British Council for Offices
Briefing Note
February 2021

THOUGHTS ON VENTILATION DESIGN AND OPERATION POST COVID-19

Introduction

The SARS-CoV-2 (COVID-19) pandemic has caused a worldwide upheaval in the way we work and live. The infection is caused by a coronavirus, in this case COVID-19, one of a family of viruses that affect the respiratory tract, causing severe acute respiratory syndrome (SARS).

Most respiratory virus transmission occurs from large, infected droplets produced by coughing, sneezing and breathing near another person. This understanding has led to social distancing being the cornerstone of public health advice, allowing for the infective particles to fall to the ground, thus reducing viral concentrations and transmission of disease.

However, there is growing evidence that microdroplets small enough to remain suspended in the air can infect people at greater distances. In July 2020, over 200 scientists signed an open letter calling for international bodies to recognise the potential for airborne spread of COVID-19, as they were concerned that people would not be fully protected by adhering solely to social distancing recommendations. This led to the acknowledgement of airborne transmission by the US Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO), and an increased focus on the ventilation of indoor spaces.

Poorly ventilated indoor spaces have been linked with COVID-19 superspreader events, highlighting the need for good ventilation in office environments. Good ventilation is an important factor in mitigating the risk of aerosol transmission indoors, where people may be in close contact, potentially for long periods of time.

Source: Allan Swart | Alamy Stock Photo

A number of professional bodies have produced guidelines on the ventilation of indoor spaces in response to the pandemic. Guidance has been published by several organisations, including the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the Chartered Institution of Building Services Engineers (CIBSE), the Air Infiltration and Ventilation Centre (AIVC) and the Building Services Research and Information Association (BSRIA), and these bodies are regularly updating their information bases relevant to infection risk. One of the most comprehensive responses has been from the Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA), and this briefing note relies largely on its recommendations.

This briefing note highlights the important role played by ventilation in offices in contributing to the health and wellbeing of occupants, and in minimising the risk of airborne disease transmission.

Context

Pathogens like COVID-19 can be 3–200 microns in size, but most are in the 5–15 micron range. The virus nucleus is surrounded by water and a protein layer to form a droplet, which can be deposited on surfaces and remain there for hours or days.

Larger droplets quickly fall to the floor, but smaller droplets (<5 microns) can spread around a space in the form of an aerosol, leading to airborne transmission. It is this route which ventilation can help to attenuate, but the use of masks and face shields, cleaning hands and social distancing remain crucial measures in preventing transmission of the disease.

Aerosols can be transmitted over long distances, beyond 2 metres, and here ventilation becomes especially important. Their half-life can be an hour or more, and studies have shown that they can remain a viable source of infection for more than 3 hours.

The importance of good ventilation

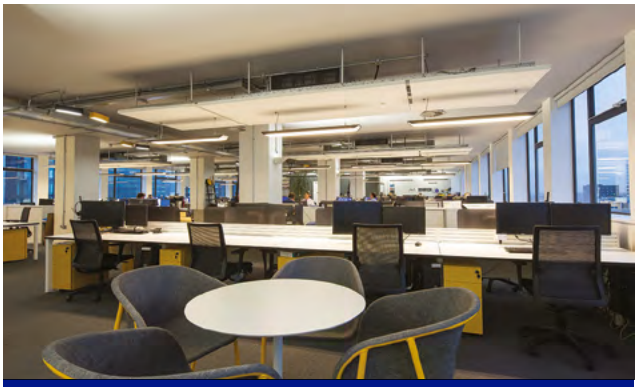
Ventilation is needed in office buildings to remove stale, used air and replace it with fresh outdoor air. It helps to maintain good internal air quality by providing oxygen for metabolism, diluting pollutants such as carbon dioxide (CO_2), volatile organic compounds (VOCs), particulates and odours, besides controlling humidity. Good ventilation provides comfortable conditions and maintains the health and wellbeing of the occupants, and it is these principles that have underpinned the design and operation of ventilation systems for the workplace.

Even before the advent of COVID-19, there was a growing recognition of the link between good ventilation and improved health and mental performance, which has been reflected in BCO guidance. The 2019 BCO *Guide to Specification*[1] recommends the use of outdoor ventilation rates above the minimum statutory standards, and this is discussed in more detail later in this briefing note.

