Guidance for Cleaner Air Spaces during Wildfire Smoke Events

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1. EXECUTIVE SUMMARY

Buildings such as libraries, community centres, malls and schools are often identified by jurisdictions as cleaner air spaces, in anticipation of smoke events, to be used as public spaces where people can seek relief from wildfire smoke. This document, which includes detailed guidance and a simplified checklist, provides advice to local jurisdictions that are creating and/or managing community-based cleaner air spaces for wildfire smoke events. It will focus on wildfire smoke, keeping in mind that smoke can also arise from prescribed burns or local fires and may include the combustion products of both natural and manufactured materials. Specific pollutants of concern and their associated health risks will be discussed. To reduce exposure and associated health impacts from these pollutants, infrastructure considerations will be presented and recommendations provided to help maintain clean air within a designated building. Recommendations applying to home environments are also included in the event that people remain at home during a smoke event. Finally, a simplified checklist is included in the appendix, which summarizes the guidance and can be used as a stand-alone tool. Decisions to move people into or out of a cleaner air space remains at the discretion of local jurisdictions. Other considerations associated with community shelters (e.g., first-aid supplies, drinking water supply, lavatories, sanitation) are beyond the scope of this document.

Provision for a community-based cleaner air space by a jurisdiction requires planning to ensure that the building is suitable for housing large numbers of people and protecting the health of its occupants.

A building identified for use as a cleaner air space will be more suitable, from an indoor air quality perspective, if it is:

- Fitted with heating, ventilation and air conditioning (HVAC) or additional/portable air filtration and air conditioning systems that are capable of filtering fine particulate matter ($PM_{2.5}$) and controlling temperature, relative humidity, and air exchange rate. Performance indicators for proper operation of a building are outlined in Standard 62.1-2019 *Ventilation for Acceptable Indoor Air Quality* of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (2019).

- Equipped with an entryway that allows occupants to enter the building via a staging area, thus preventing the direct exposure of the indoor environment to outdoor air during entry and exit.

- Able to prevent infiltration of outdoor air pollutants (e.g., quality doors, tight building envelope). If possible, windows may be sealed to reduce infiltration of outdoor air.

- Sized to accommodate the highest capacity of occupants. Maximum occupancy of buildings should be determined before an emergency to ensure that the building is capable of housing people safely. Building occupancy recommendations are outlined in ASHRAE Standard 62.1-2019. Larger communities may require larger or multiple buildings than smaller communities.

- Connected to emergency power in the possible event of a power outage. Fuel-burning generators can be used as a back-up power source, keeping in mind that they be located away from the building and downwind of any clean air intakes.

- Staffed with a facility manager/building operator who understands the operation of the HVAC system and the air distribution of the building, and is able to monitor smoke conditions, interpret the data from alarms and monitoring equipment (e.g., $PM_{2.5}$, carbon monoxide (CO), temperature, and humidity levels), and modify the operation of the system as needed. Air systems should have adequate fresh air intakes during operation to prevent negative pressure in the building, which can draw pollutants inside.

The following elements should be considered once a building meeting the above requirements has been identified.

- The HVAC system should be equipped with filters with the highest minimum efficiency reporting value (MERV) rating allowed by the system to ensure maximum filtration of incoming air. A MERV value of 13 or more is recommended to remove fine particulate matter. A building should possess enough storage capacity to maintain a stockpile of filters and would benefit from dedicated trained personnel who knows when to change filters and how to change them.

- The HVAC system must be capable of handling a pressure drop from installing a filter stack of MERV 13/14.

- Odour-removing filters may be considered for occupant comfort.

- Understanding the design and operation of the building ventilation system ensures that the indoor air will be properly mixed and vented when in operation. Modifications to the filtration system can affect air distribution within the building, and cause leakage around the filters and possible infiltration of pollutants from unexpected locations in the building envelope.
- Prior to occupancy, a facility manager may consider the installation of additional air cleaning equipment to filter indoor air during a smoke event. This should be done in consultation with HVAC specialists.

- The building should be equipped with a ventilation system that can be switched from recirculation mode to outdoor-air intake ventilation mode. Dedicated personnel should be identified who can monitor indoor and outdoor conditions, and recirculate the air when outdoor conditions are poor and draw in fresh air when the smoke plume abates, as pollutants can become trapped inside.

- The building should be equipped with $PM_{2.5}$ monitors to allow simultaneous measurement of indoor and outdoor levels.

