Witness Name:

Professor Catherine Noakes.

Statement No: 1

Exhibits: CN/01 – CN/44

Dated: 24 September 2025

UK COVID-19 INQUIRY – MODULE 8

WITNESS STATEMENT OF PROFESSOR CATHERINE NOAKES

I, **Professor Catherine Noakes**, of the School of Civil Engineering at the University of Leeds, Woodhouse Lane, Leeds, LS2 9JT will say as follows:

1: Introduction

1.1. I make this statement pursuant to the UK Covid-19 Inquiry's Rule 9 request of 13 August 2025.

1.2. The matters I set out within this statement are within my own knowledge save for where I state otherwise. Where I refer to facts not within my own knowledge, I will provide the source for those facts to the best of my knowledge. The contents of this statement are to the best of my knowledge and belief both true and correct.

1.3. This statement sets out my expertise, my contribution to advice and research to support understanding the transmission and mitigation of the SARS-COV-2 virus ('the virus') in schools during and following the pandemic, and my views on future approaches for managing pandemic risks in schools and other similar settings. This statement has been prepared in response to a very short notice request and the content is therefore time constrained. Where it is appropriate and feasible to do so, I have provided supporting evidence in the form of publicly available papers and other documents.

2: Background Expertise

2.1. I am currently a Professor of Environmental Engineering in the School of Civil Engineering, and the Pro-Dean for Research and Innovation in the Faculty of Engineering and Physical Sciences, at the University of Leeds.

2.2. I am a chartered mechanical engineer with a background in fluid dynamics. I am a Fellow of the Royal Academy of Engineering, Fellow of the Institution of Mechanical Engineers, Fellow of the Institute of Healthcare Engineering and Estate Management, and Honorary Fellow of the Chartered Institution of Building Services Engineers. Internationally I am a Fellow of the International Society for Indoor Air Quality.

2.3. For 25 years my research has focused on environmental transmission of disease and exposure to air pollution within the built environment, with a focus on exposure to pathogens in air and on surfaces as well as the role of engineering approaches (ventilation, air cleaning and disinfection technology) and behavioural and management responses to mitigating transmission. These studies have included modelling the indoor environment and its interaction with pathogens, modelling exposure to microorganisms in air and on surfaces, laboratory experiments measuring the indoor environment including ventilation parameters and airborne microorganisms, and real-world studies in a number of settings including hospitals and schools to measure indoor air parameters.

2.4. By way of a limited explanation, fluid dynamics is the study of how liquids and gasses behave, using mathematical, experimental and computational techniques. The principles of fluid dynamics can be applied to study a wide range of problems, from the weather and climate in our atmosphere through to blood flow in the human body. With respect to transmission of infectious respiratory disease, fluid dynamics can play a role in understanding how virus carrying liquid particles are formed in the respiratory system and released through the mouth and nose into the environment. Fluid dynamics can also provide an understanding of how air moves in buildings to evaluate the role that ventilation plays in exposing people to pathogens in air. Fluid dynamics cannot on its own be used to analyse disease transmission and needs to be applied alongside information from many other sources as discussed in this statement.

2.5. I was involved in the COVID-19 response in a number of ways including: as a participant of the Scientific Advisory Group for Emergencies ('SAGE'); chair of the SAGE sub-group Environment and Modelling Group ('EMG'); participant in several other SAGE sub-groups; carrying out research studies with collaborators in the UK and internationally, including studies that have directly involved and informed policy makers including the Department for Education ('DfE'); engagement with a number of other advisory and working groups led by different organisations; engagement with the media both through support to official government communications and as an individual expert.

3: Role in SAGE relevant to Module 8 and Engagement with DfE

3.1. Within SAGE and across all groups I provided expertise relating to evidence on transmission of the virus and mitigation strategies. This involved drawing from my own research experience, published scientific literature worldwide (pre and during pandemic), knowledge from other groups in the UK and ongoing research studies worldwide.