Office buildings can be ventilated in the following ways:

- naturally ventilated, through windows and openings
- mechanically ventilated, using fans and ducted systems
- mixed mode, using a combination of natural and mechanical ventilation.

All these methods can provide a well-ventilated indoor environment and help reduce the risk of infection by airborne virus transmission, but the selection of a system for a given office space requires a clear understanding of the ways in which ventilation interacts with people and the spaces they occupy.



Cundall, Manchester
Courtesy of Workspace Design

Where office designs have followed best practice guidance, they will have good ventilation. However, across the sector there are many examples of poorly ventilated buildings that do not follow best practice. It is these offices where there is no dedicated delivery of outdoor air that need to be addressed urgently.

Reducing the risk of airborne transmission

Ventilation is only one element in the hierarchy of controls helping to protect people from the risk of infection. The first action taken in a pandemic is to impose management strategies that reduce the risk of transmission by all the recognised infection pathways, of which airborne particles is one.

The management strategies include the government's instruction to work from home where it is possible to do so, and to employ multiple infection-control measures to minimise the risk for those who cannot. In the case of a respiratory illness like COVID-19, this will require social distancing in the workplace, which typically limits the occupancy of offices to half or less of their usual capacity, thus effectively increasing the outdoor air provision per person provided by existing ventilation systems.

When these restrictions are relaxed, employers need to prepare for a safe return of staff to the office. This involves a duty of care to protect people from harm, including taking reasonable precautions to protect those using these environments from COVID-19. A risk assessment should be carried out that considers any work activity or situations which might increase the risk of transmission of the virus.

The risk assessment for COVID-19 follows the same basic principles as any other workplace risk assessment, and the Health and Safety Executive (HSE) has produced some helpful guidance on this.[2]

Ventilation effectiveness

For ventilation to be effective, both the quantity of air and the patterns of air distribution are important. There are three key elements of ventilation that influence the estimated risk of airborne infection: ventilation rate, airflow direction and airflow pattern (Figure 1).

Ventilation rate

Studies have shown that increasing the ventilation rate can reduce the risk of long-range airborne virus transmission. A higher ventilation rate dilutes the contaminated air in an indoor space more rapidly, and decreases the risk of cross-infection.

A number of outbreaks in confined indoor crowded spaces, such as offices, shops and restaurants, indicate that virus transmission is particularly efficient in indoor environments.[4] In a study of 318 COVID-19 outbreaks with three or more cases of transmission, in all except one case the virus transmission occurred in an indoor space.[5]

Work by REHVA[6] has shown that:

- The probability of infection increases as occupancy time increases. It also depends on the state of health of the individual, and so can vary greatly.
- The floor area per person is important, as more volumetric space around the person helps to dilute the droplet density through dispersion.
- Energy consumption is always a consideration, but adequate ventilation should be the primary concern.

Besides the ventilation rate itself, the probability of infection depends on how well the offices are cleaned, occupant behaviour, the use of masks and face shields, hand washing and social distancing. In general, larger spaces with low occupancy densities are better than confined or smaller spaces where people are closer together.

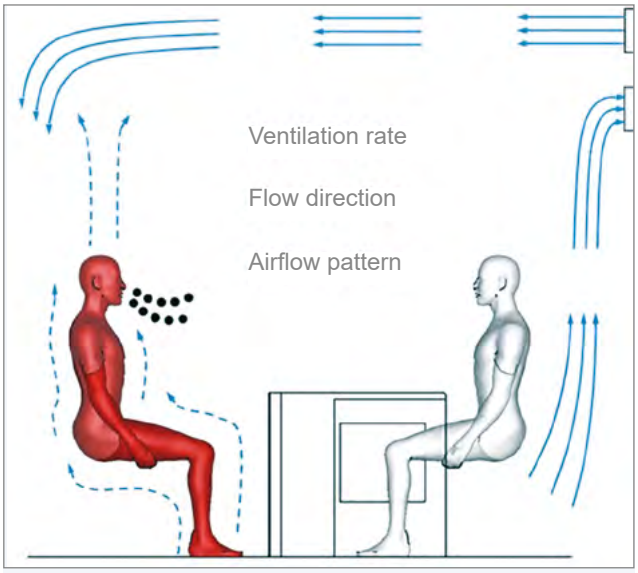


Figure 1
Three key elements of ventilation affecting the airborne transmission of viruses

Airflow direction

Typically, in commercial offices, the controlled direction of airflow is designed to create a neutral or slightly positive pressure on office floors and a negative pressure in toilets. This is intended to prevent ingress of pollutants into the occupied spaces. The pressure differences across office zones and between rooms are generally not controlled.

