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Reducing the Risk of Virus Transmission via HVAC Systems in Schools

Guidelines for Decision-Makers

THE HEATING, REFRIGERATION AND AIR CONDITIONING INSTITUTE OF CANADA

Acknowledgements

This document was prepared for the HRAI Expert Advisory Panel on Indoor Air Quality in commercial and institutional buildings by Dr. Brian A. Fleck, Ph.D. P.Eng. ICD.D, Professor, Mechanical Engineering, University of Alberta, with support from Dhyey Dandnayuk, E.I.T., B.Sc., and Kristin Berg, B.Sc.

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1. What should we do first to reduce the risk of virus transmission in our school?

Following the public health guidelines for personal protective equipment and hygiene is the easiest way for all school attendees to reduce the spread of viruses. Masks and frequent hand washing are an important first step, along with social distancing, avoiding touching your face, and keeping surfaces as clean as possible. Changes to building operations have the potential to further reduce the risk of airborne virus transmission (whereby very small invisible droplets move through the air and travel potentially long distances indoors).

Modifications to the operation of heating, ventilating, and air conditioning (HVAC) systems must be done in consultation with experts and with an understanding that any change to one part of the system will inevitably cause changes in other parts of the system. Risk mitigation strategies can include changes to ventilation, filtration, air recirculation, and humidity, and the addition of air purification and germicidal systems. In addition to the strategies you might consider, it is very important not to underestimate the importance of regular maintenance, which should include professional cleaning and maintenance of the mechanical equipment and HVAC system, and proper filter replacement according to a strict schedule.

Common questions about HVAC systems are answered below with the intent to help school administrators better understand the role HVAC systems can play in the reduction of airborne virus transmission.

2. What role does ventilation play in virus transmission?

When breathing, people are continuously expelling tiny aerosol particles, or droplets, into the air. Some of the aerosol particles are so small that they move with the air like mist much in the same way you'd see smoke move through the air, and the particles are able to easily pass around a loosely fitting mask. It is known that the flu and SARS-CoV-2 viruses are spread when people are simply breathing normally [1]. When people are gathered together indoors, in a classroom for example, new droplets are therefore being constantly added to the air, and to keep the air clean, the older contaminated air needs to be removed, while new fresh air[1] is added—this is referred to as ventilation. Natural ventilation occurs when doors and windows are opened to let fresh air in from outside, and mechanical ventilation refers to a system that is designed to supply an adequate amount of fresh air through a system of fans, ducts, and vents. A mechanical ventilation system that is properly designed, maintained, and operated is the best way to ensure ventilation is occurring at an adequate rate to clean the air.

[1] Note that throughout this document the terms "fresh air" and "outdoor air" are used interchangeably. In all cases these references are to outdoor air, which may or may not meet all definitions of "fresh."

3. Should we open our school's windows? How can we ensure an adequate amount of fresh air is provided in the school?

The air outside is naturally rid of viral contamination because of the sun, the wind, and the huge amount of air in the atmosphere (think of how quickly smoke dissipates outdoors compared to indoors). Open windows can supply clean air in the summer, but in cold climates, most buildings have their fresh air supplied by mechanical ventilation systems so the colder outdoor air can be heated during the heating season. The best place to start is to find out how fresh air is supplied in your school building(s). Many older buildings don't have mechanical ventilation systems and instead rely on fresh air coming in through doors, windows, and from natural air leakage. If you know this is true for your school, you may jump ahead to question 9.

In the heating, ventilation and air conditioning (HVAC) industry, we measure the rate at which fresh air is supplied as the number of "air changes per hour" or ACH. A higher number of ACH means fresher air inside the building and less risk of airborne virus transmission in a space [2], [3]. People often spend more than 95% of their time indoors, especially during the winter [4]. Open windows aren't able to supply a reliable source of fresh air, especially in winter, since not only can open windows result in high heating costs, but humidity can cause condensation on the windows which can lead to ice build-up, making opening and closing the windows problematic.

Carbon Dioxide (CO_2) sensors can be used to measure whether there is enough fresh outdoor air being supplied in a space. Ideally, the CO_2 sensors are tied into the ventilation system to increase ventilation automatically should CO_2 rise above a desired set point.