3.2. My primary input was as co-chair of the EMG sub-group. The EMG focused on environmental and behavioural interventions, often called Non-Pharmaceutical Interventions ('NPIs') rather than vaccines or clinical treatment. However, we considered interventions in the context of pharmaceutical strategies like the vaccine roll out particularly where there were impacts on transmission. Mitigation approaches within context were around hand and surface hygiene, physical distancing, masks and face coverings, ventilation and air cleaning, environmental conditions such as temperature and humidity, duration of exposure, design and use of spaces. Larger scale restrictions such as school closures, work from home or bubbles were typically within the remit of the Scientific Pandemic Infections Group on Modelling ('SPI-M') as their epidemic models enabled these to be evaluated at a population scale. However, the EMG worked collaboratively with both SPI-M and the Scientific Pandemic Insights Group on Behaviour ('SPI-B') on a number of papers where we considered options for a range of measures in different settings.

3.3. As well as providing leadership to the EMG, I provided technical expertise on the emission of the virus from respiratory sources, the dispersion of the virus in different environments, and the factors that influenced exposure to the virus through inhalation, direct exposure to droplets and indirect exposure through contaminated surfaces (fomites). I provided knowledge of the built environment and factors relating to building design and operation, as well as the interface with human behaviour. This advice was largely agnostic to the environments, however in some papers particular considerations relating to the design of the environment and/or the behaviour or vulnerability of particular occupants were highlighted for certain settings.

3.4. Through my co-chair role I also provided connecting expertise to work with others across SAGE sub-groups to consider the complexities, uncertainties and trade-offs associated with different strategies. Much of the information and advice which I, and others in the EMG, provided supported the practical guidance that was issued by government departments to enable both the public and those who led organisations to understand how the virus was transmitted, carry out risk assessments and implement measures in different settings.

3.5. I was a participant in the Children, Schools and Education Task and Finish Working Group ('CTFG'), which convened on a number of occasions between April 2020 and February 2022. I was not involved in every meeting, but joined the group when commissions required input around the physical school environment, routes of transmission and approaches to mitigation. In that role, I led a connected pair of papers focused on transmission risks and mitigations in higher and further education on 3rd September 2020 (Principles for managing SARS-CoV-2 transmission associated with further education, Principles for managing SARS-CoV-2 transmission associated with higher education) [CN/01 – INQ000573954 & CN/02 – INQ000075804], and contributed to papers on 8th July 2020 (TFC: Risks associated with the reopening of education settings) and 10th February 2021 (TFC: COVID-19 in higher education settings) [CN/03 – INQ000074935 & CN/04 – INQ000192115].

3.6. Alongside my SAGE activities I provided advice to the DfE on an ad-hoc basis relating to transmission and ventilation. These activities drew on the evidence from SAGE papers and the research projects summarised in section 4 of this statement and focused on providing practical explanations and advice around strategies to ventilate schools, the potential for using Carbon Dioxide (CO_2) monitoring, and the potential for using air cleaning technologies. My involvement with DfE included engagements with individuals in the engineering and science teams, reviewing guidance documents, presenting at a senior stakeholder meeting and webinars for civil servants to explain transmission and ventilation, and recording some short social media videos to support the use of CO_2 monitoring. All these activities were unpaid. My input focused on scientific evidence and engineering advice and although this may have influenced their strategy (see below) I was not involved in any decision making around investment programmes or aspects such as tender evaluation for framework partners for technology (e.g. CO_2 monitors, air cleaners) that were provided to schools.

4: Role in Relevant Research Projects

4.1. In this section I have briefly summarised my involvement in research projects relevant to transmission in schools in the UK that were carried out during and following the pandemic.

PROTECT National Core Study – CIVOS project

4.2. The PROTECT National Core Study on Transmission and the Environment was a £21 million programme that ran between 2020 and 2023 led by Professor Andrew Curran at the Health and Safety Executive ('HSE') involving, as far as I recall, 37 projects and over 200 researchers. It was funded as one of six national core studies supported directly by HM government. PROTECT was conceived in early summer 2020 after recognising the lack of robust data on transmission, particularly around where and how transmission was happening and the environmental factors that affect it. It was recognised that addressing these questions required a coordinated effort that considered the virus, environment and human behaviour together through an interdisciplinary approach. The programme had six core themes which overlapped. I led 'theme 2', focusing on understanding the physical mechanisms of transmission, modelling transmission and mitigations at a local scale (between people in the same location) and understanding ventilation mitigations in real work environments.