Current office ventilation design strategies focus on ensuring a good supply of outdoor air to the occupants, which is evenly distributed across a space, but less attention is paid to the extract air paths, which are often located at a few specific points on a floor plate. This becomes an important consideration in a cellularised space to ensure adequate distribution of supply and extract air. To be effective outdoor air needs to reach the breathing zone.

Airflow pattern

Indoor airflow is complex and depends on the position of ventilation inlets and outlets, windows and doors, and on convective flows generated by heat emitted by people and equipment. Other variables, such as people moving or talking, doors opening or closing, or changes in outdoor conditions for naturally ventilated buildings, affect these flows, and consequently influence the effectiveness of the ventilation system.

Ventilation, whether driven by wind or the stack effect within the building, or by mechanical systems, works in one of two main modes: mixing and displacement.

Mixing ventilation

Mixing ventilation is the most often used approach in offices. Ventilation inlets and outlets are placed to keep the air in a space well mixed so that temperature and contaminant concentrations are kept at a uniform level. Indoor air quality is maintained through the dilution of contaminants, and the CO_2 level, which relates to exhaled air from occupants in the occupied space, can be a useful indirect indicator of ventilation effectiveness.

Displacement ventilation

Displacement ventilation has inlet vents at low level, creating a cooler lower zone and a warmer upper zone. The goal is to minimise mixing within the lower occupied zone, allowing the heat and contaminants to rise to the top of the space, where they are extracted through upper-level vents.

The simplistic view is that exhaled air is entrained in the rising plume around a person and can be extracted at high level. However, rapidly exhaled breath, as occurs during, speaking, laughing, singing, coughing, sneezing, etc., may exit the plume and travel horizontally across the space. Care is needed to avoid stratification between the two zones, known as the 'lock-up effect', which refers to the possible trapping of exhaled breath below the warm ceiling layer.

CO_2 concentration as a measure of ventilation effectiveness

CO_2 is a relatively easy to measure proxy for indoor pollutants emitted by people, and correlates with metabolic activity. High levels may cause occupants to grow drowsy, to get headaches or to function at lower cognitive capacity. Outdoor CO_2 levels are usually in the range 350–450 ppm.

The BCO and REHVA advise that good practice for offices is to maintain CO_2 levels below 1000 ppm (Figure 2).

It is important to remember that CO_2 concentration can be used only as an indicator of potential infection risk because there are many other factors to consider; for example, an infected person spreads more viral particles as their respiratory rate increases. CO_2 production also increases at the same time, especially with increasing physical activity, but it does not take into the account the use of voice. Virus release may increase a hundred-fold as the volume of voice increases. Risk of infection also increases with exposure time and the viral load that an individual is exposed to, and is influenced by the individual's immune system response.

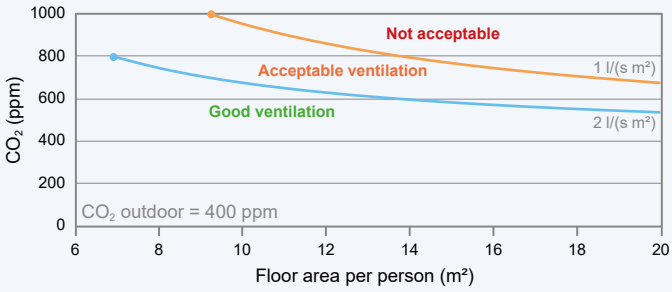


Figure 2
The dependence of CO_2 concentration (absolute values that include outdoor concentration) on ventilation rate and occupancy in offices
Source: REHVA[6]

Where CO_2 levels are used to control ventilation, it is important to take into account the room characteristics, such as delay in the concentration measurement to achieve a steady-state condition, sensor location (away from outdoor air sources, within the occupied zone, etc.) and air distribution. Also, CO_2 concentration is only one measure of indoor air quality, and other parameters that should be considered include total VOCs, particulates, humidity and temperature.

