Updated Advice on Ventilation and Aerosol Transmission Mitigation

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Introduction

This paper is a summary update on the mitigation of aerosol transmission in the light of the SAGE Environmental Modelling Group's evidence (30 September 2020)(1) and new CIBSE guidance (23 October 2020)(2).

Key summary points:

These outputs are in line with SG AG previous recommendations on ventilation with some additional guidance in support of those principles we outlined in our paper previously:

- The EMG highlights that far-field aerosol transmission depends on the interplay of several factors. This includes the viral emission rate, the ventilation rate, the duration of exposure, the environmental conditions and occupancy. These all need to be taken into account when assessing risk and implementing mitigation.
- Ventilation is one part of a hierarchy of risk controls approach to be put in place alongside other source control measures as it is one part of a complex interplay of non-pharmaceutical interventions
- Specialist ventilation engineers may be needed to give an expert ventilation assessment and advice on mitigation
- The SG AG flagged the need for research on the real-world utility of HEPA filters in COVID-19 risk mitigation, something echoed by the EMG as they call for research broadly on the real-world application of air cleaning and filtration technologies and the development of best practice guidance.
- Whilst the EMG suggest high-level steps for achieving good ventilation, a more detailed list of recommendations can be found in the October 23rd CIBSE guidance and further guidance is being developed for specific settings

In addition, use of CO2 monitors and UV light are discussed which were not a focus of SG AG's previous advice and the evidence presented indicates these are areas for further research at this point:

- The EMG and CIBSE recommend that poor ventilation can be effectively measured in multi-occupant spaces using CO2 levels (e.g. via nondispersive infrared (NDIR) CO2 sensors, CIBSE advise against equivalent CO2 sensors). A low CO2 level cannot necessarily be relied on as an indicator that ventilation is sufficient for risk mitigation in low occupancy or large volume spaces.
- CO2 monitoring is unlikely to be a reliable proxy for transmission risk in most environments. There is some preliminary research which suggests that in spaces where the same group of people regularly attend (e.g. offices, schools), continuous monitoring may be possible to use as a transmission risk indicator, this requires more research.
- The EMG paper touches on Ultra-Violet Germicidal Irradiation (UVGI) devices as a possible option for air cleaning, but with no dedicated evidence review and note there is a need for better real-world data.
- The COVID-19 Nosocomial Review Group (CNRG) are currently looking at evidence for UVGI devices in healthcare.

EMG recommendations

Ventilation

The EMG state the importance of far-field (>2m) aerosol transmission remains unknown, but evidence suggests it is a risk in poorly ventilated spaces. This remains consistent with the SG Advisory Group's previous advice statement (August 27), and continues to support ventilation as an important way to mitigate this risk.

They flag models which suggest that under steady state well-mixed conditions for the same duration, exposure to aerosols approximately halves when the ventilation rate is doubled. Consequently, and consistent with SG AG advice, is that good ventilation should be central to risk mitigation strategies for all multi-occupant public buildings and workplaces. More explicit than previous statements, is the recommendation that this should include identification of how a space is ventilated and articulation of a strategy to ensure adequate ventilation.

The ventilation strategy should at least achieve current standards for the minimum ventilation rate for the space over the occupancy period (for most workplaces and public environments this equates to a flow rate of 8-10 l/s/person based on design occupancy not on any temporary reduced occupancy, although guidance for some environments allows for lower flow rates of 5 l/s/person). This may pose an issue for some buildings (particularly older ones), where systems may not have been designed to meet current standards – they may need additional mitigations.

In most settings where such minimums are met, the EMG suggests the risk of aerosol transmission is likely to be low. Ventilation rates beyond this should ensure that thermal comfort is not significantly compromised. Indeed, they advise that in most buildings maintaining comfortable temperatures and humidity above 40%RH is likely to be beneficial for reducing risk as virus survival decreases with increasing temperature and humidity.

In a similar vein, they note that negative consequences of changes to ventilation, including financial, energy use, noise, security and health and wellbeing impacts from exposure to pollutants, must be considered. They also take the practical step of recommending the need to identify where financial or technical support will be necessary to facilitate individuals and organisations taking steps to improve ventilation while dealing with potential negative consequences around health and comfort.

Hierarchy of risk controls

The EMG highlights that far-field aerosol transmission depends on the interplay of several factors. This includes the viral emission rate, the ventilation rate, the duration of exposure, the environmental conditions and occupancy. These all need to be taken into account when assessing risk and implementing mitigation. Ventilation is one part of a hierarchy of risk controls approach to be put in place alongside other source control measures, from restricting certain activities to implementing face coverings. This mirrors the stance of CIBSE as well as previous SG AG advice that states ventilation is not an isolated solution, but part of a complex interplay of nonpharmaceutical interventions (NPIs)(3).