- The building should be equipped with certified CO alarms, such as those in *CSA 6.19-17 Residential Carbon Monoxide Alarming Devices.* Selecting an alarm featuring a low-level digital display showing real-time readings may provide additional protection. Staff should monitor the alarms routinely and respond as required.

- Portable air cleaners and replacement high efficiency particulate air (HEPA) filters can also be kept available for deployment. The size and number of cleaners will depend on the size and layout of the building. In general, portable air cleaners from retail locations are designed for home use, but may be effective in certain situations (e.g., offices, waiting rooms). Adequate electrical capacity for multiple air cleaners should be identified in advance.

- For buildings with a kitchen or cafeteria, cooking and using exhaust fans should be limited to periods when outdoor smoke levels are low. Operation of exhaust fans may increase infiltration of outdoor air through openings in the building envelope, and gas stoves can contribute to poor air quality if those fans are not operating.

- A building housing multiple businesses (i.e., shopping centres, malls) that use individual ventilation systems (e.g., restaurants, nail salons) will have to take these systems into account when considering switching the building-wide ventilation systems from fresh air intake to recirculation. Limiting the operation of businesses that contribute to poor indoor air quality will help limit exposure to indoor air pollutants.

- Air conditioning and humidification/dehumidification capabilities should be present, if possible, and able to handle the increased number of people and electrical requirements.

- Movement of people in and out of the building should be minimized to prevent pollutants from entering the building.

- Wet mopping of floors and other surfaces can reduce the amount of settled dust that can be resuspended in indoor air.

Target conditions are as follows:

- $PM_{2.5}$ should be kept as low as possible. Indoor levels should be lower than outdoor levels.
- CO should be kept below 10 ppm.
- Carbon dioxide (CO_2) should be kept below 1000 ppm.
- Temperature should be kept below 26 °C.
- Relative humidity should be kept between 35 and 50%.
- Other pollutants such as nitrogen oxides (NO_x), polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs), should also be kept as low as possible.

2. BACKGROUND

Wildfires and the smoke they produce are of increasing concern in Canada. In 2018, the National Forestry Database (2018) reported the occurrence of approximately 7000 wildfires in Canada, burning over 2.2 million hectares of land. It has been estimated that wildfire occurrences will increase 25% by 2030 and 75% by the end of the 21st century. As fire ignition and growth depend strongly on weather conditions, climate change is thus impacting forest fire activity (Wotton, Nock and Flannigan 2010).

Communities may also be exposed to smoke from events other than wildfires. Prescribed burns for forest management, burning of debris from land clearing activities, and unforeseen combustion events (e.g., building and dump fires) will expose communities to airborne pollutants from smoke. Buildings, vehicles, and other manufactured products will produce different pollutants when burned as compared to forests and grasslands. As fires move from rural to urban environments, different materials will contribute to fires and the pollutants they produce.

Smoke contains a variety of air pollutants, such as fine particulate matter ($PM_{2.5}$), carbon monoxide (CO), nitrogen oxides (NO_X), polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs), which can vary based on fuel source. Health studies have found that exposure to wildfire smoke is associated with an increase in adverse health effects, including all-cause mortality, exacerbations of asthma and chronic obstructive pulmonary disorder, and increased respiratory infections (Reid et al. 2016). Individuals with pre-existing respiratory and cardiovascular conditions, pregnant women, infants, children, and the elderly are at greater risk of health effects associated with air pollutants found in forest fire smoke (US EPA 2019).

The main threat to public health from wildfire smoke is considered to be particulate matter, with $PM_{2.5}$ contributing approximately 90% of the total particulate mass (Vicente et al. 2013) and traveling great distances from the source of the fire. Carbon monoxide exposure from wildfire smoke does not pose a significant health hazard to the public, as it does not travel far from the original source (US EPA 2019). However, in the event of an improperly vented or malfunctioning combustion appliance, or if the source of the smoke is close, CO can be a health hazard indoors. Other pollutants present in wildfire smoke (NO_x, PAHs, VOCs) contribute to the cumulative hazardous potential of exposure.

To protect health during a smoke event, it is important to maintain good indoor air quality at home or in a building identified as a cleaner air space. People spend the vast majority of their time indoors and tend to shelter when outdoor air quality is poor. Ensuring adequate indoor air quality requires an understanding of pollutants of concern and the steps that can be taken to control exposure levels. Maintaining good indoor air quality is particularly challenging when outdoor air quality is poor.

