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Recommendations on the Use of Portable Air Filtration Systems in New Brunswick Classrooms: A COVID-19 Focus

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Introduction

There is no single measure that acts as a blanket mitigation to the risk of COVID-19 transmission in indoor settings. Guidance from the Public Health Agency of Canada (PHAC) recommends the following public health measures for reducing the risk of COVID-19 [1]:

- Minimizing the number of persons in one place at the same time
- Maintaining a physical distance of at least 2 metres
- Using well-constructed, well-fitting face masks
- Practising good hand and respiratory hygiene

In addition to the above measures, proper ventilation can contribute to the reduction of COVID-19 transmission indoors. However, it has been emphasized that good ventilation alone is not a substitute for the above-listed measures.

Indoor air quality can be improved by mechanical ventilation systems and opening windows/doors, both of which can let in fresh air. In some cases, where mechanical ventilation and/or natural ventilation is not feasible, the use of portable air filtration systems can be considered. These air filtration systems do not bring fresh air into a space; however, if equipped with a suitable filter (such as a high efficiency particulate air (HEPA) filter) and appropriately sized and installed in a space, they have been shown to reduce the concentration of airborne particulate (i.e. aerosols) over time.

A review of scientific literature was conducted to better understand the role of portable air filtration systems in classrooms and their impact on COVID-19 transmission. This review focused on addressing the following questions:

1. *If portable HEPA filtration units are installed in school classrooms which do not have integrated mechanical ventilation systems, would this likely have a positive, negative or no material effect on COVID-19 airborne particulates in the classroom?*

2. *NB has 294 public schools of which 234 have some form of integrated mechanical ventilation system. In general, is the response in 1) different for schools which do have some form of integrated ventilation system where fresh air is mechanically drawn in, circulated, and exhausted?*

3. *Has there been analysis completed, or is there analysis being done in other jurisdictions specific to portable air filtration units in school classrooms? If so, what are the recommendations or what is the status of this analysis?*

4. *If a decision is made to install portable devices in some instances, what measurement might be put in place to determine impact? And what configuration will ensure the safe and effective operation of these systems?*

Literature Findings and Recommendations

Findings from the literature survey and recommendations based on the current scientific data are provided below.

Question 1: *If portable HEPA filtration units are installed in school classrooms which do not have integrated mechanical ventilation systems, would this likely have a positive, negative or no material effect on COVID-19 airborne particulates in the classroom?*

Answer: Evidence shows that portable HEPA filtration systems would likely have a positive effect on reducing SARS-CoV-2 (hereafter referred to as COVID-19) airborne particulates. For schools with no integrated mechanical ventilation systems, the deployment of portable HEPA filtration units should strongly be considered in classrooms.

Rationale: The surveyed literature provides evidence that if these units are properly sized, installed, and maintained, they can effectively reduce the aerosol concentration in a classroom, contributing to overall improvements in air quality. These units should not be considered a substitute for core public health measures such as masking, physical distancing etc., but a supplement to good health and safety strategies to fight the pandemic.

Our rationale is based on the following considerations:

i. Is there evidence to show that portable air filtration units equipped with a HEPA filter reduce COVID-19 in the air?
→ Yes.

A recent study conducted in a repurposed ward of a hospital with known and measurable airborne COVID-19 virus demonstrated that a portable HEPA filtration unit effectively removed the virus and other pathogens to non-detectable levels [2].

A review by Morawska et al. discusses several studies that have shown portable air purifiers to be effective for cleaning the air (i.e. removing airborne bacteria and fungal spores)[3].

Likewise, the Unites States Environmental Protection Agency (US EPA) has recognized that portable air cleaners help reduce airborne contaminants, including particles containing viruses [4].

ii. Is there evidence that HEPA filtration units reduce aerosol concentrations in a classroom?

→ Yes.

