Guidance on non-healthcare building ventilation during COVID-19

V2.1

Version	Date	Changes from previous version
2.1	23/7/2021	Updated conclusion
2.0	22/01/2021	New guidance outlay applied; updated information on fans; updated Public Health
1.1	14/10/2020	Added European Standards for air filters
1.0	22/09/2020	Original Version

Cover note: The content contained within this guidance document is currently under review.

Key Points

All HPSC guidance should be read and interpreted in conjunction with the Government's 'Framework of Restrictions'

- Ventilation is the movement of outdoor air into a building, and the circulation of that air within the building, through mechanical or natural means
- Poor ventilation in crowded indoor spaces is associated with increased risk of COVID-19 transmission; ensuring adequate and appropriate ventilation may mitigate some of this risk
- Recommendations for mechanical ventilation include:
  - Regular maintenance of HVAC systems
  - Use of appropriate filters as per manufacturer's specifications
  - Increase total airflow and outside air fraction
  - Disable air recirculation systems where possible
  - Extend operating hours
  - Avoid the use of ceiling mounted, desk and portable fans where possible
- In schools that rely on natural ventilation (i.e. opening windows), the following additional suggestions are made:
  - Open windows as much as possible during school time, weather and comfort permitting
  - Use an indoor air quality meter to monitor CO2 levels, and ventilate the room when indicated

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 our understanding of the role of ventilation in the transmissibility of SARS-CoV-2 (the virus that causes COVID-19) continues to evolve. This document provides an overview of the 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 using cloth face coverings or masks in public settings, social distancing, respiratory 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) in non-healthcare settings 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). While there have been situations where it appears SARS-CoV-2 has spread over long distances (>2m) or periods of time, these have occurred in specific situations (prolonged exposure to infective person in enclosed, crowded, poorly ventilated spaces). The current epidemiological evidence indicates that SARS-CoV-2 is primarily spread through droplet transmission, as there is no evidence of efficient airborne spread as seen in airborne infectious diseases like measles or tuberculosis (4). An 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 (5). However, they did note that crowded indoor environments with poor ventilation involving activities associated with forceful expulsion of air (e.g. exercising, singing, shouting) were some of the factors found to contribute to transmission risk (6). While further research is needed to determine what contribution, airborne transmission makes to the COVID-19 pandemic, crowded, poorly ventilated indoor settings in which there is evidence of increased risk of transmission need to be addressed. Improving ventilation in addition to other Public Health measures may mitigate this risk in such settings.

Ventilation and COVID-19

Crowded indoor spaces have been shown to be associated with increased SARS-CoV-2 transmission. Factors that likely play a role in increased transmission of SARS-CoV-2 in indoor settings include the infectiousness of the person, the activities of the infectious person, and the size and ventilation of the indoor space (7). Out of 318 outbreaks (classified as 3 or more cases in a single setting) examined in China, all occurred in indoor environments (8). In Japan, a pre-print article by Nishiura et al (9) 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 (10), loud, excessive talking (11), and high-exertion fitness routines (12) 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) (13). This is likely due to the increased number of droplets that are produced during activities such as singing, loud talking and exercise (14). 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 mechanical 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 (15). One of these studies examined an outbreak in a Chinese restaurant (16). 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 (17). 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 (18). 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 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 (19). 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 are still 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 (20, 21, 22):
    - 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 (cloth face coverings or masks, respiratory etiquette, social distancing, meticulous hand hygiene)
    - Appropriate use of cloth face coverings or 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 (21, 22). There is no need for additional maintenance cycles beyond the routine maintenance (22, 23)
- Where filters are used in the central HVAC system, ensure that these are replaced regularly as per manufacturer's instructions. Ensure that filters are well sealed (7). There is no need for additional cleaning or changing beyond routine maintenance (23)
- 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. (21). Increase air filtration to as high as possible without significantly diminishing design airflow/fresh air amount (23).
- Increase the outdoor air fraction of air inside buildings as much as possible (20, 23). This can be done by fully opening outside air dampers in mechanical systems, or opening windows where available, taking into account weather and comfort level of room occupants.
- Increase total airflow supply to occupied spaces by increasing number of air exchanges per hour (20, 22, 23)
- Ceiling mounted, desk and portable fans do not provide fresh air and can mask poor ventilation issues. They are difficult to keep clean, and could increase the duration of suspended particles by creating air currents in confined spaces. Such fans merely recirculate air in a room if there is no source of fresh air. Therefore, a fresh air supply, as required by building regulations, or 10L per second per person (whichever is greater), should be provided when using a fan (24). Fans should only be used where there is a single occupant in a room (21). When used, 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 (22, 23, 25). These types of HVAC systems are set to only circulate air when a certain threshold is passed, usually

the amount of CO2 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 CO2) so that the system remains ventilating at a nominal speed.