Humidity

> "Transmission is greater in dry air, infectivity is higher in dry air, and the ability of a human being to fight infection is impaired."
>
> *Dr Stephanie Taylor, Harvard Medical School*

Low levels of humidity can affect virus transmission in three ways:[7]

- there is a reduced effectiveness of the mucus membrane defence system to fight off respiratory infection
- the virus survives better in low-humidity environments
- there are impacts on the droplet evaporation rate, increasing the production of aerosol particles.

It is recommended that relative humidity should be kept above 40%.

Air-cleaning technology

Used in conjunction with good ventilation, air-cleaning technology can be used to remove viral particles from the air and, potentially, reduce infection risk. Air-cleaning devices are not a substitute for ventilation, and should never be used as a reason to reduce outdoor ventilation rates.

The effectiveness of air-cleaning devices depends on multiple factors, including the underlying technology, the design of the equipment and its location. The principal technologies being suggested for use in office applications are high-efficiency particulate arresting (HEPA) fibrous filters, ultraviolet germicidal irradiation (UVGI) and ionisation. These are discussed in more detail in the supplementary information to this briefing note (available on the BCO website[8]).

Some of the science and understanding of the application of these technologies in this context is still at an early stage, and there is limited research to verify their efficacy against COVID-19. It is therefore important to take a precautionary approach, and use only equipment that is suitable for the intended application and that will not result in unintended exposure and alternative health risks in the future.

Useful guidance is given in a publication by SAGE-EMG.[9]

BCO guidance on ventilation

The current UK Building Regulations[10] require a minimum outdoor ventilation rate of 10 l/s per person for offices.

The 2019 BCO *Guide to Specification*[1] recommends the following ventilation provisions for office spaces and indoor air quality:

- minimum outdoor air supply of 12 l/s per person
- additional 10% outdoor air allowance to provide flexibility in the fit-out of space to accommodate localised higher occupancy densities
- internal CO_2 levels should be maintained below 1,000 ppm
- ventilation plant inlets and exhausts should be separated by at least 10 m, and where possible by 20 m or more, from external sources of pollution.

Taken together, the 12 l/s per person plus the 10% allowance equates to a building occupancy-based provision of 13.2 l/s per person.

In the light of the learnings from the COVID-19 pandemic, the BCO Technical Affairs Committee (TAC) has considered the need to revise this guidance, the focus being on the outdoor air rate per person allowance and whether this should be increased.

Having reviewed the available research and guidance from bodies such as REHVA, CIBSE and ASHRAE, and the management strategies regarding office use that apply during a pandemic, the TAC has concluded that there is no immediate case to radically change the current guidance, but this situation will be reviewed as more research becomes available. However, as a first step, the TAC has decided to align the minimum best practice guidance for new buildings with BS ISO 17772-1:2017[11] Category II, which requires 14 l/s per person. The online version of the 2019 BCO *Guide to Specification*[1] will be updated to reflect this, with the 12 l/s per person + 10% allowance being replaced by a *new recommended minimum allowance of 14 l/s per person*.

UVGI system, Alphaa UV
Copyright Alphaa UV
Source: https://www.alfaauv.com/products/uvgi-air-disinfection

Previous BCO briefing papers on COVID-19 relating to office design and washrooms have stated a preference for dedicated supply and extract ventilation to toilet areas over extract-only systems. Currently, the BCO *Guide* gives no specific guidelines for shared transient occupancy spaces in office buildings, such as reception areas, lift lobbies, corridors and staircases, and in many instances these spaces are not currently provided with any dedicated outdoor air ventilation provision. Best practice would suggest that this needs to change, and the BCO will be updating its guidance to recommend that designers should consider the supply of outdoor air into these spaces to *maintain CO_2 levels below 1000 ppm in the breathing zone*.

It is noted that improving the ventilation of staircases provides a greater challenge, but with the greater use of stairways being promoted to reduce reliance on lifts and improve the health of building occupants, their use will increase in future. Alongside the cosmetic enhancements to encourage their use, it should be ensured that staircases are adequately ventilated.