A number of studies [5–8] have demonstrated that mobile air filtration units equipped with HEPA filters can effectively reduce aerosol concentrations of varying sizes in school classrooms. For example, Curtius et al. [5] showed that a homogeneous reduction in particles between 10 nm and 10 µm could be achieved with portable air filtration units. They also noted that in addition to potential reduction of COVID-19 transmission in classrooms, these units have the added benefit of improving overall air quality through reduction of particulate matter ($PM_{2.5}$ and PM_{10}) in the spaces in which they operate. The World Health Organization (WHO) recommends that the average exposure levels to $PM_{2.5}$ should be below 10 mg/m^3, as higher exposure increases the risks of a variety of diseases.

iii. Are there potential risks that need to be considered?

→Yes.

Portable air filtration units need to be positioned appropriately in the space so that they are able to clean the air for all occupants and are not just re-circulating the same air e.g. in one corner of the room [6]. Additionally, the filtration units should not directly blow air onto room occupants, as this potentially increases the risk of carrying exhaled aerosols from an infected person to other occupants [6,9,10]. The risk of exhaled aerosols from an infected person traveling to nearby occupants exists with other forms of ventilation and is not specific to portable air filtration units. For example, a modelling study on the use of windows for natural ventilation in classrooms showed that if an infected person is seated next to an open window, this may increase the risk of contaminated air being carried to nearby occupants [11]. To mitigate the risks of transmission from an infected person seated next to an open window, the authors suggested staggering seating arrangements and redirecting the window air to the ground.

A modelling study by Pease et al. [12] also demonstrated that if HVAC parameters are not properly adjusted and very high air exchange rates are used, there is an increased risk of spreading potentially virus-laden air from one room to another at a much higher rate.

Researchers studied the velocity of exhaled aerosols from masked and unmasked individuals and found that wearing masks was important for reducing the spread of aerosols from one person's breathing zone to another [11,13]. Furthermore, a study conducted by the United States Centers for Disease Control and Prevention (US CDC) demonstrated that exhaled aerosol reduction in indoor spaces was much more effective

when all occupants were wearing masks, even while portable air purifiers were operating [8].

Air flow patterns are not only relevant for portable air purifiers, but also for natural and mechanical ventilation systems, as well as with general movement around the classroom. This reiterates the importance of a multi-layered approach to reducing transmission risk of COVID-19. Given movement of air is inevitable in a classroom with or without HEPA filtration, it is our opinion that the air in rooms equipped with HEPA systems will be cleaner overall, causing a net reduction in airborne COVID-19.

iv. Is there evidence that directly shows HEPA filtration reduces COVID-19 transmission in classrooms?
→No.

While a number of studies support that portable air filtration units can reduce aerosols in classrooms and likely reduce the risk of transmission [5–8], to our knowledge, there is currently no evidence demonstrating that use of portable air filtration systems directly reduces incidents of COVID-19 transmission in classrooms [8,14].

There is currently a controlled study underway (press release issued November 5, 2021), led by researchers at the University of Leeds, to investigate whether portable air filtration systems have an effect on reducing COVID-19 transmission in school classrooms [15]. The study is investigating two different approaches to cleaning the air: one based on the use of HEPA filters, the other using ultraviolet light. Outcomes for this study were not available at the time of writing this report.

Similarly, a new randomised controlled trial, led by researchers at the University of Bristol, plans to look at the effectiveness of portable air filters in preventing respiratory infections and COVID-19 among care home residents in England (press release issued October 21, 2021) [16]. Outcomes for this study were not available at the time of writing this report.

Question 2: *NB has 294 public schools of which 234 have some form of integrated mechanical ventilation system. In general, is the response in 1) different for schools which do have some form of integrated ventilation system where fresh air is mechanically drawn in, circulated, and exhausted?*

Answer: For spaces with adequate mechanical ventilation systems, the use of portable air filters is not recommended. In our opinion, use of HEPA air filtration units should first be considered for spaces that do not have any form of integrated mechanical ventilation system. On a case-by-case basis, where mechanical ventilation systems are deemed to be insufficient and natural ventilation is not feasible, deploying portable air filtration systems should also be considered.