4. What role does humidity play in virus transmission?

Humidity is a measure of how much water vapour is present in the air. When it is humid, water evaporates much more slowly than when the air is dry. Cold air from outdoors is naturally drier, so cold winter air warmed up in a building feels very dry if it is not humidified after it is heated. Without humidification, fresh outdoor air feels dry to our skin and lungs. Most modern buildings have been designed to have low humidity to avoid musty air, mould growth, and water and ice buildup on cold windows.

The humidity of the air we breathe affects how droplets in the air change size. In dry air, very small droplets can get even smaller very quickly due to evaporation. Since smaller droplets are the ones that stay in the air the longest, they are able to move to the smallest passages of our lungs, which can be more harmful in terms of infection. Having droplets shrink in the air further increases the risk of virus transmission [5].

The humidity of the air we breathe also affects evaporation of large spray and the functioning of our lungs. When larger drops (spray from a sneeze, for example) hit the ground or land on solid surfaces, dry air can cause more rapid evaporation and the particles are then more prone to lift off again and enter the breathing air. Additionally, lungs and breathing passages work best when they are moist, because it allows them to more effectively clean themselves and expel contaminants [6].

To better limit virus transmission, a relative humidity of 40–60% is recommended [7]. In many buildings, managing humidity can be challenging because of the risk of a moisture problem, including in unseen spaces (such as the inside of walls). Some approaches to humidification (e.g., misting or ultrasonic humidifiers) can emit high particle concentrations and should be avoided. Also, most approaches to humidification require extensive maintenance to ensure that they do not cause other indoor air quality problems. Changing the humidity in your building should be done in consultation with a qualified HVAC contractor or a professional engineer who specializes in HVAC systems to avoid unwanted side effects.

5. What is recirculated air?

In any building, an important balance to consider is what portion of the air supply is fresh air versus recirculated air. Most mechanical ventilation systems recirculate air by taking some of the air already in the building, filtering it, mixing it with new fresh air, and then supplying the building with the mixture of fresh air and recirculated air. Fresh outdoor air should first be filtered to remove dust and particles, then conditioned (heated, cooled, humidified or dehumidified) by the building's HVAC system to provide an air supply that matches what is needed for indoor comfort. Recirculated air contains exhaled CO2, odours, and particles that can be partially removed by filters (for example, particles from humans, fabrics, animals, cooking, etc.), but the recirculated air is already close to the desired temperature and humidity at any given time.

6. How do we improve air filtration to reduce virus transmission and how does filtration affect building ventilation?

Air filters are a very well-known and reliable technology. The finer the mesh or pore size in the filter, the better the filter is at stopping particles from passing through it. The two ratings you may see for filters are MERV (minimum efficiency reporting value) and HEPA (high efficiency particulate air). No filters stop all unwanted particles, but for the purpose of removing exhaled droplets, a MERV rating of 13 or higher is recommended [8]. It is recommended to source filters from a reputable supplier who can verify that filters have been third-party tested to meet the indicated standard.

Finer filters, such as MERV 13 or higher, often require bigger fans to push air through them, and with the increased air pressure, there is the likelihood that air will bypass around the filter. For this reason, it becomes increasingly important to install a gasket around the filter so air can't bypass it. An incorrectly installed filter could be much less effective than its rating indicates.

As the filter catches more and more particles, it becomes "fouled" over time and requires more fan power. Regularly changing filters according to the recommended schedule is essential.

Each existing HVAC system requires a filter of a specific size and shape, so be sure to procure filters that meet those requirements. The existing HVAC system may not accommodate an increase in the filter rating without modifying the system itself by increasing the fan power or modifying the filter rack where the filter is installed. Unfortunately, this could also increase the noise level coming from the fans.

7. *Do air currents created by the HVAC system potentially increase the dispersion of droplets containing the virus?*

Some buildings have been designed and built to have well-mixed air distribution in rooms such that there is very little difference in terms of risk no matter where you are in the room [9]. However, any location where an object or barrier is blocking ventilation will have stale, poor quality air (although this is less of a concern in well-ventilated buildings).

Again, CO_2 sensors can be used to measure whether there is enough outdoor air being supplied in a space. Ideally, sensors are tied into the ventilation system to increase ventilation automatically if CO_2 rise above a desired set point.