Currently, creating cleaner air spaces is seen as the most effective intervention to reduce population level exposure to wildfire smoke (NCCEH 2019). While buildings such as libraries, community centres, malls and schools may appear to be suitable as cleaner air spaces due to their ability to house large numbers of people, steps need to be taken to maintain or improve the indoor air quality in these buildings in the event of smoke. The choice of one building over another will depend on what is deemed suitable and available for use as a cleaner air space in each individual community.

3. POLLUTANTS OF CONCERN

Wildfires and other combustion events produce a variety of air pollutants that can have an impact on human health. Exposure to these pollutants may be reduced by choosing to remain indoors during a smoke event and taking steps to limit the infiltration of these pollutants, while controlling other factors associated with poor indoor air quality.

3.1. Fine Particulate Matter

Fine particulate matter is considered the main public health threat from wildfire smoke. Fine particulate matter is a general term for all small particles found in air measuring equal to or less than 2.5 µm in aerodynamic diameter. It is a complex mixture whose constituents vary in size, shape, density, surface area, and chemical composition (Health Canada 2012; US EPA 2009). Due to its small size, $PM_{2.5}$ is able to penetrate and deposit deep into the lungs, thus increasing exposure through direct contact.

3.1.1. Health effects

At high concentrations, short-term exposure to $PM_{2.5}$ can irritate the eyes, nose, throat, and lungs. It may also cause respiratory symptoms, such as wheezing, coughing, and shortness of breath, particularly for those with pre-existing medical conditions. Studies show that $PM_{2.5}$ can also cause a decline in lung function and aggravate lung and heart conditions, such as asthma, chronic obstructive pulmonary disease, and heart disease. Exposure to $PM_{2.5}$ has also been linked to increases in medical visits, hospital admissions, and premature death. Risks are generally greater for people with chronic health conditions, pregnant women, infants, young children, and seniors (Health Canada 2015, 2012).

Health Canada recommends that indoor levels of $PM_{2.5}$ should be kept as low as possible, as there is no apparent threshold that is fully protective against the health effects of $PM_{2.5}$.

If $PM_{2.5}$ monitors are available, it is recommended that levels indoors be lower than those measured outdoors during a wildfire event.

3.1.2. Exposure and mitigation

In general, indoor $PM_{2.5}$ levels are lower than levels measured outdoors, with the possible exception of homes with smokers or improperly exhausted wood-burning and/or natural gas appliances, which can result in higher indoor levels of $PM_{2.5}$. During smoke events and in the absence of any preventative strategies, indoor $PM_{2.5}$ levels have the potential to reach levels high enough to be a significant health concern. Steps can be taken (1) to reduce $PM_{2.5}$ entering a building from outdoors by sealing the building envelope, keeping doors and windows closed, and ensuring the ventilation system is operated correctly; and (2) to filter the incoming air stream.

Filtration in a building is handled by the heating, ventilation, and air conditioning (HVAC) system. Fine particulate matter and other air pollutants produced by combustion may infiltrate into buildings through cracks in the building envelope and windows and entranceways, and during the intake of air by a ventilation system (Health Canada 2018). Institutional buildings have a range of ventilation systems and configurations, which can make it difficult selecting the best methods for improving indoor air in larger buildings (BCCDC 2014a). Properly sealing an existing HVAC system will improve effectiveness, ensuring that all air is directed through the filters. Other methods for improving HVAC system performance include (as described in the sections below) switching to recirculation mode when outdoor air quality is poor; using pre-filters and/or higher minimum efficiency reporting value (MERV) filters; frequently changing filters; using odour-removing filters; and using portable air cleaning devices.

Recirculation mode

Recirculation mode refers to switching the air handling system to recycle the air in the building instead of drawing air from outside. It is important to switch to recirculation mode when the outdoor air quality is poor and to draw in fresh air when the smoke plume abates because pollutants can otherwise become trapped indoors (Reisen et al. 2019).

Pre-filters and/or higher-rated filters

Effective filtration for cleaner air spaces can be accomplished with a two-stage filtration system, incorporating pre-filters as a first stage. These filters allow removal of larger debris from the incoming air stream and reduce the burden on the second-stage filter. Pre-filters are often lower-efficiency panel- or roll-type media (CCIAQB 2013). A MERV value of 8 is recommended for pre-filters used in the operation of a central air-handling unit (NAFA 2012).