Ventilation will not address other transmission routes and attention must always be paid to core control measures such as handwashing, physical distancing, mask use and cleaning of surfaces. Such NPIs will be also be important in mitigating aerosol transmission, for instance where there is enhanced aerosol generation (e.g. speaking loudly, singing, aerobic activity), measures such as mask wearing for audiences, and restricting duration/group sizes should be included.

Expert input

Concurring with the SG AG's previous advice, the EMG notes that engineers may be needed to give an expert assessment and advice on mitigation. This will be all the more important in specialist settings such as healthcare and chilled food processing with specific environmental challenges and dedicated building regulations to be considered. It is recommended that those preparing proposals for amended ventilation provision undertake full public consultation with ventilation experts to ensure that guidance is technically correct and reflects current global good practice.

Advice for occupants

Due to the complexity of variation in buildings and their uses, there is not a simple approach to ventilation requirements that everyone can be advised to follow.
Nevertheless, both the SG AG's advice and the EMG recognise that effective ventilation is closely tied to user behaviour and therefore highlight the need for clear messaging on the importance of and achievement of good ventilation. For the public, the EMG recommend the development of a simple guide on ventilation that is coproduced between ventilation experts and lay individuals, and supported by public health campaigns.

Research areas

The SG AG flagged the need for research on the real-world utility of HEPA filters in COVID-19 risk mitigation, something echoed by the EMG as they call for research broadly on the real-world application of air cleaning and filtration technologies and the development of best practice guidance. EMG also highlight the potential interplay between temperature/humidity and ventilation and call for additional analysis of the potential compounding of transmission risk in low temperature environments with ventilation issues, such as in chilled food processing where aerosol transmission has been indicated as a potential factor in outbreaks.

In addition to calling for research, the EMG also reflect on the need to embed infectious disease transmission considerations into building ventilation regulations and associated statutory guidance in the long-term.

CIBSE guidance

Whilst the EMG suggest high-level steps for achieving good ventilation, a more detailed list of recommendations can be found in the October 23rd CIBSE guidance (2). This advice is intended primarily for buildings with largely sedentary occupants (e.g. schools and offices). CIBSE are currently working with other institutions to

provide specialist guidance for specialist buildings, such as healthcare or food production venues, and for indoor spaces with activities that involve higher aerosol creation (e.g. singing, loud talking, aerobic exercise).

Ventilation

Detailed guidance is offered for a range of circumstances, from rooms with single sided natural ventilation to roof turrets. However, the fundamental principle is to "increase the air supply and exhaust ventilation, supplying as much outside air as is reasonably possible."

Recirculation

In keeping with past ECDC advice (4) noted by the SG AG's last advice statement, recirculation should be avoided where possible. However, it should be considered if it is the only way of maintaining adequate provision of outside air (10 l/s/person for typical offices) to occupied spaces without triggering undue thermal discomfort.

Winter and natural ventilation

Agreeing with the SG AG's previous advice that ventilation provision in winter will need to be considered, CIBSE and the EMG highlight that ventilation must be mindful of thermal comfort. Based on preliminary models from historical school ventilation data, EMG predict reductions in ventilation rates in winter (without interventions) could increase far-field airborne transmission risk in winter months by 25-35% compared to conditions in September.

CIBSE state that in the colder months, environmental factors mean windows and vents do not need to be opened as wide to achieve ventilation in naturally ventilated spaces. Whilst it is better to open all the windows or vents a small amount, even opening just the high-level vents can enable more mixing of the outside air with air in the space without causing so much thermal discomfort. Importantly, where natural ventilation openings are the only mechanism for delivering outside air into a space, they should not be completely closed when the spaces are occupied.

Possible mitigation options for any thermal discomfort include increased heating, moving room furniture so occupants aren't in a direct draught and relaxing dress codes to enable wearing warmer clothes.

Room air cleaners

Air cleaners need to have filters capable of filtering out virus particles (e.g. HEPA filters) and to have a substantial proportion of room air pass through them. However, such systems usually have limited airflow through them and consequently, the floor area they can effectively serve is small (typically less than 10 m2). Positioning of air cleaners is key.

Room air cleaners do not remove CO2, odours, gaseous pollutants and volatile organic compounds from the air.

HEPA filters in mechanical ventilation

HEPA filters were a point of discussion in the SG AG's previous advice, with the view at time that organisations should locally risk assess the need for the addition of air cleaning devices, such as HEPA filters, in spaces which cannot be effectively ventilated and no alternate can be found. It was also acknowledged that retrofitting HEPA in HVAC systems involves major refurbishment (5) and time so their widespread use was likely to face significant practical hurdles. The recent EMG advice supports such practicality barriers.