- Keep ventilation running at all times (i.e. 24/7), regardless of building occupancy (23). 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 (22,23,25). This ensures that rooms are well ventilated before occupancy each day.
- Ensure extractor fans in bathrooms are functional and running 24/7 (23). When the building is occupied, they should operate at full capacity (25). 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 (23).
- Avoid directing air flow directly onto individuals or across groups of individuals, as this may facilitate transmission of pathogens between individuals (22)
- Avoid the use of air-recirculation systems in HVACs as much as possible (22, 23). Use 100% outdoor air if supported by the HVAC system and compatible with outdoor/indoor air quality considerations (25). 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%) (21). Increase air filtration to as high as possible without significantly diminishing design airflow/fresh air amount (23).
- While there is evidence in experimental settings that coronaviruses like the SARS-CoV-2 virus deteriorate faster in high temperatures and humidity (26), the levels that need to be achieved are not attainable or acceptable in buildings (23). In addition, indoor humidification is not a common feature in most HVAC systems, and would incur additional maintenance and equipment costs (20). However, low relative humidity (<20%) is known to increase an individual's susceptibility to infection (20, 23). Where such systems do exist, the advice is to maintain a relative air humidity of 30-50% if feasible (7).
- 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 (25).

School specific recommendations

Schools can pose a particular challenge to adequate ventilation, given that many European schools rely on natural ventilation (i.e. windows) (27). 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, weather and student comfort permitting.
- 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 to ventilate the room (27).
- Consider installing an indoor air quality (IAQ) meter in each classroom that relies on natural ventilation. IAQ meters monitor the level of CO2 in an area, alerting the user to when the level rises above a set parameter, indicating that there is poor ventilation. Preference should be given to Non-dispersive Infra-red (NDIR) CO2 sensors, which detect actual CO2 in a space, as opposed to the less expensive equivalent CO2 (eCO2) sensors that do not measure actual CO2 levels but rather infer a CO2 concentration based on room volatile organic compound (VOC) concentrations (28). 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 CO2 (27). 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, weather and student comfort permitting. 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 CO2 monitor levels during the school day and respond appropriately when the threshold is reached (800ppm CO2 recommended as threshold)

References

1. Atkinson J, Chartier Y, Pessoa-Silva CL, et al., editors. Natural Ventilation for Infection Control in Health-Care Settings. Geneva: World Health Organization; 2009. Available from: https://www.ncbi.nlm.nih.gov/books/NBK143277/ [Accessed 17 September 2020]
2. Li Y, Leung GM, Tang, JW, et al. (2007) ‘Role of ventilation in airborne transmission of infectious agents in the built environment – a multidisciplinary systematic review’, Indoor Air, 17(1), 1-18, DOI: 10.1111/j.1600-0668.2006.00445.x
3. World Health Organization. Transmission of SARS-CoV-2: implications for infection prevention precautions [Internet]. Geneva: WHO; 09 July 2020. Available at: https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions [Accessed 17 September 2020]
4. CDC. Scientific Brief: SARS-CoV-2 and Potential Airborne Transmission [Internet]. Atlanta, Georgia: CDC; 05 October 2020. Available at: https://www.cdc.gov/coronavirus/2019-ncov/more/scientific-brief-sars-cov-2.html [Accessed 20 January 2021]
5. Health Information and Quality Authority. Evidence summary for airborne transmission of SARS-CoV-2 via aerosols [Internet]. Dublin: HIQA; 21 August 2020. Available at: https://www.hiqa.ie/reports-and-publications/health-technology-assessment/evidence-summary-airborne-transmission-sars [Accessed 16 September 2020]
6. Health Information and Quality Authority. Evidence summary on activities or settings associated with a higher risk of SARS-CoV-2 transmission. [Internet] Dublin: HIQA; 18 November 2020. Available at: https://www.hiqa.ie/reports-and-publications/health-technology-assessment/activities-or-settings-associated-higher-risk [Accessed 20 January 2020]
7. Government of Canada. COVID-19: Guidance on indoor ventilation during the pandemic [Internet]. Ottawa: Ontario; 18 January 2021. Available at: https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/guidance-documents/guide-indoor-ventilation-covid-19-pandemic.html [Accessed 20 January 2021]
8. Qian H, Miao T, Liu L, et al. (2020) ‘Indoor transmission of SARS-CoV-2’, Indoor Air, 31 October 2020, DOI: 10.1111/ina.12766
9. Nishiura H, Oshitani H, Kobayashi T, et al (2020) ‘Closed environments facilitate secondary transmission of coronavirus disease 2019 (COVID-19)’, medRxiv, DOI: 10.1101/2020.02.28.20029272 [Accessed 17 September 2020]
10. Hamner L, Dubbel P, Capron I, et al (2020) ‘High SARS-CoV-2 Attack Rate Following Exposure at a Choir Practice – Skagit County, Washington, March 2020’, CDC Morbidity and Mortality Weekly Report, 69(19), pp. 606-610
11. Park SY, Kim, YM, Yi S, et al (2020) ‘Coronavirus Disease Outbreak in Call Center, South Korea’, Emerging Infectious Diseases, 26(8), pp 1666-1670
12. Jang S, Han SH, Rhee JY. (2020) ‘Cluster of Coronavirus Disease Associated with Fitness Dance Classes, South Korea’, Emerging Infectious Diseases, 26(8), pp 1917-1920

