if indoor air quality complaints arise.	Y/N	Y/N
Inspect and keep all equipment and controls in proper working order in accordance with manufacturer's recommendations.	Y/N	Y/N
Ensure that repairs and adjustments to the HVAC system are completed on a regular schedule by a qualified person (e.g., adjustment and calibration of control system components, including sensors, thermostats, time clocks, dampers, and valves).	Y/N	Y/N
Ensure all elements are fully operational, such as dampers (open and close freely), linkages, damper set points, and drainage, including clearing drains (free of snow or rain).	Y/N	Y/N
Use manufacturer-recommended equipment and replacement parts. Make sure they are suitable for the intended function.	Y/N	Y/N
Keep the interior of equipment and ductwork clean and dry.	Y/N	Y/N
Prevent water accumulation, condensation or stagnation, especially in and around HVAC system mechanical components (e.g., cooling coils of air handling units, condensate drip pans, and water towers).	Y/N	Y/N
Regularly clean and disinfect surfaces that are normally in contact with water in accordance with manufacturer's recommendations. Use products at concentrations that are safe.	Y/N	Y/N
When disinfection of the HVAC system is required, conduct activities while the building is vacant and allow sufficient time for off-gassing and dispersal of any potential contaminant.	Y/N	Y/N
Cleaning	**Completed**	**Requires Action**
Schedule maintenance and cleaning operations when there is low or no occupancy, particularly if the procedures require turning off the HVAC system.	Y/N	Y/N
Follow the manufacturer's recommendations regarding the cleaning schedule, which parts should be cleaned, and which cleaning products to use.	Y/N	Y/N

Follow the supplier's instructions when using cleaning or disinfection products, including the use of personal protective equipment. Refer to Section 8 (Exposure Controls/Personal Protection) of the safety data sheet when using any hazardous product.	Y/N	Y/N
Thoroughly rinse and dry all coils and drip pans after cleaning to prevent contaminants from entering the air system.	Y/N	Y/N
Water and Leaks	**Completed**	**Requires Action**
Investigate and repair any dampness on walls, windows, and ceilings. Seek and remediate the cause of the moisture.	Y/N	Y/N
Dry area immediately and remove any wet materials.	Y/N	Y/N
Insulate pipes, ducts or other surfaces whose temperatures are expected to be lower than the surrounding air to prevent condensation or moisture.	Y/N	Y/N
Maintain the building to prevent water from entering (e.g., roof, gutter/ eavestrough, downspouts, exterior flashings around openings, graded soil for run off, stormwater management).	Y/N	Y/N
Follow guidance for cleanup following a flood (Health Canada 2014, 2021a)	Y/N	Y/N
Filters	**Completed**	**Requires Action**
Replace all filters on a regular basis to maintain efficiency and prevent fungal growth and buildup of dust and particles.	Y/N	Y/N
Place and install all filters properly (e.g., no gaps or cracks between filter and rack), as any small opening can allow a large volume of supplied air to bypass the filters.	Y/N	Y/N
Use filters as required and rated for the HVAC system.	Y/N	Y/N
Use the highest efficiency filters the system pressure drops will permit based on manufacturer's recommendations.	Y/N	Y/N
Ceilings	**Completed**	**Requires Action**
Keep the space above ceiling tiles clean and free of debris or loose material, and ensure any hazardous materials such as asbestos-containing materials are managed in accordance with applicable regulations.	Y/N	Y/N
Mechanical Rooms and Mixing Plenums	**Completed**	**Requires Action**
Make sure that the mechanical room containing the HVAC system is clean and dry. Issues can occur when "dirty" return air is circulated through openings or unsealed seams and then back throughout the building.	Y/N	Y/N