4.3. As part of the PROTECT National Core Study I was a Co-Investigator in a short project, called 'Changes In the Ventilation Of Schools when monitoring CO_2' (CIVOS), to evaluate the use of CO_2 monitors in schools to understand ventilation. The CIVOS study was led by Imperial College with the University of Leeds and the UK Health Security Agency ('UKHSA') and was carried out in four naturally ventilated schools (2 primary, 2 secondary) in Northern England. Phase 1 involved the installation of research project sensors to measure CO_2, temperature and humidity (supported by DfE and the Department of Health and Social Care ('DHSC') test and trace) which provided a remote data feed on conditions in 40 classrooms. Phase 2 then considered the school response to the DfE supply of CO_2 monitors to schools and used focus groups to assess whether ventilation training and the provision of indicator displays influenced school staff being able to better balance ventilation and comfort.

4.4. CIVOS monitored data showed seasonal variations and significant variations between schools and between classrooms in the same school. Ventilation rates were typically lower in colder weather (indicated by higher CO_2), however the study showed variations between similarly cold periods suggesting that there may be difference in behaviours over the measurement period. The study demonstrated both the feasibility of remote monitoring but also the challenge in interpreting data from measurements. These findings were published in an academic journal paper [CN/05 - INQ000653295].

4.5. CIVOS evaluation of ventilation understanding and behaviours showed a positive engagement with visual display CO_2 monitors though suggested that engagement dropped over time and the devices were not always continuously utilised. Staff in schools reported taking protective behaviours to try to improve ventilation but indicated barriers including windows not opening, thermal comfort and concerns around noise and safeguarding. The CIVOS phase 2 study, which has not been published, also showed challenges with engaging schools in research. School staff are substantially overloaded, and engaging in surveys and focus groups on ventilation is not a high priority for schools.

4.6. The outcomes from the CIVOS study together with work on Co-TRACE (see paragraph 4.12 below) supported the DfE decision to provide CO_2 monitors to all schools. As of 24th June 2022, 386,699 CO_2 monitors had been provided to state-funded education settings in England [CN/06 - INQ000542957] , and by 2023 all state-funded education settings in England had received CO_2 monitors [CN/07 - INQ000653297].

Class-ACT study

4.7. The Class-ACT (Air Cleaning Technologies) study, 2021-22 was a DHSC funded project (£1.85M) on air cleaning interventions in schools to mitigate infection transmission. The project was led by Bradford Teaching Hospitals/University of Leeds with Leeds Beckett University, Queen Mary University London and Imperial College. I was Co-investigator on this project and provided expert input on ventilation and transmission. Funding was via the COVID-19 test and trace innovation team in DHSC and was then managed by UKHSA with input from DfE.

4.8. A key part of Class-ACT was a randomised cluster study carried out with 31 primary schools in the Bradford area. 10 schools were allocated HEPA (High Efficiency Particulate Air)-filter air cleaners, 10 UV-C (Ultraviolet light) based air cleaners and the remaining 11 were a control group with no intervention. Air quality parameters (CO_2, temperature, humidity, particles) were measured in every classroom, and illness absence was recorded. Data was analysed between September 2021 and April 2022 (when COVID-19 restrictions were lifted). The Class-ACT study also undertook supporting analysis including an acoustics survey, evaluation of filter performance, evaluation of UV-C exposure levels, and computational fluid dynamics modelling of airflow and infectious particles in classrooms.

4.9. The study provided both data and practical insights in to implementing air cleaners in schools. Schools with HEPA-filter devices showed reduction in particles in the air (this is as expected and is general air quality not COVID-19 specific) and a lower number of sessions missed through illness as a proportion of sessions attended. Testing of pupils was not carried out, so it is not possible to be certain that all the illness was

COVID-19, however this was the main infection circulating at the time. Although the intervention was effective, some schools in both the control group and the HEPA-filter group had occasional large outbreaks. A significant delay related to guidance and regulation on the use of UV-C devices in schools meant that we could not switch on UV-C devices for several months. We therefore did not manage to assess their impact on illness absence, although gained some insights into practicalities around installation. These are discussed later in this statement.