Filtration of smaller particles occurs at the second stage, thus requiring filters with higher MERV values. Higher-efficiency filters (e.g., filters rated at MERV 13 or higher) are recommended because they can capture more of the $PM_{2.5}$ associated with smoke and reduce the number of outdoor particles that get indoors (US EPA 2019).

Filter change frequency

As a routine practice, it is recommended that pre-filters be changed two to four times a year and higher efficiency filters once annually (CCIAQB 2013). Due to the episodic nature of wildfire smoke, particulate matter can quickly overload filters and increase the power requirements of the filtration system. Buildings will need to store additional filters for use during these events and routinely assess whether filters require changing. As frequent change of filters will increase building operating costs, decisions should be made concerning how many filters to stock and which ones are necessary. Priority should be given to maintaining a stock of higher-rated filters as compared to pre-filters or odour-removing filters in order to provide maximum protection of occupants.

Odour-removing filters

Filters are also available which incorporate activated charcoal or other adsorbent media designed to capture gases from the incoming air stream. Perception of risk may be high when the odour of wood burning is present, and incorporation of odour-removing filters can help mitigate this.

Additional filtration and portable air cleaners

In addition to the primary filtration adjustments described above, supplemental filtration can be included in a building. Properly sized filtration equipment can be installed in larger buildings following recommendations and installation by a building HVAC professional. As well, portable air cleaners can be used in small areas – such as a single room – to reduce $PM_{2.5}$ from smoke.

There are two main types of portable air cleaners: mechanical filters and electrostatic precipitators (ESP). Mechanical filters use suction to pull air through a high-efficiency particle air (HEPA) filter, while ESPs charge an incoming stream of particles and collect them on an oppositely charged metal plate. Portable air cleaners are designed to clean air from a single room in a building, although in some conditions they have been shown to reduce whole house $PM_{2.5}$ levels (BCCDC 2014b; Henderson, Milford and Miller 2005). The Association of Home Appliance Manufacturers and the California Air Resources Board maintain certification programs for air cleaners, which can help in the selection of the most appropriate air cleaner. Portable air cleaners should be sized to provide a filtered airflow, as indicated by a clean air delivery rate (CADR), for smoke at least two to three times the room volume per hour. Most high-quality portable units state on the packaging the CADR for smoke, the room size they are suitable for, and their particle removal efficiency (US EPA 2019).

In addition to HEPA-filter equipped portable air cleaners, ESPs or other electronic particle air cleaners can sometimes be installed by a technician to central air conditioning systems to keep particle levels in indoor air within acceptable levels during a prolonged smoke event. However, ESPs may produce some amount of ozone as a by-product, so only ESPs that have been independently tested and produce little or no ozone should be used (US EPA 2019).

Canada advises against using ozone generators in homes. They are sold as indoor air cleaners, but the level of ozone they produce may harm human health.

3.2. Carbon Monoxide

Carbon monoxide is a product of incomplete combustion and is present in smoke. Other indoor sources of CO include tobacco smoke, exhaust fumes from vehicles or gas-powered equipment like power generators or space heaters (if used indoors, in an attached garage or near an air intake), blocked fuel-burning equipment vents, and external environmental conditions. Fuel-burning equipment should be checked regularly by a qualified service contractor to be sure it is operating safely.

3.2.1. Health effects

Short-term exposure to low levels of CO (e.g., 6 to 8 hours to 35 ppm) is associated with headaches, nausea, and flu-like fatigue. Exposure to intermediate levels (e.g., 2 to 3 hours to 200 ppm) can cause symptoms such as headaches, dizziness, fatigue, chest pain, shortness of breath, poor vision, difficulty thinking, and impaired motor functions (e.g., difficulty walking or problems with balance). Exposure to very high levels (e.g., > 20 minutes to 400 ppm) can cause convulsions, coma, and death (Health Canada 2017, 2010; Goldstein 2008).

3.2.2. Exposure and mitigation

Health Canada recommends the installation and maintenance of CO alarms for all residential and non-residential indoor environments. It is also recommended in buildings used to house people for extended periods of time (NCCEH 2016). Alarms should be certified by the Canadian Standards Association (CSA) Standard, *CSA 6.19-17 Residential Carbon Monoxide Alarming Devices*, or the Underwriters Laboratories of Canada (Standards Council of Canada 2017).