Rationale: Our assessment of the need for portable air filtration units in schools with integrated mechanical ventilation systems was based on the following scientific evidence found in the literature:

> Mechanical ventilation systems can vary greatly in configuration [17], but if they are bringing in sufficient fresh air, this can help to dilute airborne contaminants in classrooms. Some systems may have filters in place as well, which can further reduce aerosols in the air.
>
> Schools with some form of integrated mechanical ventilation can also take advantage of natural ventilation (e.g. opening windows) if feasible. On a case-by-case basis, where mechanical ventilation systems are deemed to be insufficient and natural ventilation is not feasible, deploying portable air filtration systems should be considered.
>
> This approach is consistent with the World Health Organization's "Roadmap to improve and ensure good indoor ventilation in the context of COVID-19" [18], which recognizes the importance of both mechanical and natural ventilation.
>
> This position is also held by the German Federal Environment Agency [19] which prioritizes integrated mechanical ventilation systems and natural ventilation for improving overall air quality and reducing aerosol concentrations over the use of portable air filtration units.
>
> Evidence in the literature indicates that mechanical ventilation, natural ventilation, and air filtration are all means to reduce aerosols in indoor spaces and can be combined as necessary to improve indoor air quality [20,21].
>
> The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) has published detailed guidance on heating, ventilating, and air-conditioning (HVAC) systems in schools and universities [22]. From the ASHRAE Epidemic Task Force "Core Recommendations for Reducing Airborne Infectious Aerosol Exposure" [23] , they note:

> "[…] that within limits ventilation, filtration, and air cleaners can be deployed flexibly to achieve exposure reduction goals subject to constraints that may include comfort, energy use, and costs. This is done by setting targets for equivalent clean air supply rate and expressing the performance of filters, air cleaners, and other removal mechanisms in these terms."

Question 3: *Has there been analysis completed, or is there analysis being done in other jurisdictions specific to portable air filtration units in school classrooms? If so, what are the recommendations or what is the status of this analysis?*

Answer: A number of jurisdictions have considered the use of portable air filtration in classrooms. Many authorities have also issued statements on the use of portable air filtration units in schools.

Researchers from Germany have conducted a number of relevant studies on portable and mobile air filtration units in school classrooms for reducing aerosol concentrations [5–7]. In light of this work, the German Federal Environment Agency supports the use of portable air filtration in classrooms to reduce aerosols in cases where no mechanical ventilation system is in place and sufficient natural ventilation is not feasible [24].

Similarly, the Government of Ontario has moved to implement portable air filtration units in classrooms with no mechanical ventilation and in spaces where masks are not worn, such as full-day kindergarten classrooms (even if these classrooms have mechanical ventilation) [25].

The Gouvernement du Québec completed a review on portable air filtration units for use in classrooms in January 2021 and did not recommend their use based on a lack of direct evidence that the units reduced incidents of COVID-19 in the classroom, concerns around ineffectiveness if the units were not installed properly, and concerns around noise [26]. Since the publication of that report, a number of studies have emerged that specifically looked at the effectiveness of portable air filtration units in classrooms and which addressed concerns around proper placement and noise [5–8].

While a number of studies support that portable air filtration units can effectively reduce aerosols in classrooms [5–8], there is currently no evidence showing that use of portable air filtration systems directly reduces incidents of COVID-19 transmission in classrooms [8,14].

A study conducted by the United States Centers for Disease Control and Prevention on indoor aerosol concentrations and the effects of masking and portable air purifiers noted [6]:

> "The addition of two HEPA air cleaners that met the Environmental Protection Agency (EPA)-recommended clean air delivery rate (CADR) (5) reduced overall exposure to simulated exhaled aerosol particles by up to 65% without universal masking. Without the HEPA air cleaners, universal masking reduced the combined mean aerosol

concentration by 72%. The combination of the two HEPA air cleaners and universal masking reduced overall exposure by up to 90%. The HEPA air cleaners were most effective when they were close to the aerosol source. These findings suggest that portable HEPA air cleaners can reduce exposure to SARS-CoV-2 aerosols in indoor environments, with greater reductions in exposure occurring when used in combination with universal masking."