Existing system operation

A good starting point is to review the capability of the currently installed ventilation system, in particular the outdoor air allowance per person, and to then ensure that it is operating at its optimum level.

The focus on ventilation in offices needs to extend beyond the design and specification of the systems used. Care needs to be taken to ensure that the systems are properly installed, commissioned and maintained. Systems should continue to operate effectively throughout their life and as the use and layout of the spaces they serve change with the requirements of the building users.

The facilities management team should monitor indoor air quality to ensure the ventilation systems are performing correctly in line with the design intent, and that the building is clean and well maintained.

Repeated post-occupancy feedback surveys of facilities management staff and building users should be conducted to identify poorly ventilated spaces, which may give rise to:

- a rising number of complaints of fatigue or headache
- flu-like symptoms out of season
- dizzy spells and nausea
- complaints of odours or stale air
- stuffy environments.

This is also an area where air-quality monitoring may prove useful.

REHVA provides comprehensive practical guidance for the operation of building services systems during a period of pandemic infection. The advice covers 15 main items, most of which relate directly or indirectly to the part played by ventilation to minimise the risk of airborne transmission of disease. The recommendations can be found in the supplementary information to this briefing note.[8]

Key considerations for future design

In addition to providing a well-ventilated environment for office users and adhering to minimum regulatory standards, designers will also need to consider the effectiveness of the solutions in maintaining a healthy indoor environment and minimising airborne infection transmission.

Some key steps to consider in future designs include:

- Levels of outdoor air ventilation should be, as a minimum, in line with the new BCO guidance.
- All occupied and transient spaces should be provided with outdoor air.
- Attention should be paid to the design of high-occupancy spaces such as conference areas, social hubs and meeting rooms, to ensure that adequate outdoor air supply and exhaust air ventilation is provided.
- Air-supply diffusers should be carefully selected to ensure good mixing, and to limit airflow distances and terminal velocities within the occupied space.
- Supply and extract systems are both important in defining airflow distribution, so the location of supply inlets and extract outlets must be carefully considered.
- Exhaust air points should be sited at high level.
- The supply air should be conditioned to maintain humidity levels above 40% RH.
- Sensible cooling at terminal air-conditioning units should be prioritised so that coils and internal surfaces do not get wet, keeping them clean and preventing the build-up of fungi, mould and bacteria.
- The use of air recirculation in central ventilation plant should be avoided.
- There should be adequate separation of central air-handling unit intake and discharge locations to avoid unintended recirculation of air.
- Localised recirculation of air within an occupied space to maintain thermal comfort conditions is acceptable provided that the appropriate level of outdoor air is supplied to the space (fan coil units, induction units, chilled beams, fan convectors, etc.).
- Systems must be properly maintained and their performance monitored.
- Where natural and mixed-mode ventilation strategies are used, careful consideration is needed to ensure that they continue to provide adequate ventilation under all external conditions, while maintaining a comfortable working environment.
- Facilities management professionals should be provided with training and educational resources as health and wellbeing permeate our thinking and the priorities in operating buildings evolve.

In future, there will be much greater interest in understanding the mechanisms of good ventilation in offices, and their effectiveness in limiting virus transmission. One of the methods used to quantify infection risk from airborne transmission in indoor spaces is a mathematical modelling technique known as the Wells–Riley model.[12] This model is commonly used to test the effectiveness of ventilation strategies in clinical settings, where the risk of infection is much higher than in offices, but could be used by designers for cases where more detailed analysis is desired. Details of the technique are given in the supplementary information to this briefing note.[8]

Energy use

The virus causing COVID-19 can be spread by airborne transmission.[13] Poorly ventilated places are considered to be high risk, and, on a precautionary principle, current advice is for buildings to be as well ventilated as possible.[14] There is a clear tension between this requirement and the ability to maintain thermal comfort in buildings without excessive energy consumption.

Natural ventilation is seen as a good way of saving energy, and it can be helpful in diluting virus droplets in small spaces. However, the dilution achieved depends on how the occupants use openable windows, the airflow path through the building and how that flow path interacts with internal doorways and objects.[15] Purging rooms with fresh air at intervals is advised. The WHO guidelines[15] also recognise the limitations of natural ventilation because of the fluctuation in the ventilation rate due to variable driving forces, and the difficulty in achieving a consistent airflow direction and a comfortable internal temperature in extreme climates.