It is recognized that exposure to levels below the typical thresholds for CO alarms can still pose a health risk to some individuals, particularly those who are susceptible to the health effects of CO exposure, such as the elderly and those with pre-existing health conditions (Health Canada 2010). Therefore, building managers may choose to install certified alarms featuring a digital display of real-time low levels of CO close to identified sources, and monitor/respond as indicated on the manufacturer's instructions for the device.

The following are Health Canada's Residential Indoor Air Quality Guidelines (RIAQG) for CO, which are short-term (1 hour) and long-term (24 hours) recommended health-based maximum exposure limits (Health Canada 2010). Note that these levels are considered to be protective for the entire population, including those that are susceptible to the health effects of CO.

Averaging time	**Concentration**	
	mg/m^3	**ppm**
1 hour	**28.6**	**25**
24 hours	**11.5**	**10**

The CSA 6.19-17 standard applies to CO alarming devices intended for use in ordinary locations in residential occupancies, but may also apply to buildings that are being used as cleaner air spaces during a wildfire or other combustion events. This standard provides information on alarming devices to be used for low-level CO indication and the implications for indoor air quality at different concentrations of CO. The standard recommends the following.

- If there is a display of a CO level below 10 ppm, no immediate action is required. However, repeated display of CO levels below 10 ppm may indicate the presence of a CO source.
- If there is a regular display of CO levels from 10 to 24 ppm, there is likely to be an abnormal source of CO in your dwelling, which should be investigated.
- If CO is at or above 25 ppm, increase the fresh air in your dwelling by operating the ventilation system and/or opening doors and/or windows to increase ventilation if outdoor levels are low.

Carbon monoxide levels can be controlled by periodically bringing in fresh air whenever possible (i.e., taking into consideration infiltration of other wildfire pollutants, such as $PM_{2.5}$) to displace CO within the building.

3.3. Carbon Dioxide

The primary source of CO_2 in indoor spaces is occupant respiration, with unvented or poorly vented fuel-burning appliances also considered significant contributors (Health Canada 2020b). Therefore, the potential for elevated CO_2 concentrations in a cleaner air space should be considered, particularly in a location where large numbers of people can gather.

3.3.1. Health effects

The published literature shows that there may be an increased risk of various health effects (e.g., mucous membrane, respiratory, neurocognitive or neurophysiological symptoms) at elevated CO_2 concentrations observed in indoor air in Canada, particularly for vulnerable and susceptible populations (Health Canada 2020b). Studies on prolonged or repeated exposure to CO_2 in humans showed associations between elevated CO_2 concentrations and increased prevalence of neurophysiological symptoms (e.g., eye irritation, sore or dry throat, stuffy, congested or runny nose, sneezing, coughing, headache, dizziness, heavy headedness, and tiredness) (Health Canada 2020b).

3.3.2. Exposure and mitigation

Since the primary indoor source of CO_2 is exhaled air from the occupants of the indoor space and because any community-based space used for emergencies may experience high occupant density, these facilities may have elevated CO_2 levels if ventilation is inadequate or if the outdoor air supply needs to be reduced or eliminated (i.e., to prevent entry of outdoor air pollutants).

The proposed Health Canada long-term exposure limit for CO_2 is 1000 ppm (based on a 24-hour average).