4.10. The evidence from Class-ACT was shared regularly throughout the project with DfE and UKHSA, and, after analysis, with other policy stakeholders, for example Hertfordshire Council who have implemented an air cleaner scheme in some of their schools. I believe that the findings directly influenced the DfE decision to launch their scheme to provide air cleaners in schools aimed at those with the worst ventilation, as well as their current web-based guidance which includes the use of air cleaners [CN/07 - INQ000653297] As of 24th June 2022, 8,026 air cleaning units had been provided to state-funded education settings in England [CN/06 - INQ000542957].

4.11. Key practical learning from Class-ACT was shared with schools through two articles in TES (formerly known as the Times Educational Supplement) which I co-authored, providing broad guidance on the importance of ventilation [CN/08 - INQ000653256] and the practical application of air cleaners [CN-09 – INQ000653257]. The study protocol is published [CN/10 - INQ000653258] and a brief summary of the practical findings and some results have also been presented at academic and stakeholder conferences. This includes the Royal College of Paediatrics and Child Health ('RCPCH') annual meeting in 2023 [CN/11 - INQ000653298] and a World Health Organization ('WHO') indoor air event (September 2023), which was subsequently reported by the New Scientist [CN/12 - INQ000653259]. A peer reviewed paper has been published on modelling the energy performance vs air quality and infection risk performance of HEPA-filter air cleaners [CN/13 - INQ000653260] A paper on the illness absence results is in the process of publication, but this has been delayed due to the long journal peer review processes to be followed. The CHILI project (see 4.14) plans to undertake further analysis of the Class-ACT data.

Other studies

4.12. The Co-TRACE study, led by Cambridge University and Imperial College and funded through the UK Research and Innovation ('UKRI') rapid pandemic funding developed transmission risk models which were applied to school environments and provided practical web-based guidance and information based on research evidence [CN/14 –

INQ000653261]. Although I was not part of the Co-TRACE project team, I was a co-author on two risk modelling studies aligned to the project [CN/15 – INQ000653262 and CN/16 – INQ000653263] and contributed to developing some of the web-based guidance and videos.

4.13. Schools Air Quality Monitoring for Health and Education ('SAMHE') led by Imperial College built on the learning from Co-TRACE and CIVOS and deployed air quality monitoring to schools through a citizen science approach. While the focus of SAMHE is much wider than infection transmission, the study has provided highly valuable information on ventilation and air quality at a national scale [CN/17 – INQ000653264]. I was part of the project advisory board for SAMHE.

4.14. Child and adolescent Health Impacts of Learning Indoor environments under net zero (CHILI) is a recently funded UKRI and National Institute for Health and Care Research ('NIHR') programme (2025-2030) led by University College London ('UCL') with Imperial College, Leeds University, York University, Swansea University and UKHSA [CN/18 – INQ000653265]. The project aims to assess how adapting schools for energy efficiency affects the indoor environment and health of children. The project will explore aspects such as ventilation and air cleaning, as well as changes to the building fabric, and will use a combination of environmental monitoring data, mathematical modelling, health data, citizen science, toxicology and qualitative analysis. I am a co-investigator in this project.

5: Understanding of Transmission and Mitigation and Relevance to Schools

5.1. In this section I give a brief explanation of the routes of transmission and the implications for infection mitigation and set out the specific considerations for schools that may be different to other settings. A more in-depth discussion on transmission and mitigation, including how evidence evolved in the pandemic is in my Module 2 statement [CN/19 - INQ000236261]

5.2. At the outset of the pandemic guidance worldwide focused on transmission through touching eyes and nose via contamination on hands/surfaces, as well as close-range exposure to large droplets that were assumed to land on mucous membranes. As such advice, including to schools, focused on reducing risk through hand hygiene, cleaning and physical distance as primary mitigation measures. By summer 2020 several large outbreaks had raised the prospect that airborne transmission was important for the transmission of COVID-19. Airborne transmission happens when small particles (typically less than 5-10 micron in diameter but sometimes larger) are inhaled directly and deposit within the respiratory system. Measures such as ventilation and air cleaning were increasingly recognised as important for reducing risk. Such measures work by diluting and removing infectious particles from the air and therefore reducing the likelihood or level of exposure. Measures such as well-fitting masks can also be effective both in reducing the dispersion of virus carrying particles from infected people and reducing exposure to inhaled particles.

