Heating, ventilation and air-conditioning systems in the context of COVID-19

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Scope of this document

Guidance on ventilation of indoor spaces

Target audience

Public health authorities in EU/EEA countries and the UK

Evidence for transmission in closed spaces and the role of heating, ventilation and air-conditioning (HVAC) systems

Heating, ventilation and air-conditioning (HVAC) systems are used to provide comfortable environmental conditions (temperature and humidity) and clean air in indoor settings such as buildings and vehicles. HVAC systems can be configured in a variety of ways, depending on their application and functions of the building/vehicle. Ventilation systems provide clean air by exchanging indoor and outdoor air and filtering. Air-conditioning systems can be part of integrated HVAC systems or stand-alone, providing cooling/warming and dehumidification. Stand-alone systems usually recirculate the air without mixing it with outdoor air.

Poor ventilation in confined indoor spaces is associated with increased transmission of respiratory infections [1]. There have been numerous COVID-19 transmission events associated with closed spaces, including some from pre-symptomatic cases [2-4]. The role of ventilation in preventing COVID-19 transmission is not well-defined (i.e. by preventing dispersal of infectious particles to minimise the risk of transmission, or preventing transfer of an infectious dose to susceptible individuals). COVID-19 is thought to be primarily transmitted via large respiratory droplets, however, an increasing number of outbreak reports implicate the role of aerosols in COVID-19 outbreaks. Aerosols consist of small droplets and droplet nuclei which remain in the air for longer than large droplets [5,6].

Studies indicate that SARS-CoV-2 particles can remain infectious on various materials, as well as in aerosols in indoor environments, with the duration of infectivity depending on temperature and humidity [7]. So far, transmission through fomites has not been documented, but it is considered possible.

Several outbreak investigation reports have shown that COVID-19 transmission can be particularly effective in crowded, confined indoor spaces such as workplaces (offices, factories) and during indoor events - e.g. churches, restaurants, gatherings at ski resorts, parties, shopping centres, worker dormitories, dance classes, cruise ships and vehicles [8]. There are also indications that transmission can be linked to specific activities, such as singing in a choir [9] or during religious services that may be characterised by increased production of respiratory droplets through loud speech and singing.

In a study of 318 outbreaks in China, transmission in all cases except one occurred in indoor spaces [10]. The only case of outdoor transmission identified in this study involved two people. However, outdoor events have also been implicated in the spread of COVID-19, typically those associated with crowds, such as carnival celebrations [11] and football matches [12], highlighting the risk of crowding even at outdoor events. However, exposure in crowded indoor spaces is also very common during such events.

The length of time that people stay in indoor settings appears to be associated with the attack rate. For example, in a 2.5 hour choir practice in Washington, US, there were 32 confirmed and 20 probable secondary COVID-19 cases among 61 participants (85.2%). In an epidemiological investigation at a call centre in South Korea, there was an attack rate of 43.5% among 216 employees on the ninth floor of the call centre, indicating extensive transmission in a crowded indoor workplace environment [13]. Nearly all of the infected employees were sitting on the same side of the ninth floor. There was no obvious relationship between the risk of transmission and the distance from the index case on this side of the 9th floor. The authors also concluded that the length of time people were in contact played the most important role in spreading of COVID-19, since the cases were limited almost exclusively to the ninth floor, despite interaction with colleagues in other settings (such as in elevators and in the lobby).

From the reports published to date, it is not as yet possible to clarify the role of physical proximity and direct contact, and the possibility of indirect transmission through contaminated objects and surfaces, or longer distance transmission through aerosols. In addition, there is a potential for publication bias, with fewer communications of negative findings; and confirmation bias, with published studies re-confirming known science. However, the current body of evidence demonstrates the risk of transmission in crowded indoor settings and the importance of combining bundles of prevention measures.

Several studies have addressed the role of ventilation in COVID-19 outbreaks. Three outbreaks involved an index case that was reported to be pre-symptomatic, and ventilation in an enclosed space, aided by air conditioning.

In a restaurant outbreak in Guangzhou, China, there were 10 cases across three families [14]. They developed symptoms between 26 January and 10 February 2020, having eaten lunch on 23 January at the same restaurant, which is a five-floor building without windows. Their tables were more than a metre apart. The index case was pre-symptomatic, developing a fever and cough that evening. The secondary cases were sitting along the line of airflow generated by the air-conditioning, while diners sitting elsewhere in the restaurant were not infected. The authors of the report attribute transmission to the spread of respiratory droplets carrying SARS-CoV-2 via the airflow generated by the air-conditioning.

The authors of a pre-print manuscript describing two other outbreaks from China in January 2020 attribute air conditioning systems using a re-circulating mode as a probable aid to transmission [15].

The first outbreak was associated with a 150-minute event at a temple. The index case, who had previously visited Wuhan, was pre-symptomatic until the evening after the event. The attack rates in the outbreak were highest among those who shared a 100-minute bus ride with the index case (23 out of 67 passengers; 34%). Passengers sitting closer to the index case did not have a statistically higher risk of COVID-19 than those sitting further away. However, all passengers sitting close to a window remained healthy, with the exception of the passenger sitting next to the index case. This supports the hypothesis that the airflow along the bus facilitated the spread of the virus. In contrast, there were seven COVID-19 cases among 172 other people who attended the same 150-minute temple event, all of whom described having had close contact with the index case.

