Guidance on Non-Healthcare Building Ventilation during COVID-19

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1.0	22/09/2020	Original Version
1.1	14/10/2020	Added European Standards for air filters

Contents

Background

Ventilation refers to the movement of outdoor air into a building, and the circulation of that air within the building or room. This can be achieved through natural means (e.g. opening a window) or mechanical means (e.g. a central heating, ventilation and air conditioning (HVAC) unit) (1). Lack of appropriate ventilation within healthcare settings has been associated with increased rates of infection with airborne diseases (1). Similarly, inadequate ventilation in non-healthcare settings has been shown as a contributing factor in outbreaks of highly infectious airborne diseases like measles and TB (2).

COVID-19 is a new disease, and the effect of ventilation on the transmissibility of SARS-CoV-2 (the virus that causes COVID-19) is still unclear. This document provides an overview of the current literature examining the association between ventilation and COVID-19, and provides recommendations based on the literature, specifically for non-healthcare settings.

Modes of transmission

SARS-CoV-2 is transmitted through direct or indirect contact from an infected person. Development of respiratory droplets carrying the SARS-CoV-2 virus occur when an infected person coughs or sneezes; these droplets usually only travel a short distance (<2m) due to their size. The infective droplet may directly reach the respiratory tract of susceptible individuals in close proximity, and result in infection. Alternatively, these droplets may land on surfaces conducive to the SARS-CoV-2 survival. Uninfected individuals who touch these surfaces and then touch their face may inadvertently transmit the virus to themselves indirectly (3). It is for this reason that the current Public Health recommendations of social distancing, cough etiquette and regular hand washing are so important in limiting transmission of the virus.

The possibility of airborne transmission of SARS-CoV-2 through aerosols (smaller than droplets) is still uncertain (3). Airborne transmission occurs when droplet nuclei (residue from evaporated droplets) remain suspended in air for prolonged periods of time, and may be blown over long distances (>2m). A recent evidence summary by HIQA noted that while there is limited, low certainty evidence that SARS-CoV-2 may be aerosolised, there is as of yet no conclusive evidence that SARS-CoV-2 remains viable or infective in aerosolised form in real-world situations (4). Further research is needed to determine what contribution, if any, airborne transmission makes to the COVID-19 pandemic.

Ventilation and COVID-19

Crowded indoor spaces have been shown to be associated with increased SARS-CoV-2 transmission. Out of 318 outbreaks (classified as 3 or more cases in a single setting) examined in China, only 1 could be traced back to transmission in an outdoor space (5). In Japan, a pre-print article by Nishiura et al (6) examined 110 cases and found that a primary case is 20 times more likely to transmit SARS-CoV-2 in a closed environment than in an open-air environment.

The nature of indoor activities also appears to be associated with increased risk of transmission in closed environments. Activities involving forceful expulsion of air, such as singing (7), loud, excessive talking (8), and high-exertion fitness routines (9) have been associated with COVID-19 outbreaks. In contrast, there were no secondary cases from an infective source on a 15-hour flight between Wuhan and Toronto, despite the flight being full (350 passengers) (10). This is likely due to the increased number of droplets that are produced during activities such as singing, loud talking and exercise (11). Determining what proportion of this transmission is due to proximity and poor hygiene practices, and what is due to poor ventilation though, is difficult, as detailed investigations of these outbreaks suggest that droplet and fomite transmission alone could explain the spread (3).

There are limited studies that have examined the direct effect of ventilation on COVID-19 transmission. A systematic review that sought to determine whether indoor HVAC systems contribute to the spread of COVID-19 found only 6 studies specific to SARS-CoV-2: 4 supported the hypothesis by using computer simulations, while 2 excluded the hypothesis based on epidemiological considerations (12). One of these studies examined an outbreak in a Chinese restaurant (13). The authors concluded that the strong airflow created by the individual air-conditioning unit, combined with low ventilation rates due to lack of outdoor air supply, and overcrowding, led to the outbreak of COVID-19 in 3 non-associated families.

Poor ventilation was also associated with an outbreak on a 100-minute bus ride, during which 23 out of 67 passengers were infected from a single index case (14). The bus used a recirculating air-conditioning system. In this instance, passengers sitting closer to the infected individual did not have a statistically higher chance of contracting COVID-19 when compared to those sitting further away, as cases were spread throughout the bus (some more than 5m from index case). Apart from the passenger sitting next to the index case, none of the passengers sitting next to windows with air-vents on the infected case side of the bus contracted COVID-19, nor did the driver or passengers sitting close to the door; while only one person sitting next to an openable window (there were 4 such windows on the bus) developed COVID-19. The authors concluded that closed environments using recirculated air increases the transmissibility of SARS-CoV-2.

A study examining a large COVID-19 outbreak in a meat-processing plant in Germany came to a similar conclusion (15). The authors considered the social and working conditions of the affected cases, and concluded that transmission of SARS-CoV-2 occurred over a distance of at least 8m due to the confined working space, proximity of workers, low outside air infiltration rate, and high rate of recirculated unfiltered air.

Conclusion

There is currently no strong evidence to suggest that SARS-CoV-2 is spread through aerosol transmission via HVAC systems. However, there is evidence that COVID-19 outbreaks are more commonly associated with crowded indoor spaces, and that poor ventilation may increase the risk of transmission in such settings by facilitating the spread of droplets over longer distances. The SARS-CoV-2 virus shows similar viability to SARS-CoV-1 (the airborne coronavirus that caused the 2003 SARS epidemic) in aerosol form in experimental laboratory conditions (16). While it is possible that experimental viability may be maintained in real-world situations, there is currently no conclusive evidence that this is the case. Given that there is still a lot of unknowns around SARS-CoV-2, it is worth applying the precautionary principle until further conclusive evidence is available regarding airborne transmission.