5.3. While the specific contribution of different routes of infection for COVID-19 still has some uncertainty, global consensus is now that the majority of transmission is probably through direct inhalation of respiratory particles carrying the SARS-CoV-2 virus from the air, either at close proximity to an infected person or from the air in a shared room. Evidence for airborne transmission comes from a range of sources including: evidence that almost all transmission appears to happen indoors; large outbreaks over a short time period within single settings; cases of transmission where there is no direct contact between people or evidence they have touched shared surfaces; increased risk of transmission during activities which increase exhalation (e.g. singing, aerobic exercise); measurements of virus in exhaled breath showing the majority of virus is found in particles smaller than 5 micron diameter; environmental sampling which has found virus in the air and within air systems such as Heating, Ventilation and Air Conditioning ('HVAC') filters; and modelling and measurement studies that demonstrate the physics of small aerosols from human exhalation activities.

5.4. Evidence for transmission of COVID-19 via hands/surfaces is weak and has not grown substantially during the pandemic. However modelling studies and environmental sampling suggests that transmission via surfaces cannot be ruled out and may still contribute to a small proportion of cases. It is also important to recognise that other pathogens are known to transmit via hands/surfaces including gastroenteritis pathogens such as norovirus as well as a number of bacteria, and therefore hand and surface hygiene has a wider role to play for several diseases.

5.5. Transmission of a communicable disease such as the SARS-CoV-2 virus is complex and uncertain and there remain many gaps in knowledge. While many laboratory and modelling studies show that mitigation measures are likely to be effective and provide theoretical quantification, they are inevitably idealised. The real world of transmission is a complex interaction between the virus, the environment and human behaviour, and therefore the actual effectiveness of many measures is difficult to quantify. Human behaviour plays a substantial part in the effectiveness of mitigation measures.

5.6. There are features of some settings that increase or decrease risk of transmission and the ability for mitigations to be effective. For example, public transport settings are inherently environments where people are close together, hospitals are settings where there are higher numbers of vulnerable people. School environments have several specific factors that need to be considered when evaluating transmission risks and determining both local and population scale mitigation measures:

- School and nursery populations consist of both children and adults (school staff and to some extent parents), and therefore the range of vulnerability to the disease and risk of transmission to others for people within both groups needs to be considered. While COVID-19 is generally milder for children than adults, some children can be severely affected, and a substantial number of children have long COVID. Office for National Statistics ('ONS') data between September 2020 and January 2021 indicated that teaching and education professionals were one of the groups most likely to test positive for COVID-19 [CN/20 - INQ000503388].

- Children (particularly younger ones) may be harder to identify as infected both in terms of the ability to reliably apply testing methods, and in terms of being symptomatic. It is common (indeed encouraged) to send children to school with mild respiratory symptoms. As such infected cases may be present in schools without staff or other children being aware.

- School and nursery environments are designed to bring together the same groups in the same spaces on a daily basis for a significant period of time, and the occupancy density of classrooms tends to be considerably higher than other regularly attended settings such as workplaces. As such exposure to an infected case may be greater than in many other settings.

- Schools facilitate a range of activities that can make transmission of COVID-19 and other respiratory infections more likely including indoor sports and singing.

- School and nursery environments can facilitate very close interactions, particularly for very young children, which may be important for close range aerosol exposure and any risks for transmission on surfaces. School activities and travel to school often also involve close interaction on buses and trains.

- Schools act as a social hub for a community often facilitating connectivity between adults through their children as well as wider out of school activities which further promote close interactions between groups of children.

