AIRBODS: Airborne Infection Reduction through Building Operation and Design for SARS-CoV-2

Benjamin Jones

University Of Nottingham
University Park
Nottingham, NG7 2UH, UK

SUMMARY

The Airborne Infection Reduction through Building Operation and Design for SARS-CoV-2 (AIRBODS) project aim is to deliver guidance on the ventilation operation and future design of non-domestic buildings and to quantify the risk of, and reduce the transmission of SARS-CoV-2 in buildings. It is doing this through experimentation, computer simulation and fieldwork supporting the guidance and tools.

KEYWORDS

SARS-CoV-2, COVID-19, Ventilation, Transmission, Metrics, Measurement, Relative Exposure Index

1 BACKGROUND

Airborne Infection Reduction through Building Operation and Design for SARS-CoV-2 (AIRBODS) is an 18 month UK Research and Innovation funded research programme. It comprises seven research partner organisations and includes many of the contributors to the UK's COVID-19 ventilation guidance (UK Government; 2020, 2021). The project runs until the end of 2022. Project objectives are defined by the work packages described in Table 1.

The need to better understand airborne transmission of viruses such as SARS-CoV-2 within the built environment is now undeniable. It is well recognized that indoor locations, particularly when poorly ventilated, can increase the risk of infection transmission. The project is using experimentation, simulation, analysis and fieldwork to explore the physical and biological fate and transport of aerosols carrying virus particles under various scenarios. The AIRBODS team is developing guidance on how to design and operate buildings to minimize the risk of airborne transmission acknowledging any implications on energy use and thermal comfort (especially in winter) along with indoor air quality and occupancy levels as a combined consideration. The Chartered Institution of Building Services Engineers are a project partner and work is being disseminated via their Emerging room Lockdown advice documents (CISBE 2021). The project will also provide guidance on the application of current simulation and analysis tools to more accurately estimate the benefits of possible mitigation measures that could be used to reduce airborne transmission now and in the future.

Key questions being considered include: what do we mean by 'poor' and 'sufficient' ventilation? How does ventilation and air movement affect transmission? What's an acceptable balance between conflicting drivers such as air change rate and energy consumption? To what extent can we use indoor air properties such as CO_2, air temperature and relative humidity as proxies for airborne transmission risk?

Table 1: AIRBODS research objectives

Work package	Overview of work
1. Experiments	Use class 2 environmentally controlled chambers to provide experimental data on the transport and distribution of aerosols.
2. Modelling	Use simulation and analysis incorporating three key areas: i. Use analytical methods to develop an understanding of the physical processes involved in aerosol transport; in particular to consider the correlation between temperature, relative humidity and the behaviour and evaporation of aerosols. ii. Compare different computational fluid dynamics (CFD) modelling techniques, e.g. URANS and LES, and inform a Relative Exposure Index. The work will also underpin design and operation guidance for practicing engineers wishing to use CFD for other scenarios and geometries. iii. Augment an existing indoor environment Relative Exposure Index model using the mathematical models generated by the analytical models and outputs from the CFD simulations. Explore individual and population risks.
3. Field studies	It is now recognised that COVID-19 is airborne indoors and so indoor air quality and high standards of ventilation play a crucial part in enabling society to adapt to a *new normal* safely. Field studies are undertaken to understand the real-world air quality and ventilation of buildings in a wide variety of settings, to understand primarily where exhaled breath builds up indoors and why. It is recognised that CO_2 does not directly correlate to the concentration of the virus in the air, but correlates to exhaled breath in indoor air. Exhaled breath might accumulate because of poor ventilation for the space, high occupancy for the space (temporarily or consistently), or, more often, both. The field studies entail: • Air Quality measurement: CO_2, temperature, relative humidity in a large number of internal spaces of various sizes with different ventilation schemes. • Airflow measurements, for validation of CFD simulations • Analysis of ventilation systems and their effectiveness And in some settings, also: • Microbiological sampling of surfaces and air; PCRs for SARS-CoV-2 • Crowd movement and analysis of social grouping The AIRBODS team has contributed to the UK Government's Events Research Programme by carrying out the environmental study of a wide range of venues and events, between April and July 2021. This study helped to build the evidence base on air quality at a wide range of venues and events and improved understanding of potential risks of airborne transmission at events, and their mitigations. The study enabled the UK to re-open events in culture, music and sports industries whilst improving safety at these events. Analysis of the data is ongoing.
4. Design guidance and dissemination	Use the lessons learnt from Work Packages 1, 2 and 3 to inform practical guidance on responses to SARS-CoV-2 for at least the building typologies investigated, and provide prediction tools and modelling advice.

