Simple summary of ventilation actions to mitigate the risk of COVID-19
SAGE Environment and Modelling Group

The potential for aerosol transmission (1) and the role of ventilation (2) and air cleaning (3) have been previously considered by the SAG Environmental and Modelling Group (EMG). This paper aims to summarise, in an accessible way, why ventilation is important and the key practical steps that could be taken to improve ventilation to mitigate the risk of SARS-CoV-2 transmission. While this paper focuses on ventilation it is important that other measures are maintained too, including distancing, hand hygiene, cleaning, wearing face coverings when appropriate and limiting social interactions.

Why is ventilation important?

The virus that causes COVID-19 is spread through very small aerosols and droplets released in exhaled breath. There is evidence to show that in some cases these aerosols can be carried more than 2m in the air and could cause infection if they are inhaled (1). This is most likely to happen in indoor environments when the ventilation in a room is poor. If people spend sufficient longer periods of time in the room, the virus can build up in air and people can inhale enough of it to cause infection. The risk appears to increase when people are performing activities such as high intensity exercise, singing or loud talking that may cause them to breathe out more aerosols (1,4). The risk is also likely to be higher in places where face coverings or masks are not worn, as these reduce the amount of virus that is emitted into the air (5,6).

Ventilation is also important for human health beyond COVID-19. Studies have shown that good ventilation is associated with improved health, better concentration, higher levels of satisfaction with an environment, lower rates of absence from schools and work, better quality of sleep and reduced exposure to a wide range of air pollutants (7-10).

How are buildings ventilated?

Ventilation is the process of bringing in fresh air from outside and removing indoor air, which may contain pollutants including virus particles.. The method of ventilation will depend on the building.

Naturally ventilated buildings provide ventilation air without using any fans and rely on openings. A level of background ventilation is provided through small openings, typically trickle vents (small vents usually at the top of a window) and sometimes air bricks or grilles. These ensure there is always some airflow so it is important to make sure that the trickle vents are open. However, the flow rate through these can be rather low and cannot be increased, so it is therefore necessary to use other openings such as windows in order to increase ventilation. These are most often operated manually, so will rely on occupants to open and close them.

Mechanically ventilated buildings provide ventilation using fans to move air into and out of rooms. In small spaces and buildings these may be in the room, but larger buildings may use a network of ducts and fans to blow clean air into rooms and/or extract the stale air. This can vary from a simple system such as a bathroom extract in a house, to a very complex and sophisticated system in a large commercial building. Small systems may be controlled by the occupants (using controls or switches in the space), but larger systems may be centrally or automatically controlled. Mechanical ventilation has the advantage that, providing it is working correctly, it provides more consistent ventilation, but it may be more costly, requires energy to operate the system and needs to be properly maintained.

Many buildings have a mixture of natural and mechanical ventilation, with different systems in different spaces.

What is the ventilation rate?

The ventilation rate refers to the volume of air that is provided to a room over a period of time, and is often stated in buildings guidance as recommended values. Some guidance recommends ventilation rates in terms of litres per second per person – a value of 10 l/s/person is recommended in many guides as a suitable value for most commercial buildings (11). The evidence so far suggests that COVID-19 transmission risk increases when the ventilation rate is very low; values in the range 1-3 l/s/person have been cited for a number of super-spreading events (2).

Some documents state ventilation rates in terms of air changes per hour, which is a measure of the air flow rate relative to the room size. This measure can be useful to understand how quickly the ventilation removes contaminants from the air. A ventilation rate of 6 air changes per hour would mean that 6 times the volume of the room is provided every hour by the ventilation system. However this doesn't mean that all the air is changed 6 times in the hour – the new air mixes with the air that is already in the room causing dilution with time. At 6 air changes per hour, 95% of the contaminants in the air would be removed in 30 minutes.

What measures can be taken in the home?

Regular ventilation in the home is widely recognised as important to keep both people and the home healthy. Many people will find they have to balance ventilation with thermal comfort, especially in the winter months where the home relies on opening windows for ventilation.

For COVID-19, it is most important to ventilate spaces if someone in the home has the virus as this can help prevent transmission to other household members. Providing additional ventilation when there are visitors in the home and just after they leave is also likely to reduce risks in case they are infected.

Ventilation can be provided by making sure that any background ventilation devices are opened, and opening the windows will be the simplest method of increasing ventilation for most people. Simple actions such as ensuring background trickle vents are left open and avoiding blocking up vents can ensure there is constant background ventilation. Wider openings will provide more air flow, but this doesn't mean that a window must be wide open all the time. Ventilation rates through openings are determined by the wind speed and temperature difference between indoors and outdoors (12), and in colder weather opening the window a small amount can result in ventilation that is almost as effective as opening the window fully in the summer. If windows have openings at both high and low levels (such as sash windows) using just the top opening can be helpful in colder weather because incoming cold air will mix with warm room air and help temper cold draughts. In warmer weather when cold draughts are not a potential problem then using both the lower and upper openings will help provide even more airflow. If noise or security is a problem, or it is uncomfortable to have windows and vents open for long periods of time, or there are concerns over the costs of heating, regular airing of a room by opening windows for shorter periods of time can be effective at reducing the concentrations of virus in the air (14).

Ventilation can also be increased by leaving extract fans in bathrooms, toilets and kitchen areas running for longer than usual, with the door closed, after someone has used the room. In homes with mechanical ventilation systems it is important to ensure these are operating correctly, and the filters are changed regularly. The boost mode can be used increase ventilation when there are visitors or if someone in the home is sick. If someone is isolating in a room, keeping the door closed and having the vents and the window open slightly may help to keep this room separate from the rest of the home.