Do not store products that could contaminate the air, such as flammables, solvents, and cleaners. Check the label and refer to Section 7 (Handling and Storage) of the safety data sheet for advice on safe storage of hazardous products.	Y/N	Y/N
Humidifiers	**Completed**	**Requires Action**
Drain and clean humidifiers every two to four months in accordance with manufacturer's recommendations.	Y/N	Y/N
If the humidifier contains stagnant or dirty water, drain and clean and determine if there are blocked nozzles or if pumps need repair. Determine if biocides are used to control microbial growth and check dosing and choice of chemicals. Note: a clean steam humidification system will avoid this issue.	Y/N	Y/N
Remove rust and mineral deposits from HVAC system components once or twice a year, or more often if needed.	Y/N	Y/N
Drip Pans	**Completed**	**Requires Action**
Make sure that drip pans under cooling coils have effective drain lines so that water drains completely and does not remain standing.	Y/N	Y/N
Ducts	**Completed**	**Requires Action**
Make sure ducts are tightly sealed (leakage rate of less than 3%).	Y/N	Y/N
Clean ducts in accordance with manufacturer's recommendations and when the building is unoccupied. Do not operate the air handling unit while cleaning to prevent the spread of contaminants. Run the system for at least eight air changes after cleaning is completed, before allowing occupants back in.	Y/N	Y/N
Combustion Sources	**Completed**	**Requires Action**
Make sure that air from combustion sources (e.g., stoves, hot water tanks, furnaces) is properly exhausted and not recirculated.	Y/N	Y/N

APPENDIX D: SAMPLE INDOOR AIR QUALITY ASSESSMENT FORM

The following is a sample checklist. Always adapt any checklist to the needs of the workplace.

Sample Indoor Air Quality Assessment Form			
Name of investigator:			
Date:			
Location:			
Assessment			
OK ☐	Not OK ☐	**Item Inspected:**	
		Observations:	
OK ☐	Not OK ☐	**Item Inspected:**	
		Observations:	
OK ☐	Not OK ☐	**Item Inspected:**	
		Observations:	
OK ☐	Not OK ☐	**Item Inspected:**	
		Observations:	
Notes:			

APPENDIX E: INDOOR AIR QUALITY HEALTH EFFECTS REPORTING FORM

The following is a sample checklist. Always adapt any checklist to the needs of the workplace.

Sample Indoor Air Quality Health Effects Reporting Form		
Date:		
Name:		
Contact information:		
Work area:	*(floor, department, location)*	
Please indicate if any of the following applies to you:	☐ You wear contact lenses. ☐ You work in front of a computer screen for at least one hour a day. ☐ You work next to a printer/photocopy machine. ☐ You frequently use a photocopier (times a week: _____). ☐ You work near a lunchroom/cafeteria. ☐ There is an air vent near your desk. ☐ You use chemical products for your work (e.g., cleaning products). ☐ You smoke or vape tobacco or cannabis products.	
Health effects experienced:	☐ Headache ☐ Dizziness ☐ Nausea ☐ Fatigue ☐ Cold ☐ Sinus congestion ☐ Shortness of breath ☐ Skin rashes and irritation	☐ Drowsiness ☐ Blurred vision ☐ Wheezing ☐ Allergies ☐ Dry eyes ☐ Nose and throat irritation ☐ Other:
Time of day health effects are first noticed:	☐ am	☐ pm
Time of day health effects worsen:	☐ am	☐ pm
Day of the week health effects appear or worsen: ☐ Monday ☐ Tuesday ☐ Wednesday ☐ Thursday ☐ Friday ☐ Weekend *(specify)*		
Frequency and duration of health effects and if/when they go away:		
History of health effects *(when were they first noticed)*:		
Occupant's observations about building conditions that may be related to IAQ issues:		
Other:		

Note: Consult a health care professional if you are experiencing symptoms that you suspect are related to indoor air quality issues.

APPENDIX F: SAMPLE SUMMARY ASSESSMENT NOTES

The following is a sample checklist. Always adapt any checklist to the needs of the workplace.

Sample Summary Assessment Notes from the Resolution Team	
Name of investigator:	*[Insert text here]*
Date:	*[Insert text here]*
Location on floor plan:	*[Insert text here]*
Reported health effects:	*[Insert text here]*
Time and frequency of health effects and if/when they go away:	*[Insert text here]*
Potential causes:	*[Insert text here]*
Possible action:	*[Insert text here]*
Location on floor plan:	*[Insert text here]*
Reported health effects:	*[Insert text here]*
Time and frequency of health effects and if/when they go away:	*[Insert text here]*
Potential causes:	*[Insert text here]*
Possible action:	*[Insert text here]*
Location on floor plan:	*[Insert text here]*
Reported health effects:	*[Insert text here]*
Time and frequency of health effects and if/when they go away:	*[Insert text here]*
Potential causes:	*[Insert text here]*
Possible action:	*[Insert text here]*