In large office spaces, it is more likely that mechanical ventilation or air-conditioning will be installed. These systems rely on sophisticated control systems and energy recovery to maintain comfortable conditions and minimise energy consumption.

Conclusion

We are still at an early stage in understanding what the full impact of COVID-19 will be on how we use our offices in the future, the altered expectations of occupants and the potential changes in workplace regulation. All these issues may affect the design of ventilation systems. The BCO will continue to monitor the situation closely, and will update its guidance in line with the latest research and emerging best practice advice.

In the meantime, ventilation has taken its place alongside 'hands–face–space' in the UK government's latest public health campaign, after research has shown that being in a well-ventilated space can reduce infection from airborne particles by over 70%.[16]

Notes

This is the fourth in a series of briefing notes produced by the BCO Technical Affairs Committee to provide a COVID-19 information resource for the property industry.[17–19] These publications will be linked to the 2019 BCO *Guide to Specification*,[1] the online version of which will be updated to provide more guidance in this area to inform the industry response to the learnings from the pandemic and its impact on the workplace.

Supplementary information and an extensive bibliography related to this briefing note are available on the BCO website.[8] ■

References

1. BCO (2019) *Guide to Specification*. Available at: https://www.bco.org.uk/Research/Publications/BCOGuideToSpec2019.aspx (accessed 11 February 2021).
2. HSE (2020) *Making your Workplace COVID-secure During the Coronavirus Pandemic*. Available at: https://www.hse.gov.uk/coronavirus/working-safely/index.htm (accessed 11 February 2021).
3. Hua Qian and Xiaohong Zheng (2018) Ventilation control for airborne transmission of human exhaled bio-aerosols in buildings. *Journal of Thoracic Disease* **10**(Suppl 19): S2295–S2304. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6072925 (accessed 11 February 2021).
4. Leclerc QJ, Fuller NM, Knight LE, Funk S and Knight GM (2020) What settings have been linked to SARS-CoV-2 transmission clusters? *Wellcome Open Research* **5**: 83. Available at: https://wellcomeopenresearch.org/articles/5-83 (accessed 11 February 2021).
5. Hua Qian, Te Miao, Li Liu, Xiaohong Zheng, Danting Luo, Yuguo Li (2020) Indoor transmission of SARS-CoV-2. *Indoor Air*, 31 October. Available at: https://doi.org/10.1111/ina.12766 (accessed 11 February 2021).
6. REHVA (2020) *REVA COVID 19 Guidance*, version 4. Available at: https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_guidance_document_V4_09122020.pdf (accessed 11 February 2021).
7. McQuigge M (2020) Researchers look at how humidity can impact virus transmission. *The Canadian Press*, 3 April. Available at: https://www.theglobeandmail.com/canada/article-researchers-look-at-how-humidity-can-impact-virus-transmission (accessed 11 February 2021).
8. BCO (2021). *Thoughts on Ventilation Design and Operation Post COVID-19. Supplementary Information and Bibliography*. Available at: https://www.bco.org.uk/Research/Publications/Thoughts_on_Ventilation_Design_and_Operation_Post_COVID-19_Supplementary_Material_and_Bibliography.aspx (accessed 11 February 2021).
9. SAGE-EMG (2020) *Potential Application of Air Cleaning Devices and Personal Decontamination to Manage Transmission of COVID-19*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/939173/S0867_EMG_Potential_application_of_air_cleaning_devices_and_personal_decontamination_to_manage_transmission_of_COVID-19.pdf (accessed 11 February 2021).
10. HM Government (2010) *Building Regulations. Ventilation: Approved Document F (2010 edition incorporating 2010 and 2013 amendments)*. Available at: https://www.gov.uk/government/publications/ventilation-approved-document-f (accessed 11 February 2021).
11. British Standards Institution (2017) BS ISO 17772-1:2017. Energy performance of buildings. Indoor environmental quality. Indoor environmental input parameters for the design and assessment of energy performance of buildings. BSI, London.
12. Noakes CJ and Sleigh PA (2008) Applying the Wells–Riley equation to the risk of airborne infection in hospital environments: the importance of stochastic and proximity effects. In: *Indoor Air 2008: The 11th International Conference on Indoor Air Quality and Clean Indoor Air, Copenhagen, Denmark*. Available at: https://eprints.whiterose.ac.uk/7702/1/Noakes-indoorair2008.pdf (accessed 11 February 2021).
13. Bhagat RK, Wykes MSD, Dalziel SB and Linden PF (2020) Effects of ventilation on the indoor spread of COVID-19. *Journal of Fluid Mechanics* **903**(Nov): F1. Available at: https://doi.org/10.1017/jfm.2020.720 (accessed 11 February 2021).
14. WHO (2020) *Country & Technical Guidance – Coronavirus Disease (COVID-19)*. Available at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance (accessed 11 February 2021).
15. WHO (2009) *Natural Ventilation for Infection Control in Health-care Settings*. WHO Guidelines. Available at: https://www.who.int/water_sanitation_health/publications/natural_ventilation/en (accessed 11 February 2021).
16. HM Government (2020) *New Film Shows Importance of Ventilation to Reduce Spread of COVID-19*. Press release. Available at: https://www.gov.uk/government/news/new-film-shows-importance-of-ventilation-to-reduce-spread-of-covid-19 (accessed 11 February 2021).