General recommendations

Several organisations have produced documentation relating to building ventilation during COVID-19. The suggestions below are specifically for commercial and public buildings. Residential and healthcare settings fall outside the scope of this document. It is advised to speak to the building engineer or system manufacturer before implementing any of the suggestions relating to mechanical ventilation.

- Continue appropriate Public Health measures (17, 18, 19):
    - Maintain social distancing of at least 2m
    - Allow staff to work from home where possible
    - Avoid crowding in indoor spaces

    - Provide visible guidance material on appropriate Public Health measures (respiratory etiquette, social distancing, meticulous hand hygiene)
    - Appropriate use of face masks as per government guidelines (https://www.gov.ie/en/publication/aac74c-guidance-on-safe-use-of-face-coverings/)
- Make sure that any mechanical ventilation systems are adequately maintained as per manufacturer's instructions (18, 19). There is no need for additional maintenance cycles beyond the routine maintenance (19, 20)
- Where filters are used in the central HVAC system, ensure that these are replaced regularly as per manufacturer's instructions. There is no need for additional cleaning or changing beyond routine maintenance (20)
- If filters are used as part of a central ventilation system, consideration should be given to installing the most efficient filter for the system (MERV 13 to 16; ISO 16890 ePM1 rating 60-90%). HEPA filtration should be considered where air is re-circulated. (18)
- Increase the outdoor air fraction of air inside buildings as much as possible (17, 20). This can be done by fully opening outside air dampers in mechanical systems, or opening windows where available.
- Increase total airflow supply to occupied spaces by increasing number of air exchanges per hour (17, 19, 20)
- Mechanical fans should only be used where there is a single occupant in a room (18). If this is not possible, then fans should be directed to exhaust directly to the exterior environment (e.g. open window), to minimise potential spread of pathogens.
- Disable demand controlled mechanical ventilation if possible (19, 20, 21). These types of HVAC systems are set to only circulate air when a certain threshold is passed, usually the amount of CO_2 build-up in the room, or the ambient room temperature. If it is not possible to bypass this system, then set the threshold to the lowest possible setting (e.g. 400ppm or less of CO_2) so that the system remains ventilating at a nominal speed.
- Keep ventilation running at all times (i.e. 24/7), regardless of building occupancy (20). When unoccupied, ventilation can be reduced to the lowest setting.
- Extend the hours of nominal HVAC operations to begin two hours before the building is occupied, and to only reduce to lowest setting 2 hours after the building has emptied (19,20,21). This ensures that rooms are well ventilated before occupancy each day.
- Ensure extractor fans in bathrooms are functional and running 24/7 (20). When the building is occupied, they should operate at full capacity (21). As with the central HVAC

system (above), they can be set to the lowest speed 2 hours after the building is emptied, and ramped up again 2 hours before occupancy if the system allows (20).

- Avoid directing air flow directly onto individuals or across groups of individuals, as this may facilitate transmission of pathogens between individuals (19)
- Avoid the use of air-recirculation systems in HVACs as much as possible (19, 20). Use 100% outdoor air if supported by the HVAC system and compatible with outdoor/indoor air quality considerations (21). If it is not possible to disable the air recirculation system, then HEPA filtration or the highest efficiency filter possible according to the HVAC manufacturer's specifications should be considered (MERV 13 to 16; ISO 16890 ePM1 rating 60-90%) (18).
- While there is evidence in experimental settings that coronaviruses like the SARS-CoV-2 virus deteriorate faster in high temperatures and humidity (22), the levels that need to be achieved are not attainable or acceptable in buildings (20). In addition, indoor humidification is not a common feature in most HVAC systems, and would incur additional maintenance and equipment costs (17). However, low relative humidity (<20%) is known to increase an individual's susceptibility to infection (17, 20). Where such systems do exist, the advice is to maintain a relative air humidity of 20-60% if feasible (17, 18, 20).
- Create "clean" ventilation zones for staff that do not include high-risk areas (e.g. visitor reception). This can be done by re-evaluating the positioning of the supply and exhaust air diffusers and adjusting flow rates to establish measurable pressure differentials (21).

School specific recommendations

Schools can pose a particular challenge to adequate ventilation, given that many European schools rely on natural ventilation (i.e. windows) (23). This becomes problematic when the temperature differential between the inside and outside air is large, for example during winter time. **In addition** to the general recommendations above, the following guidance can be applied in schools:

- Ensure that windows and air vents can be accessed and opened when needed
- In classrooms that rely on natural ventilation, consider opening the windows 15 minutes before the classroom is occupied to ventilate the room. Similarly, leave windows open for 15 minutes after the classroom is emptied.

- Consider installing an indoor air quality (IAQ) meter in each classroom that relies on natural ventilation. IAQ meters monitor the level of CO_2 in an area, alerting the user to when the level rises above a set parameter, indicating that there is poor ventilation. They should be mounted in a visible location, away from fresh air inlets. The Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA) recommend setting the lower limit to 800ppm of CO_2 (23). When this limit is reached, the necessary steps need to be taken to increase classroom ventilation (e.g. opening a window).
- Provide teachers with instructions on how to manage classroom ventilation:
  - Open windows and air vents as much as possible during school time to facilitate ventilation. Opening windows just below the ceiling will reduce the risk of cross-draughts.
  - Ensure regular airing with windows during break time by opening windows fully
  - Make sure the ventilation system openings are not blocked by furniture or curtains
  - Observe IAQ CO_2 monitor levels during the school day and respond appropriately when the threshold is reached (800ppm CO_2 recommended as threshold)

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