- School buildings vary substantially in design and quality and many school buildings are aging and have challenges with maintenance. However, a large proportion of UK schools are wholly or partially naturally ventilated.
- There tends to be limited expertise on the indoor environment and ventilation within schools. While larger secondary schools may have dedicated estates professionals supporting the school environment, smaller schools rarely have environment specific expertise to hand.
- There is a social justice element to the quality of school environments. A paper from the SAMHE study indicates that schools in more deprived areas tend to have worse ventilation per person and state schools are usually less well-ventilated than fee-paying schools [CN-21 – INQ000653267].
- The ability to apply some mitigation measures including wearing masks, hand hygiene and physical distancing is heavily behaviour dependent. It is likely to be considerably more challenging to successfully implement such measures in schools compared to for example workplaces.

6: Ventilation and Air Cleaning Evidence and Practical Considerations

6.1. The following sections consider the evidence for ventilation and air cleaning at reducing transmission of infection in school environments, and practical considerations relating to implementing such technologies. I have briefly set out what is known and the opportunities and challenges in collecting evidence as well as some the real-world considerations for implementing measures based on knowledge from research studies. Given the timescale for preparing this statement the evidence presented here represents a selection of studies rather than a comprehensive review.

Principles of Ventilation and Air Cleaning

6.2. Ventilation is well recognised as an important strategy to manage the risks of airborne disease and is part of infection prevention guidance worldwide. Ventilation works by diluting the concentration of contaminants in air and physically removing them from the space as air is exhausted outdoors. In a space where the air mixing is good, the higher the ventilation rate the lower the concentration and the more rapidly contaminants are removed. The action of ventilation is predominantly a physics process, however there are some bio-chemical effects due to the temperature, humidity and presence of pollutants in the air which can affect the survival of pathogens.

6.3. Ventilation in schools can be provided through several means. Most UK schools are fully or partially naturally ventilated, which relies on passive openings (usually opening windows) with external wind and temperature to drive airflow through buildings. Some schools have mechanical ventilation, where the air is supplied and extracted using fans and ducts. These range from very simple systems like a bathroom extract fan, to standalone units that supply a single classroom, to full HVAC systems that supply a whole building. Mechanical ventilation can also be combined with heating, cooling or filtration and so in some cases can manage temperature and air quality alongside ventilation rate. Mechanically ventilated spaces usually operate independently of the occupants.

6.4. It can be challenging to measure ventilation in buildings, however over the past 10 years, low-cost CO_2 monitors have become increasingly widely used as proxy measure for ventilation. In the absence of other sources (e.g. combustion) CO_2 in indoor air is primarily from occupant exhaled breath. CO_2 concentrations increase with the number of occupants and the intensity of their activities and decrease with increased ventilation. While CO_2 concentrations cannot be treated as an absolute measure, they can give a useful indication as to whether the ventilation in a space is good, adequate or poor. I led a paper from SAGE EMG and SPI-B in 2021 which explored the potential for using CO_2 monitoring and recommended that 800ppm (parts per million) or below indicated good ventilation and values consistently 1500ppm or higher suggested poor ventilation [CN-22 – INQ000653268].

6.5. Air cleaning refers to using devices (local, portable or installed) in a classroom to reduce the concentration of particles or microorganisms in the air. The most common devices are filter based, using a fine filter (often a HEPA filter) in a box with a recirculating fan. The fan draws air through the filter physically removing particles from the air. The effectiveness of such devices depends on the airflow rate and the filter efficiency. There are a large number of these devices on the market with different costs, airflow rates, filter efficiencies, sizes and noise ratings. In the USA, home-made devices constructed from four filters and a fan (Corsi-Rosenthal boxes) are popular in schools; these have also been used in the UK but are less cost effective as the filters are less readily available.