The second outbreak was associated with a training workshop from 12—14 January in Hangzhou city, Zhejiang province. It had 30 attendees from different cities, who booked hotels individually and did not eat together at the workshop facility. The workshop had four 4-hour group sessions, which were in two closed rooms of 49 square metres and 75 square metres. An automatic timer on the central air conditioners circulated the air in each room for 10 minutes every four hours, using 'an indoor re-circulating mode'. No trainees were known to be symptomatic during the workshop. During the period 16—22 January 2020, 15 of them were diagnosed with COVID-19.

High Efficiency Particulate Air (HEPA) filters have demonstrated good performance with particles of the SARS-Cov-2 virus size (approximately 70–120 nm) and are used in aeroplanes and in healthcare settings. The role of HEPA filters in buildings outside of healthcare settings in preventing transmission of infectious diseases is unclear. A modelling study of the infection risk from SARS-CoV-1, the virus causing SARS, conferred by three types of ventilation systems in relatively large commercial aeroplanes, found that mixing ventilation systems had the highest risk and conventional displacement systems had the lowest risk. The authors recommended personalised ventilation systems for airline cabins, as they were best in maintaining thermal comfort, while also reducing the infection risk [16].

In conclusion, the available evidence indicates that:

- Transmission of COVID-19 commonly occurs in closed indoor spaces.
- There is currently no evidence of human infection with SARS-CoV-2 caused by infectious aerosols distributed through the ventilation system ducts of HVACs. The risk is rated as very low.
- Well-maintained HVAC systems, including air-conditioning units, securely filter large droplets containing SARS-CoV-2. It is possible for COVID-19 aerosols (small droplets and droplet nuclei) to spread through HVAC systems within a building or vehicle and stand-alone air-conditioning units if air is recirculated.
- Air flow generated by air-conditioning units may facilitate the spread of droplets excreted by infected people longer distances within indoor spaces.
- HVAC systems may have a complementary role in decreasing transmission in indoor spaces by increasing the rate of air change, decreasing recirculation of air and increasing the use of outdoor air.

Guidance

Infection control measures with proven evidence for reducing the risk of SARS-CoV-2 transmission should be emphasised. Organisers and administrators responsible for gatherings and critical infrastructure settings should provide guidance material to participants regarding the application of the preventive measures, including:

- Physical distancing
- Meticulous hand hygiene
- Respiratory etiquette
- Appropriate use of face masks, if required for staff, and in areas where physical distancing cannot be maintained due to structural or functional impediments.

Building administrators should maintain heating, ventilation, and air-conditioning systems according to the manufacturer's current instructions, particularly in relation to the cleaning and changing of filters [17]. There is no benefit or need for additional maintenance cycles in connection with COVID-19. Energy-saving settings, such as demand-controlled ventilation controlled by a timer or CO2 detectors, should be avoided. Consideration should be given to extending the operating times of HVACs before and after the regular period [17,18].

Direct air flow should be diverted away from groups of individuals to avoid pathogen dispersion from infected subjects and transmission.

Organisers and administrators responsible for gatherings and critical infrastructure settings should explore options with the assistance of their technical/maintenance teams to avoid the use of air recirculation as much as possible [17,18]. They should consider reviewing their procedures for the use of recirculation in HVAC systems based on information provided by the manufacturer or, if unavailable, seeking advice from the manufacturer.

The minimum number of air exchanges per hour, in accordance with the applicable building regulations, should be ensured at all times. Increasing the number of air exchanges per hour will reduce the risk of transmission in closed spaces. This may be achieved by natural or mechanical ventilation, depending on the setting [4,18,19].

The application of the above guidance should be in accordance with national and local regulations (e.g. building regulations, health and safety regulations) and appropriate to local conditions.

Technical specifications and standards for mechanical ventilation systems to reduce the risk of COVID-19 transmission in indoor spaces still need to be defined on the basis of scientific studies that are tuned to COVID-19 research developments. The technical specifications will need to be defined for categories of room or location type, taking into account the room size, the degree of enclosure and non-mechanical ventilation, and the probable purpose for which the room will be used. Moreover, options should be provided for protected buildings that be subject to engineering modifications. The technical standards should ideally recommend minimum criteria to be met in order for authorities to permit the intended use of an enclosed space.

The technical specifications regarding the logistical arrangement of enclosed spaces, including the physical placement of mechanical ventilation systems, also need to be informed by scientific evidence and technical expertise, so as to minimise the risk of transmission. These specifications will also need to take into account the expected number of users, the types of user and the user activity. For example, in supermarkets, cashiers and customers have different levels of mobility and durations of occupancy. As a general principle, mechanical ventilation should be arranged to minimise the direction of sustained air flow for stationary persons.

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Appendix

Table 1. Retention capacity of different filter types used in HVAC system

Ventilation system	Typical filter type	Retention capacity			
		MERV rating [a)]	Degree of separation [b)]	SARS-CoV-2 containing droplets (> 5µm)	SARS-CoV-2 containing aerosol [c)] (< 5µm)
Specialised HVAC systems (operating theatres, special laboratories)	H13 -14 [DIN EN]	16–20	99.99%	Yes	
HEPA filter	H13 [DIN EN]	16–20	99.95 %	Yes	
HVAC systems for office buildings, churches, cruise ships, etc.	ePM1 [EN ISO]	9–13	>80 %	Yes	No
Standalone air-conditioner (e.g. apartments, shops, restaurants)	- Fiberglass - Polyester/pleated air filters	1–4 8–13	<40% 45%	Yes	No
Pedestal fans	n/a	n/a		No	

a) Minimum Efficiency Reporting Value (MERV), American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE);
b) Minimum separation efficiency for test particles, EN ISO 16890 (particle sizes 0.2 to 1.0 µm, depending on the filter type);
c) Particles, droplet nuclei of different sizes.