17. BCO (2020) *Thoughts on Lift and Escalator Design and Operation after COVID-19*. Available at: https://www.bco.org.uk/Research/Publications/Thoughts_on_Lift_and_Escalator_Design_and_Operation_After_Covid-19.aspx (accessed 11 February 2021).

18. BCO (2020) *Thoughts on Office Design and Operation after COVID-19*. Available at: https://www.bco.org.uk/Research/Publications/Thoughts_on_Office_Design_and_Operation_After_Covid-19.aspx (accessed 11 February 2021).

19. BCO (2020) *Thoughts on Washroom Design and Operation Post COVID-19*. Available at: http://www.bco.org.uk/Research/Publications/Thoughts_on_Washroom_Design_and_Operation_Post_COVID-19.aspx (accessed 11 February 2021).

CITATION

Derek Clements-Croome and Neil Pennell (2020) *Thoughts on Ventilation Design and Operation Post COVID-19*. https://www.bco.org.uk/Research/Publications/Thoughts_on_Ventilation_Design_and_Operation_Post_COVID-19.aspx

DISCLAIMER

This document is based on the best available evidence and knowledge of dealing with general viral infection outbreaks. The BCO excludes any liability for any direct, indirect or incidental damages or any other damages resulting from or connected with the use of the information presented in this document. Specific advice should always be sought from an appropriately qualified professional for individual cases.

ABOUT THE BCO

The BCO is the UK's leading forum for the discussion and debate of issues affecting the office sector. Established in 1990, its membership base comprises organisations involved in creating, acquiring or occupying office space, including architects, lawyers, surveyors, financial institutions and public agencies.

The BCO recognises that offices don't just house companies, they hold people and so what goes on inside them is paramount to workplace wellbeing.

ABOUT THE AUTHORS

The Technical Affairs Committee (TAC) is the voice for the BCO on technical aspects of the built environment. It is responsible for the organisation's globally recognised best practice guides on office specification and fit-out, and acts as a forum for new ideas and discussion to address the technical challenges facing the workplace sector. This briefing note has been based on a technical paper prepared for the BCO TAC by Derek Clements-Croome, Professor Emeritus at University of Reading and Visiting Professor at Queen Mary University London. Derek is a member of the TAC and a key contributor to the 2019 BCO *Guide to Specification*. Derek was also one of the 239 signatories to the letter to WHO, and a contributor to the WHO report *Natural Ventilation for Infection Control in Health-care Settings* (2009).

ACKNOWLEDGEMENTS

The BCO would like to thank the following members of the BCO Technical Affairs Committee for their insightful contributions to and peer review of the final publication:

Neil Pennell, Chair, BCO Technical Affairs Committee; Head of Design Innovation and Property Solutions, Landsec

Peter Williams, Technical Advisor to Stanhope

Peter Stocks, Partner, Cundall