6.6. Ultraviolet ('UV-C') air disinfection or air purifying devices work by inactivating but not physically removing microorganisms from the air. Conventional UV-C devices operate with 254nm light and can be enclosed in a portable or installed unit similar to a HEPA filter device or installed as shielded upper-room devices; 254nm light is hazardous to eyes and skin and hence must be enclosed or shielded. Emerging far UV-C technology at 222nm wavelength is safer and can potentially provide UV-C light across a whole room. A number of other technologies are available including devices which use plasma or ionisers, however there is limited data on the efficacy of these devices. I led the authorship of a SAGE EMG paper in 2020 which summarizes the potential for using air cleaning approaches based on knowledge at the time [CN/23 - INQ000074950].

Evidence for Ventilation and Air Cleaning on Infection Transmission

6.7. There is a substantial body of evidence that shows that ventilation and air cleaning reduce the concentration of microorganisms and contaminants in air. Most of this comes from real-world and chamber measurements which show lower concentrations of airborne microorganisms and other contaminants under higher ventilation rates or with effective air cleaning devices. Evidence also comes from mathematical models which quantify the physics of aerosol removal under different airflow conditions. There are a substantial number of studies across multiple settings including schools which measure a range of different contaminants in air, including microorganisms. Some studies do also show that airflows in indoor spaces are complex and on rare occasions local airflow patterns created by ventilation, air conditioning or air cleaning devices can increase concentrations at certain locations at the same time as reducing for other locations in the same room.

6.8. Evidence that demonstrates ventilation or air cleaning reduces transmission of infection or illness is very limited. This is primarily because such data is very challenging to obtain for two reasons:

(1) There is not necessarily a linear relationship between the reduction in the concentration of a pathogen in the air (and hence the exposure) and the reduction in the likelihood of infection. The likelihood of infection depends on the infectious dose (or dose-response), which will depend on the particular pathogen as well as the susceptibility of the individual. For example, improving ventilation or adding air cleaning (or indeed any other measure) could reduce airborne exposure by 50%, but if this is still at or above the infectious dose for the pathogen then the reduction in infection risk will be much less than 50%, and could be negligible. Data on the dose-response for pathogens is challenging to acquire; it is often estimated from outbreaks but has a high degree of uncertainty. In addition, while ventilation measures may reduce some of the exposure, there may be other transmission which happens at close proximity or via hands/surfaces which is not impacted by the air interventions.

(2) Direct evidence from intervention studies is difficult to measure. Unlike medical trials where different treatments can be given to individuals and the treatment only affects that person, ventilation is an environmental measure which affects a building and everyone in the space. As such it may have different effects over a day or season depending on aspects such as the weather and the occupant behaviours. It is hard to conduct studies which compare directly between spaces which have different levels of ventilation, as it is difficult to control parameters within and between spaces. Where an intervention is applied in one setting (e.g. in school classrooms), the same people can be exposed through interactions in other spaces (e.g. homes, transport, social settings) which can reduce or even negate any effects in the intervention. There has also historically been little funding available to carry out environmental studies with health outcomes in comparison to medical trials, and therefore the number of studies is very small.

6.9. Most of the studies that attempt to quantify the effect of ventilation or air cleaning on infection risk in schools or other environments are modelling based and use data on the estimated dose-response of a pathogen to estimate risk from exposure. Modelling in this context refers to mathematical models used to quantitatively represent the process of transmission and the factors that influence it. These typically include parameters to quantify the emission rate of virus from an infected individual, the dispersion of virus carrying particles through the air, environmental factors including the effect of ventilation or air cleaning measures, potential exposure to susceptible individuals through inhalation, and in some cases a prediction of whether the amount of virus inhaled could cause infection. These models range from simple representations of individuals in a room where all the air is considered to be uniformly contaminated, to more sophisticated approaches that use computational fluid dynamics to represent complex spatial dispersion of microorganisms and airflow patterns. There are several studies that have specifically considered schools and used ventilation measurements (for example CO_2 as a proxy for exhaled breath) together with well-established risk modelling approaches to explore the impact of ventilation on infection risk. There are also a number of studies that have modelled airflows in classrooms using computational fluid dynamics which show the complexity of airflows and how exposure to virus may depend on local flow patterns and the relative position of infected and susceptible children in classrooms. Such models can be incredibly valuable to understand how different parameters interact and the levels of risk reduction that could be expected. While these studies almost all show a positive effect of ventilation, they are inevitably based on simplifications and assumptions about the real world and are limited particularly in their ability to capture complex human behaviours that happen in real settings.