"Although the study provides useful information about the dynamics of respiratory aerosol particles and the effects of HEPA air cleaners and universal masking, many other factors are also important for disease transmission, including the amount of virus in the particles, how long the virus survives in air, and the vaccination status of the room occupants."

There is currently a controlled study underway (press release issued November 5, 2021), led by researchers at the University of Leeds, to investigate whether portable air filtration systems have an effect on reducing COVID-19 transmission in school classrooms [15]. The study is investigating two different approaches to cleaning the air: one based on the use of HEPA filters, the other using ultraviolet light. Outcomes for this study were not available at the time of writing this report.

Similarly, a new randomised controlled trial, led by researchers at the University of Bristol, will look at the effectiveness of portable air filters in preventing respiratory infections and COVID-19 among care home residents in England (press release issue October 21, 2021) [16]. Outcomes for this study were not available at the time of writing this report.

Many authorities recognize that portable air filtration units can play a role in providing additional protection from COVID-19. Some examples are provided below.

Public Health Agency of Canada on portable air filters [1]:

"When properly used, portable air filtration devices with high-efficiency particulate air (HEPA) filters have been shown to reduce the concentration of some viruses from the air. The use of these devices could be considered as an additional protection in situations where enhancing natural or mechanical ventilation is not possible and when physical distancing can [sic] be achieved."

World Health Organization statement on portable air filters from December 23, 2021 [27] :

"Air filters do not provide ventilation and do not replace other ventilation methods. However, they can help to reduce the concentration of the COVID-19 virus in the air, thus reducing the possibility of transmission. A MERV14/ISO ePM1 70-80% air filter can improve air quality when used in indoor settings."

United States Environmental Protection Agency on portable air filters in schools [4]:

> "Consider using portable air cleaners to supplement increased HVAC system ventilation and filtration, especially in areas where adequate ventilation is difficult to achieve. Directing the airflow so that it does not blow directly from one person to another reduces the potential spread of droplets that may contain infectious viruses."

United States Centers for Disease Control and Prevention on portable air filters in schools and childcare programs [28]:

> "Opening windows, using portable air cleaners, and improving building-wide filtration are ways you can increase ventilation in your school or childcare program."
>
> "Consider portable air cleaners that use high-efficiency particulate air (HEPA) filters to enhance air cleaning wherever possible, especially in higher-risk areas such as a nurse's office or sick/isolation room."

Question 4: *If a decision is made to install portable devices in some instances, what measurement might be put in place to determine impact? And what configuration will ensure the safe and effective operation of these systems?*

Determining impact:

The role of an air purifier equipped with a HEPA filter is to reduce the concentration of aerosol particles in the air. Before and after installation of portable air filtration units in a classroom, the aerosol concentration at multiple locations in the room could be measured with particle sizer/counter equipment to verify effectiveness of the air filters. For long-term continuous monitoring, indoor air quality monitoring devices can be deployed to track particulate matter. Other experiments could be designed that employ aerosol generators. Computational models could also be employed.

Safe and effective operation:

There are multiple considerations when selecting and installing a portable air filtration system and not all units may be suitable for all classroom settings.

The German Federal Environment Agency (Umweltbundesamt, UBA) and the Association of German Engineers (Verein Deutscher Ingenieure, VDI) have developed requirements and test criteria for mobile air purifiers, as described in the VDI publication "VDI-EE 4300 Part 14: Measurement of indoor pollution - Requirements for mobile air purifiers to reduce aerosol-borne transmission of infectious diseases" [29]. (Note: the original publication is in German, but an English translation can be ordered).

Air purifiers that meet these requirements are considered suitable by the UBA and VDI for reducing the virus load, for example, in classrooms that are not adequately ventilated.