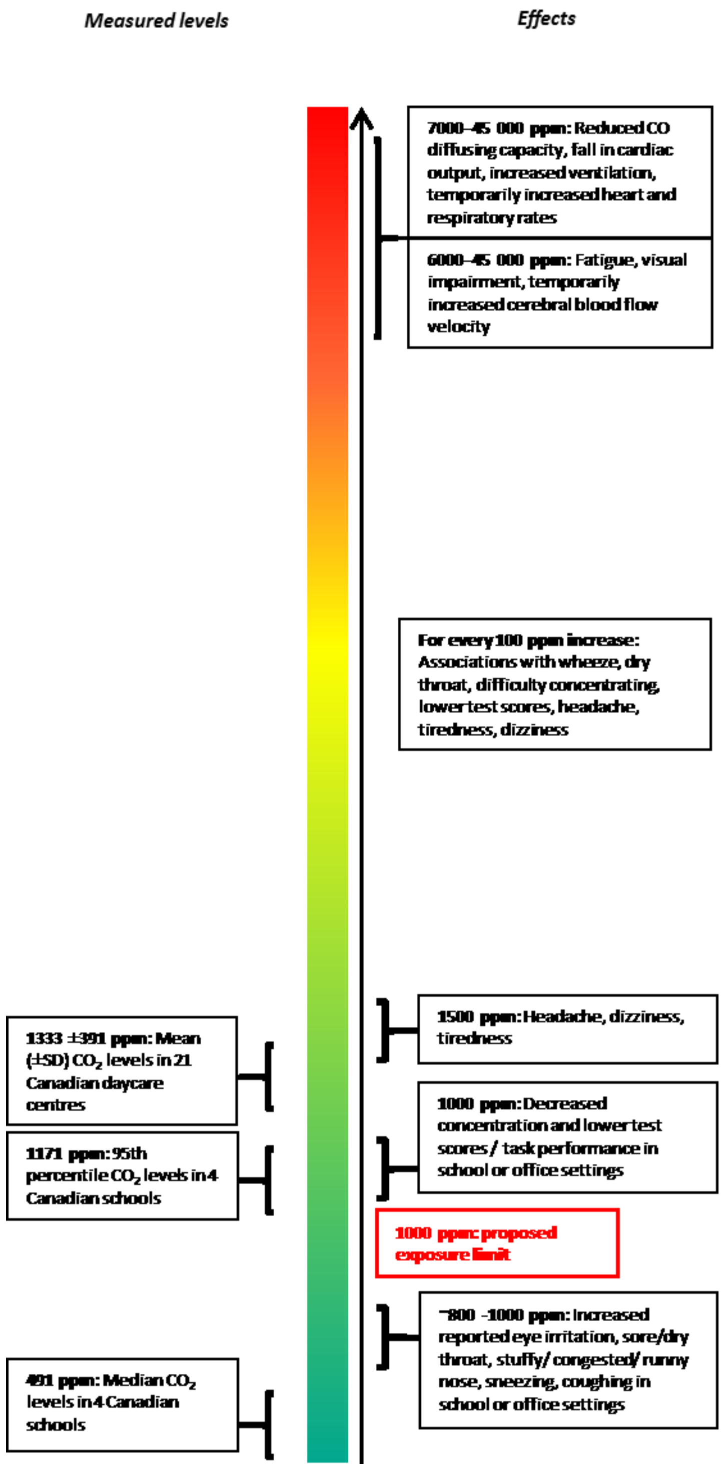

Figure 1. Comparison of CO_2 concentrations in a limited number of Canadian schools and daycare centres to CO_2 concentrations associated with health effects (from Health Canada 2020b)

While CO_2 levels can be controlled by periodically bringing in fresh air to displace CO_2 produced within the building, this would likely lead to the infiltration of other wildfire pollutants, such as $PM_{2.5}$, which would result in significant adverse health effects. Therefore, the exposure limit of 1000 ppm may not be appropriate and/or achievable in all situations. Figure 1, which is a comparison of CO_2 levels and observed health effects in a limited number of studies conducted in schools and daycare centres, may serve as a useful tool to identify the potential health implications of CO_2 levels above the proposed exposure limit.

3.4. Other Pollutants

Smoke can be the source of several other pollutants, such as NO_X, PAHs, and VOCs. Wildfires may result in the burning of buildings or vehicles, and the combustion of building materials and consumer products can produce different pollutants than burning vegetation. These pollutants can also have an impact on human health.

While it is impossible to monitor every single pollutant entering a building, alternating between recirculating air during high smoke episodes and allowing fresh air to enter the building during low smoke episodes will also help minimize exposure to these pollutants.

4. MONITORING CONSIDERATIONS

4.1. Filtration Effectiveness

The ability of the HVAC system to effectively remove particulate matter from the incoming air can be assessed by indoor and outdoor $PM_{2.5}$ monitors. Comparing indoor and outdoor $PM_{2.5}$ levels is an effective method for monitoring how well the filtration system is working, and can be accomplished by installing multiple high-quality, low-cost sensors. Building managers can use this real-time information to see if HVAC filters are operating effectively, if they require replacement, and if there are any changes to indoor or outdoor levels. The deployment of $PM_{2.5}$ monitors can also help determine if there is a source of $PM_{2.5}$ (e.g., cooking stove, improperly vented appliance) indoors. In the event of low outdoor $PM_{2.5}$ levels, building managers can let the HVAC system exchange air with the outdoors to bring in fresh air.