As outside air is not seen as a high-risk source of SARS-CoV-2 viral aerosols CIBSE advise there is no need to replace existing filters with other filter types. For recirculation in centralised air handling units, HEPA filters (or others which filter out virus particles) should only be used in systems that have been designed for use with higher efficiency filters. Otherwise there is a high risk of air leakage due to the increased resistance of the unit, which defeats the purpose the filter. In addition, they note the increased resistance of the filter may also reduce the rate of supply of outside air and have other unintended consequences. All of which demonstrates the importance of seeking expert input prior to modifying installed filters.

New focus: CO2 monitors

The EMG and CIBSE recommend that poor ventilation can be effectively measured in multi-occupant spaces using CO2 levels (e.g. via nondispersive infrared (NDIR) CO2 sensors, CIBSE advise against equivalent CO2 sensors). They also agree that a low CO2 level cannot necessarily be relied on as an indicator that ventilation is sufficient for risk mitigation in low occupancy or large volume spaces.

Both advise that regularly used multi-occupant spaces that are identified as poorly ventilated (below 5 l/s/person or above 1500ppm CO2) should be prioritised for improvement. In addition, spaces liable to see higher aerosol generation (due to activities such as singing, loud speech, aerobic activity) should aim to ensure ventilation is sufficient to maintain CO2 concentrations below 800ppm (typically 10-15 l/s/person).

In addition, CO2 is not advocated as a good indicator for transmission risk where there is additional air cleaning (filtration or UVC), which removes the virus but not CO2, or in spaces where there are other CO2 sources present (e.g. combustion devices). Indeed, the EMG suggests continuous CO2 monitoring is unlikely to be a reliable proxy for transmission risk in most environments. Nevertheless (with the caveat of low confidence) they say that preliminary research suggests that in spaces where the same group of people regularly attend (e.g. offices, schools), continuous monitoring may be possible to use as a transmission risk indicator.

New focus: Ultra-Violet Germicidal Irradiation

The EMG paper touches on Ultra-Violet Germicidal Irradiation (UVGI) devices as a possible option for air cleaning, but with no dedicated evidence review or strong advocacy in its favour. They simply acknowledgement that it may be an option but note practical and safety considerations. The EMG do state that there is a need for better

real-world data and the COVID-19 Nosocomial Review Group (CNRG) are currently looking at evidence for UVGI devices in healthcare.

CIBSE provide far more detail on UVGI. They advise that whilst there is significant emerging evidence of its efficacy to deactivate SARS-CoV-2, there are ongoing uncertainties about factors affecting UV performance (including dosage and exposure time), and how these might depend upon the ventilation rate of outside air. In addition, they note there are important practical considerations in its deployment such as room and system configuration, air flow, distribution, humidity, and safety. The latter arises because UV-C is invisible to the human eye, but has the potential to cause damage to human tissue, such as corneal inflammation and reddening of the skin akin to sunburn. CIBSE point out the importance of proper installation in avoiding such issues.

Overall, CIBSE say where there is adequate ventilation the cost benefit of using UV may be limited. They go on to provide more precise advice about different types of UVGI:

Upper room UVGI: UV light in the upper air of a room to deactivate viral material, relying on mixing in the space. They say this can be installed at low cost (by an expert) and may reduce the risk of transmission, particularly in poorly ventilated spaces. A review by the International Commission on Illumination concluded that upper-room UVGI air disinfection could be safely used without significant long-term risk.

CIBSE's positive stance on upper room UVGI is supported even more strongly by Eadie (Ninewells) and Wood (St Andrews) in their summary report to SG. They advocate in favour of "the immediate installation of the safe and proven upper room 254nm UVGI in indoor public spaces with low air changes per hour and/or recirculated air."(6). In that report they also seek funding to assess the safety and efficacy of 222 nm full room illumination, which is a relatively novel technology which they say is used in hospitals throughout Japan and some businesses in the US. They argue it may be faster at inactivating micro-organisms than upper room UVGI.

In duct systems: UV-C lamps in the air ducts of mechanical ventilation systems. These may be effective where it is possible to manage duct velocity and radiation levels to achieve a high level of disinfection within the treated section of the system. Need to check noise.

Portable units: Installed in a room, use UV-C lamps mounted inside an enclosure, with a fan to draw air through the irradiated zone. They only disinfect the air that passes through the device. These may be effective, but careful attention is needed to size them. Need to check noise.

They note the importance of paying close attention to safe maintenance, accredited testing certification and appropriateness for the intended purpose. As EMG did, CIBSE emphasise the need for real world application research on these devices.

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