Some of the key considerations identified in the VDI document are summarized below:

- Installation positions in the room should be in accordance with the manufacturer's instructions
- Filter classes such as HEPA H13 (according to EN 1822 plus pre-filtering e.g. ISO ePM10 50% according to ISO 16890), combinations of ePM1> 50% and ePM1> 80% according to ISO 16890 (formerly F7 + F9) or equivalent for devices with filters
- Security and protection against vandalism
- For UVC air purifiers: Avoiding UV radiation outside the device
- Air volume flow for mobile air cleaning devices, where the cleaning performance takes place in the device, should correspond to at least 4 air changes per hour. This achieves an air throughput that is high enough to direct all of the room air through the devices within a sufficiently short period of time
- Noise development with the required air volume flow (e.g. for schools sound pressure level less than / equal to 35 dB (A))
- Comfort aspects need to be considered (e.g. avoidance of drafts)
- Cleaning performance with filter devices (filtering efficiency> 90%, testing in the laboratory under real-room-like conditions)

Studies using mobile air purifiers in classrooms conducted by Curtius et al. [5], Burgmann and Janoske [6] and Duill et al. [7] provide information on placement of units and found that when units operated with 5 to 6 (equivalent) air changes per hour, an 80%+ reduction in aerosols was observed within 30 minutes of running the air purifiers. Ideally, air exhausted from the air purifiers should not have air outlets directed at the breathing zones of occupants in the room.

Curtius et al. [5] note the following:

- When just a single purifier is installed, the positioning should ideally be at a central place in the room.
- If several purifiers are installed, the units should be distributed evenly in the room.
- Placement in the corners is possible as long as the flows toward the air intake and from the clean air outlet are not obstructed. Any blocking of free circulation, e.g., by placing the air purifier underneath a table, reduces the efficiency of the purifier substantially.
- Safety aspects need to be considered. For example, emergency exits must not be blocked when installing the mobile air purifiers.
- The air purifiers should be equipped with HEPA filters (DOE STD 3020 2015, H13 or H14), and a high clean air delivery rate of around 1000 m^3/h or higher should be applied.
- In order to achieve high air exchange rates and homogeneous mixing in the entire room it can be of advantage to install several smaller purifier units

- In addition to the HEPA filters, the purifiers need to be equipped with pre-filters to remove the coarse dust efficiently and the pre-filters need to be cleaned or exchanged regularly.
- If deployed in classrooms, the noise levels from operating the air cleaners need to be considered. While large ventilation rates are desirable, the noise level needs to be sufficiently low so as not to disturb the ongoing classes. Use of multiple air purifiers in a space can lead to increases in noise.

Duill et al. [7] present the following considerations from their study:

- The placement of an air purifier in a classroom is dependent on various factors including room geometry, air outlet direction, and features of the room ceiling (e.g., protruding lamps, crossbars; this is important if the air purifier has an outlet that is directing air out towards the ceiling).
- If mobile air purifiers are integrated into a classroom, modifications to the existing furniture may be necessary.
- The mobile air purifiers used in this study were large floor-standing units that are characterized by the fact that the discharged air flows out horizontally at a height of more than 2 m or is directed towards the ceiling at a height of less than 2 m. This generates a flow along the ceiling, which leads to a large-area distribution of the filtered air, reducing the aerosol concentration in the room as homogeneously as possible.
- A critical factor for the suitability and acceptance of such units for use in classrooms is the noise level. For the devices tested, this is not bigger than 40 dB(A) at the volume flow of about 1000 m^3/h used. A survey among the teachers also showed that this volume and the accompanying air flow had no negative influence on the teaching process.

Lindsley et al. [8] highlight the following:

- Portable HEPA air cleaners offer a simple means to increase the filtration of aerosol particles from a room without modifying the existing building ventilation system.
- The optimal location for HEPA air cleaners will depend upon the unique conditions in each room, but they are likely to be most effective when they are placed as close to the occupants as is practical.
- Larger reductions in exposure occur when air cleaners are used in combination with universal masking.

Conclusions

According to the scientific literature reviewed and recommendations from various regulatory bodies, portable HEPA air filtration systems likely reduce COVID-19 transmission in certain indoor settings and should be considered for use in classrooms with no or insufficient ventilation systems. Proper sizing, placement, direction of air flow, operation and maintenance is important for reaping the benefits of portable HEPA air filters and reducing risks associated with air flow from filtration units.

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