A sign of effective filtration is when indoor $PM_{2.5}$ levels are lower than outdoor $PM_{2.5}$ levels.

4.2. Temperature

Extreme heat is a significant risk to health and can lead to serious illness or death when communities are not prepared (Health Canada 2011a). There has been little research, however, assessing the impact of rising indoor temperature on health of populations. The few health effects evaluated were varied, as were the different ways of measuring exposure to heat or the population evaluated from one study to another (van Loenhout 2016; Franck et al. 2013; White-Newsome et al. 2012).

There remains limited information on the physiological strain associated with excessive indoor heat. Beyond the numerous environmental factors, personal factors such as sex, age, and state of health can influence an individual's ability to thermoregulate, and must therefore be considered (Kenny et al. 2018). The ability of people to acclimatize to the local climate has also been recognized as an important factor; people living in different regions, cities, urban and rural areas are accustomed to different temperatures and react to heat differently (Kenny et al. 2018).

Uncertainty remains in terms of the potential health effects of indoor temperatures at specific thresholds. **Toronto Public Health (2015), however, is exploring the feasibility of implementing a health-based maximum indoor temperature standard of 26 °C and the Heat Wave Plan for England (2020) recommends that hospitals and care homes should maintain indoor temperatures below 26 °C during high outdoor temperatures**.

Temperature can be maintained at a suitable level by continuous measurement and controlling with air conditioning. Many larger building have centralized HVAC systems that can be used to cool the building as a whole. In the absence of this type of system, or in the event that cooling is to be limited to specific rooms, portable air conditioning units can also be used for short-term relief.

Many buildings used as shelters do not have air conditioning (e.g., libraries, community centres, and schools) and so alternative means of keeping people cool and safe may need to be employed in hot conditions. These can include closing blinds to reduce indoor heat, spending time in a basement or other cooler areas of buildings, staying hydrated, using a fan, cool showers, misting, sponge or assisted baths, use of damp wet towels, avoiding hot meals, reducing use of electrical appliances, and removing clothing layers (Health Canada 2011a).

During prolonged stay in a shelter, which can happen during wildfire events, elevated temperatures in these shelters is a particularly important risk factor for populations susceptible to heat illness, such as the elderly, people with chronic health conditions, and young children (World Health Organization 2015; Yardley, Sigal and Kenny 2011; Kenny et al. 2010). Most wildfire smoke events happen in the summer, which means that people sheltering in buildings from wildfire smoke may also have to contend with high temperatures that may be dangerous to their health.

Some people utilizing shelters may already be experiencing heat strain and because heat illness can progress rapidly, staff should be able to recognize symptoms in clients, know how to provide assistance with cooling and when to seek emergency medical attention for heat stroke. Elevated temperatures within shelters can lead to heat stress, which may trigger heat edema, heat rash, heat syncope (fainting), heat exhaustion or other heat-related health impacts. Heat stroke, a medical emergency that requires immediate action from a health care worker and potential hospitalization, is a serious, life-threatening outcome of heat stress (Health Canada 2011b).

Health Canada has information on reducing risks from extreme heat for the public (Health Canada 2020a) and guidance that can be used by shelter staff (Health Canada 2011b).

4.3. Humidity

High humidity can contribute to decreased comfort, perception of higher temperature, and other humidity-related health risks (Health Canada 2016, 2014).

Health Canada recommends an optimal relative humidity range of 35 to 50%.

Relative humidity can be maintained by monitoring and controlling with ventilation by drawing drier air into the building. In the presence of high outdoor humidity or poor outdoor air quality, indoor humidity can be lowered through the use of dehumidifiers. In summer, the use of air conditioning will also reduce the levels of moisture in the air during the cooling process. Some buildings may have HVAC systems equipped with energy recovery ventilators, which have the ability to regulate the amount of moisture from the incoming fresh air (Health Canada 2018).

5. SHELTERING AT HOME

In certain cases, individuals may decide or be required to shelter at home rather than in a cleaner air space. In these circumstances, the following strategies can be employed to help protect indoor air quality during wildfire events.

Reduce sources of indoor air pollution. Sources include:

- smoking;
- vacuuming, unless your vacuum cleaner is equipped with a high efficiency particulate air (HEPA) filter (settled dust can be removed by wiping and wet mopping during a wildfire event);
- burning incense and candles;
- using wood stoves (consider choosing a low emission stove); and
- using cleaning products that can emit high levels of volatile organic compounds (VOCs) improperly.