13. Schwartz KL, Murti M, Finkelstein M, et al (2020) 'Letters: Lack of COVID-19 transmission on an international flight', Canadian Medical Association Journal, 192(15), pp E410. DOI: 10.1503/cmaj.75015 [Accessed 17 September 2020]
14. Asadi S, Wexler AS, Cappa CD, et al (2019) 'Aerosol emission and superemission during human speech increase with voice loudness', Scientific Reports, 9, 2348, DOI: 10.1038/s41598-019-38808-z. Available at: https://www.nature.com/articles/s41598-019-38808-z [Accessed 17 September 2020]
15. Chirico F, Sacco A, Bragazzi NL, et al (2020) 'Can Air-Conditioning Systems Contribute to the Spread of SARS/MERS/COVID-19 infection? Insights from a Rapid Review of the Literature', International Journal of Environmental Research and Public Health, 17(17), 6052, DOI: 10.3390/ijerph17176052. Available at: https://www.mdpi.com/1660-4601/17/17/6052 [Accessed 16 September 2020]
16. Li Y, Qian H, Hang J, et al (2020) 'Evidence for probable aerosol transmission of SARS-CoV-2 in a poorly ventilated restaurant', medRxiv, DOI: 10.1101/2020.04.16.20067728. Available at: https://www.medrxiv.org/content/10.1101/2020.04.16.20067728v1 [Accessed 17 September 2020]
17. Shen Y, Li C, Dong H, et al (2020) 'Community Outbreak Investigation of SARS-CoV-2 Transmission Among Bus Riders in Eastern China', JAMA Internal Medicine, DOI: 10.1001/jamainternmed.2020.5225. Available at: https://jamanetwork.com/journals/jamainternalmedicine/fullarticle/2770172?utm_campaign=articlePDF&utm_medium=articlePDFlink&utm_source=articlePDF&utm_content=jamainternmed.2020.5225 [Accessed 17 September 2020]
18. Günther T, Czech-Sioli M, Indenbirken D, et al (2020) 'Investigation of a superspreading event preceding the largest meat processing plant-related SARS-Coronavirus 2 outbreak in Germany', SSRN, DOI: 10.2139/ssrn.3654517. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3654517 [Accessed 18 September 2020]
19. Van Doremalen N, Bushmaker T, Morris D, et al. (2020) 'Correspondence: Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1', New England Journal of Medicine, 382(16), pp 1564-1567
20. Dietz L, Horve PF, Coil DA, et al. (2020) '2019 Novel Coronavirus (COVID-19) Pandemic: Built Environment Considerations to Reduce Transmission', mSystems, 5:e00245-20. DOI: 10.1128/mSystems.00245-20. Available at: https://msystems.asm.org/content/5/2/e00245-20 [Accessed 17 September 2020]
21. Global Heat Health Information Network. Q&A: Do air conditioning and ventilation systems increase the risk of virus transmission? If so, how can this be managed? [Internet] GHHIN; 22 May 2020. Available at: http://www.ghhin.org/heat-and-covid-19/ac-and-ventilation [Accessed 18 September 2020]
22. ECDC. Heating, ventilation and air-conditioning systems in the context of COVID-19. [Internet] Stockholm: ECDC; 22 June 2020. Available at: https://www.ecdc.europa.eu/en/publications-data/heating-ventilation-air-conditioning-systems-covid-19 [Accessed 16 September 2020]
23. REHVA. How to operate HVAC and other building service systems to prevent the spread of the coronavirus (SARS-CoV-2) disease (COVID-19) in workplaces. Brussels: REHVA;

3 August 2020. Available at: https://www.rehva.eu/activities/covid-19-guidance/rehva-covid-19-guidance [Accessed 17 September 2020]

24. IHEEM. Use of Air Conditioning systems (Permanent & Temporary) & Desk Fans during COVID-19 Pandemic. UK: IHEEM, 21 August 2020. Available at: https://www.iheem.org.uk/use-of-air-conditioning-systems-permanent-temporary-desk-fans-during-covid-19-pandemic/ [Accessed 16 October 2020]
25. World Health Organization. Q&A: Ventilation and air conditioning in public spaces and buildings and COVID-19. Geneva: WHO; 29 July 2020. Available at: https://www.who.int/news-room/q-a-detail/q-a-ventilation-and-air-conditioning-in-public-spaces-and-buildings-and-covid-19 [Accessed 17 September 2020]
26. Chan KH, Malik Pereis JS, Lam SY et al (2020) 'The effects of Temperature and Relative Humidity on the Viability of the SARS Coronavirus', Advances in Virology, 2011, Article ID 734690. DOI: 10.1155/2011/734690. Available at: https://www.hindawi.com/journals/av/2011/734690/ [Accessed 21 September 2020]
27. REHVA. Guidance for Schools. Brussels: REHVA; No Date. Available at: https://www.rehva.eu/activities/covid-19-guidance/rehva-covid-19-guidance [Accessed 17 September 2020]
28. CIBSE. CIBSE COVID-19 Ventilation Guidance. UK: London; 23 October 2020. Available at: https://www.cibse.org/knowledge/knowledge-items/detail?id=a0q3Y00000HsaFtQAJ [Accessed on 20 January 2021]