What is important in workplace or in public spaces?

The ventilation in workplace or public spaces should be considered as an important part of the COVID risk assessment (14). In larger buildings that have mechanical ventilation systems, the facilities management team will normally look after the ventilation. Workplaces should be able to provide employees with guidance on how systems should be operated if there are user controls. In many buildings settings have been adjusted where possible, following recommendations by CIBSE (15) and REHVA (16), to ensure that sufficient outside air ventilation is provided.

In workplaces that rely on natural ventilation it is important to keep vents open and regularly open windows especially in spaces that are shared with other people. Opening windows (and sometimes doors as well) intermittently, for example for 10 minutes every hour, can be effective at reducing the risk from virus in the air. If this is combined with a break where occupants leave the room (e.g. in meeting rooms or class rooms) this is even more effective (17).

Detailed guidance is provided for workplaces and public buildings by the Chartered Institution of Building Services Engineers (CIBSE) that provides information about different ventilation systems and explains approaches to assessing and managing ventilation for COVID (16).

Does air conditioning pose a risk?

Air conditioning refers to changing the temperature and humidity of the air, usually cooling the air when it is too hot for people to be comfortable. Air conditioning is sometimes connected to the ventilation system, but many rooms have a stand-alone air conditioner which just recirculates the room air. Recirculating air conditioners may pose a risk if they are operated in a room which has a very low outdoor flow rate – the air conditioner can make occupants feel comfortable, but masks the poor air quality and can allow any virus to build up in the air. A number of studies have linked transmission to recirculating air conditioners, with the high velocities created by these units potentially allowing larger viral aerosols to remain airborne over longer distances (18,19). It is possible that directional flow from desk fans could have a similar effect.

How can you determine whether a space is well ventilated?

It can be very difficult to work out how places are ventilated, but there are some clues. If there are vents (and sometimes ducts) on the ceiling or high on the walls then it is very likely that a place has mechanical ventilation. Some spaces like theatres often have these vents in the floor or under seats. Schools often have ventilation units mounted under windows (20). If a space has doors or windows open, and no sign of other vents, then it is most likely to be naturally ventilated. If a space feels stuffy or is smelly then it is likely to have a low ventilation rate. Any room with openings that can be used by occupants can be naturally ventilated.

Spending a very short period of time in a poorly ventilated space is unlikely to pose a significant risk, especially if people are wearing face coverings. However if you are in a poorly ventilated room with a lot of people for a long time, this is likely to be a much higher risk environment for transmission.

Can ventilation be measured?

It is very difficult to accurately measure ventilation, but in some spaces it is possible to use carbon dioxide (CO_2) meters to estimate the effectiveness of the ventilation. We all exhale CO_2 when we breathe, and the concentration that is in the air in a room depends on the number of people in the room and the ventilation rate.

Most buildings guidance recommends that CO_2 concentrations should be maintained below 1000ppm for effective ventilation. Previous analysis suggests that a CO_2 concentration that regularly exceeds 1500ppm indicates that a room is likely to be poorly ventilated and may pose a greater risk for COVID-19 (2). Extra precautions are recommended when aerosol emitting activities such as high intensity exercise, singing and loud prolonged speech take place, with the CO_2 level maintained below 800ppm (4). A CO_2 meter can be used to identify spaces where ventilation is poor, but they are less effective at showing good ventilation.

Estimating ventilation using CO_2 meters needs to be done with care as it is possible to get false or inaccurate readings. Measurements should always be taken when the space is occupied with the number of people who would normally be in the space, and it is a good idea to measure for at least 1 hour to get reliable readings. It is only possible to use CO_2 meters if there are no other sources of CO_2 – a gas hob or a gas/solid fuel fire generates CO_2 and may give false readings. Measurement is much more reliable in spaces where there are higher numbers of people and measurement needs to be made in away from open windows or vents. A meter that uses infra-red gas sensors (NDIR) is more likely to give an accurate reading than other types of sensors.

Does temperature and humidity matter?

There is evidence from laboratory studies that shows that the virus that causes COVID-19 survives better in colder and drier conditions (21) and there is evidence from other viruses that relative humidity is a particularly important parameter (22). It is possible that humidity may also impact on the human physiological response too, with greater susceptibility in drier environments experienced in UK winters (23,24). In most indoor spaces the ventilation rate is likely to be more important to the risk of transmission than the effect of temperature and humidity. However, maintaining spaces at comfortable temperatures and maintaining the humidity between 40% and 60% RH indoors may help to further reduce risks.

Are air cleaners an effective solution?

Air cleaners were recently reviewed in detail by SAGE EMG (3) and may be suitable for spaces where there is insufficient ventilation and the ventilation can't be improved. There is currently very little evidence that air cleaners are an effective control to prevent COVID-19, however the principles of air cleaning suggests that they may be useful in some cases.

There are a vast number of different air cleaners on the market and it can be difficult to choose one that is effective. Air cleaners that are based on filtration (with a HEPA filter) are likely to be most effective, and those that include ultra-violet lamps may also work. It is a good idea to avoid any devices that produce ozone or other chemicals as these may be a respiratory irritant. It is also important to consider how much air the device can clean; a small device in a large room will have very little effect. Noise is also an important consideration, particularly for larger devices with a higher fan speed which can be noisy. Air cleaners should never be used as a substitute for ventilation.

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