Prevent infiltration of outside air, by:

- properly sealing windows and doors and keeping them closed;
- installing a high-quality air filter to remove particulate matter from the incoming air, in homes with forced air ventilation;
- setting the HVAC system to recirculation mode; and
- limiting the use of exhaust fans, when not cooking.

Other strategies include:

- using portable HEPA filters, which may reduce indoor particulate levels. The frequency of filter changes and/or replacements depends on use and conditions. Look for certified air cleaners when possible;
- having air conditioning and humidification/dehumidification capabilities present (try to maintain humidity levels between 35 and 50%); and
- installing and maintaining at least one CO alarm in the home.

To learn the quality of the outdoor air in your community, check the Air Quality Health Index at www.airhealth.ca.

6. CONCLUSIONS

During a wildfire or any other smoke event, it is important that people have access to clean air. Provision for a cleaner air space by a jurisdiction can allow the housing of large numbers of community members when outdoor air conditions are poor. Provision for filtration, cooling, dehumidification, and monitoring within the cleaner air space can contribute to reducing the health effects of pollutant exposure from smoke.

A community-based cleaner air space would benefit from dedicated staff when in operation. Trained staff will be well positioned to operate HVAC systems; deploy portable filtration units; change filters; monitor particle detectors, temperature, humidity and CO alarms; and make changes to the ventilation system (e.g., recirculation vs. drawing fresh air) depending on conditions.

In situations where sheltering at home is the best option, many of the same practices can be used to protect health.

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8. APPENDIX: CLEANER AIR SPACE CHECKLIST

Smoke from wildfires produces a variety of pollutants that can have an impact on human health. Exposure to these pollutants may be reduced by choosing to remain indoors during a wildfire event and taking steps to limit infiltration of these pollutants, while controlling other factors associated with poor indoor air quality. The following are recommendations for selecting or retrofitting a building to be used as a cleaner air space and operational considerations during a wildfire event.

Preparing the cleaner air space:

- Select a central heating, ventilation, and air conditioning (HVAC) system that is capable of filtering fine particulate matter ($PM_{2.5}$), and controlling temperature, relative humidity, and air exchange rate. An HVAC specialist may also recommend additional air filtration or air conditioning equipment for use during a wildfire smoke event, where necessary.
- If available, consider having a vestibule or other entryway that does not directly expose the indoor environment to outdoor air, to limit infiltration of pollutants during entry and exit.
- Create a tight building envelope (i.e., well sealed doors and windows) to prevent infiltration of pollutants from outdoor air.
- Install carbon monoxide (CO) alarm(s), preferably those featuring a low-level digital display showing real-time readings.
- Install $PM_{2.5}$ monitors to allow simultaneous measurement of indoor and outdoor levels.
- Ensure adequate space is available to accommodate the highest capacity of occupants.
- Ensure suitable electrical capacity to handle additional equipment.
- Consider emergency power in the possible event of a power outage, keeping in mind to locate any generators away from the building and downwind of any clean air intakes.

During a wildfire event:

- Assign a facility manager who has an understanding of the HVAC system operation and the air distribution of the building, and can monitor indoor and outdoor pollutant levels and control the environmental conditions.
- Use filters for the HVAC system with a minimum efficiency reporting value (MERV) rating of 13 or more to remove $PM_{2.5}$. Ensure replacement filters are available. Replace filters as required. Odour-removing filters may be considered for occupant comfort.
- Consider using portable air cleaners with high efficiency particulate air filters.
- Recirculate the air when outdoor conditions are poor and draw in fresh air when the smoke plume abates to reduce the levels of pollutants trapped indoors, such as carbon dioxide (CO_2).
- Evacuate immediately if the CO alarm sounds. Consider using monitoring alarms with low-level displays and take appropriate action as recommended. Evacuation procedures should be planned in advance.
- For buildings with a kitchen or cafeteria, limit cooking and using exhaust fans to periods when outdoor smoke levels are low. Individual HVAC air handling systems may need to be adjusted or curtailed when the building is used as a cleaner air space, as determined by an HVAC specialist or facility manager.

- Strive for a humidity level of 35 to 50% and a temperature of 26 °C or lower, using air conditioning and dehumidifiers.
- Minimize movement of people in and out of the building.
- Wet-mop the floors and other surfaces to reduce the amount of settled dust that can be resuspended in indoor air.