The impact of the COVID pandemic on the lives and livelihoods of everyone around the world has been substantial. There will be many repercussions in the coming years as part of the endeavour to design and operate safer environments within which we live and work. Some guidance has already been given on the opening up of shared indoor spaces, essential for economic recovery and mental wellbeing, as part of an emerging evidence base. The development of validated biophysics models within this project with a built environment context, together with better wellbeing standards supporting better indoor air quality and productivity, can only be further supported by an increased industry and public focus on ventilation and understanding of airborne transmission risk.

1.1 Measurements

AIRBODS contributed to the UK Government's Events Research Programme (UK Government, 2022) by carrying out the environmental study of a wide range of venues and events, between April and July 2021. This study helped to build the evidence base on air quality at a wide range of venues and events and improved understanding of potential risks of airborne transmission at events, and their mitigations. The study enabled the UK to re-open events in culture, music and sports industries whilst improving safety at these events. Analysis of the data is ongoing.

1.2 Risk metrics

Uncertainty in the parameters required to estimate probability of becoming infected in an indoor space is so significant that it has little utility. We established a Relative Exposure Index (REI) that reduces the need to understand the infection dose probability but is nevertheless a function of space volume, viral emission rate, exposure time, occupant respiratory activity, and room ventilation (Jones *et al.* 2021). This metric is used to consider personal risk in a space. However, the number of occupants in a space influences the risk of airborne transmission of SARS-CoV-2 because the likelihood of having infectious and susceptible people both correlate with the number of occupants. Therefore, a Proportion of the Population Infected (PPI) metric has been developed to consider how indoor spaces can be manipulated to minimize the transmission risk to a wider population of people (Iddon *et al.* 2022).

2 ACKNOWLEDGEMENTS

AIRBODS is financed by the Engineering and Physical Sciences Research Council (EP/W002779/1).

Principal Investigator: Malcolm Cook; *Co-Investigators:* Zulfikar Adamu, Lena Ciric, Liora Malki-Epshtein, Shaun Fitzgerald, Abigail Hathway, Benjamin Jones, Thorsten Steosser; *Consultants:* Darren Woolf, Patricia Pino; *Research Associates:* Filipa Adzic, Melissa Canales, Paul Cropper, Arthur Hajaali, Chris Iddon, Rupy Matharu, Murat Mustafa, Majeed Oladokun, Ben Roberts, Elpida Vangeloglou, Oliver Wild.

Research Partners: Loughborough University, University of Cambridge, University College London, The University of Sheffield, University of Nottingham, London South Bank University, Wirth Research Ltd.

3 REFERENCES

CIBSE (2022) Emerging from Lockdown. https://www.cibse.org/knowledge-research/knowledge-resources/engineering-guidance/emerging-from-lockdown-cibse-covid-19-guidance

Iddon C, Jones B, Sharpe P, Cevik M, Fitzgerald S. (2022) A population framework for predicting the proportion of people infected by the far-field airborne transmission of SARS-CoV-2 indoors. *Building and Environment. 221:109309*

Jones B, Sharpe P, Iddon C, Hathway EA, Noakes CJ, Fitzgerald S. (2021) Modelling uncertainty in the relative risk of exposure to the SARS-CoV-2 virus by airborne aerosol transmission in well mixed indoor air. *Building and Environment.191:10761*

UK Government. (2020) Role of ventilation in controlling SARS-CoV-2 transmission. Scientific Advisory Group for Emergencies Environmental Modelling Group. https://www.gov.uk/government/publications/emg-role-of-ventilation-in-controlling-sars-cov-2-transmission-30-september-2020

UK Government. (2021) Application of CO_2 monitoring as an approach to managing ventilation to mitigate SARS-CoV-2 transmission, 27 May 2021. Scientific Advisory Group for Emergencies Environmental Modelling Group. https://www.gov.uk/government/publications/emg-and-spi-b-application-of-co2-monitoring-as-an-approach-to-managing-ventilation-to-mitigate-sars-cov-2-transmission-27-may-2021

UK Government. (2022) Events Research Programme: Phase II and III findings. Department for Digital, Culture, Media & Sport. https://www.gov.uk/government/publications/events-research-programme-phase-ii-and-iii-findings