8. *Will increasing ventilation have an impact on our heating bills?*

Since reducing the spread of viruses can be accomplished by filtration, a germicidal system, increased ventilation, or by using a combination of these strategies, it is important to consider the limits of each system when deciding how best to clean the air in the school. In terms of increased outdoor air, an important balance must be made between the amounts of fresh air and recycled (recirculated) air. During the heating season, increasing the amount of fresh outdoor air means that more air would need to be heated, resulting in higher heating bills. Since buildings are often designed to recirculate air, the heating system may not have the capacity to heat 100% outdoor air. For this reason, there is a limit in the winter to how much fresh air is possible and also because of potential impacts on humidity. A filter can remove contamination from the air as it's recirculated. Filters that remove particulate matter more effectively have a tighter, finer mesh and therefore require larger

fans to push the air through them. Without modifying the system, a building may only be capable of improving the filtration efficiency to the limit of the fan's capacity, and of increasing the fresh air supply to the heating system's capacity.

9. How does a germicidal system work to reduce virus transmission?

Ultraviolet (UV) light is invisible to the human eye and most wavelengths are harmful for your eyes and skin; however, the germicidal effects of UV radiation have been quite well known for more than 30 years. UV light is very effective at destroying viruses and bacteria [10], [11], and UV lamps have been made for this purpose. UV-C wavelengths have the strongest germicidal effect, and a wavelength of approximately 254 nm is the most common. HVAC systems can include UV light devices, or they can be added aftermarket. To kill viruses suspended in the air, the air must be slowed down to pass through a UV light device powerful enough to ensure the proper dosage of UV-C radiation. Small weak lamps are ineffective, and powerful lamps can also be ineffective if the air passes by the lamps too quickly. Air exposed to UV radiation is breathable and safe for ventilation.

10. What other germicidal technologies exist?

Filters, increased ventilation, humidity, and UV are well-documented ways to reduce airborne viral transmission. There are numerous other emerging technologies and novel products on the market today that employ other methods of killing viruses or inducing particles to settle more rapidly. Because the technology is new, there aren't standards available to ensure reliable testing and the effectiveness of these technologies varies widely. Many work well, some don't work well, and some introduce other unwanted contaminants into the air so newer systems should be carefully evaluated before an investment is made. Professional engineers and qualified HVAC contractors are unbiased experts in ventilation systems and indoor air quality and can help inform these decisions

11. Should we consider small mobile air purifiers?

Because the ventilation system of a building is primarily designed to provide comfort and to control temperature, odour, and humidity, any modification to the system to reduce virus transmission could make for a system that cannot meet all the requirements. In-room air purification is a potential solution for improving problem areas such as crowded classrooms or high traffic areas [12], [13] and for school buildings without mechanical ventilation systems. In-room purification systems should function automatically to avoid human errors in operating them. The effectiveness of in-room purification systems depends on various factors, and proper system selection requires the specialized knowledge of a trained, independent professional.

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APPENDIX A: About the HRAI Expert Advisory Panel on IAQ

In October, 2020, HRAI has established an Expert Advisory Panel on Indoor Air Quality in commercial and institutional buildings. With businesses, educational institutions and governments all trying to understand the most efficient and safest ways to return to near-normal conditions that will support the social and economic well-being of Canadians over the months ahead this group was intended to produce easy-to-use and understand materials on the best practices currently in place to limit the transmission of COVID-19 through HVAC systems.

Governments at all levels, as well as school boards and commercial business operators need information to make sound choices about re-opening and maintaining safe facilities. The HRAI panel aids in making technical information more accessible and readily available.

Chaired by Joe Muchynski, Arvin Air Systems, and member of the Contractors Division Board, the panel includes members from each of the three member divisions as well as representatives from the Building Owners and Managers Association (BOMA), the Public Health Agency of Canada (PHAC), the National Research Council (NRC), the University of Toronto and University of Alberta, the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), and the Air-Conditioning, Heating and Refrigeration Institute (AHRI).

The panel includes the following members:

David Barnes (P.Eng.), Biocontainment Engineer, Public Health Agency of Canada

Gerry Cellucci, Vice President, Yorkland Controls and Environmental Solutions

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About HRAI

HRAI-Canada is the national trade association for the heating, ventilation, air conditioning and refrigeration (HVACR) industry, representing over 1,250 member companies across the country. HRAI's members include manufacturers, wholesalers and contractors who collectively employ tens of thousands of skilled trade professionals across the country and contribute more than $12B annually to the Canadian economy. HRAI also provides technician certification training that is recognized throughout Canada.

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