6.10. A very small number of studies have looked to directly correlate ventilation rates to illness in schools. Pre-pandemic, two studies in the USA considered ventilation and illness absence data. A study in 28 schools in California showed an association between better ventilation and reduced illness absence [CN/24 - INQ000653270]. Measurements in 144 mechanically ventilated classrooms in Midwestern USA also showed lower illness absence with both increased ventilation and lower particulate matter [CN/25 - INQ000653271]. A pre-pandemic study in 60 classrooms in Scotland also showed lower CO_2 concentrations (and hence better ventilation) was correlated to better school attendance but did not specify the reason for absence [CN/26 - INQ000653272]. All these studies have attempted to quantify the benefits in terms of either reduced absence days or cost of absence due to increasing ventilation.

6.11. Data from during the pandemic is more limited. A study in the USA with the original SARS-CoV-2 variant suggested that improved ventilation and the addition of air cleaning were associated with 35% and 48% less transmission, respectively, but this was based on self-reported data rather than measurements [CN/27 - INQ000653273]. An analysis of clusters of COVID-19 cases in schools in Italy suggested up to 80% lower relative risk of infection in schools with mechanical ventilation compared to schools with natural ventilation, however ventilation rates were estimated rather than measured and the study couldn't rule out cofounding covariates [CN/28 - INQ000653274].

6.12. From the perspective of air cleaning technologies, there are fewer studies in schools than for ventilation. Data from the 1940s suggested that application of UV-C technologies could reduce or modify the transmission of measles in school classrooms [CN/29 - INQ000653275], and subsequent UK based work in 1954 also showed reductions in chicken pox but not influenza [CN/30 - INQ000653276]. In a TES article on air cleaning in 2022 that I co-authored [CN/09 - INQ000653257] we stated that there was no direct evidence that air cleaners will decrease COVID-19 transmission rates in schools. This statement meant that no studies had been carried out at that time to explicitly measure (rather than model) the impact of air cleaners on infection rates. There have since been a small number of studies published on air cleaning in schools or kindergartens that do explicitly consider infection rates or illness absence related to COVID-19 and other respiratory viruses as a measure. A study in a German

Kindergarten found no effect from HEPA filter devices on COVID-19 transmission but did not consider the ventilation rates in the setting [CN/31 - INQ000653277]. It is likely that the close interactions of very young children during play enable transmission regardless of the ventilation. However, an intervention study in two day-care settings in Helsinki suggested around 30% lower rates of parents being absent from work due to child illness in these settings with air cleaners installed compared to the rest of the city [CN/32 - INQ000653278]. A very small cross-over study with 38 students in two classes in a Swiss Secondary School indicated improved air quality and lower illness absence due to respiratory infections when air cleaners were present [CN/33 - INQ000653279]. Our Class-ACT study results (see paragraph 4.9 above) also suggest a positive impact with lower illness absence in primary schools with HEPA air cleaners. While these results have not yet been peer reviewed, we have confidence that they show an overall reduction in illness absence across the schools with HEPA filters in this study at this particular time in the pandemic.

Practical considerations for improving ventilation and adding air cleaning

6.13. Schools with mechanical ventilation may be able to improve airflow through better maintenance, but beyond this are unlikely to be able to increase airflow rates without significant modification to the system. However, mechanically ventilated classrooms are already likely to have higher and more consistent airflow rates than naturally ventilated classrooms.

6.14. School classrooms that rely on opening windows have ventilation which is highly dependent on human behaviour as well as the local environment around the school and the weather. In most cases windows must be manually opened which therefore relies on staff or pupils within a classroom to respond appropriately to the conditions in the room to enable ventilation. Studies reliably show that people respond to thermal conditions, opening windows when a room feels too hot, but do not respond well to parameters such as high CO_2 which is indicative of poor ventilation. In addition to awareness of the need to open windows, other barriers to ventilation include inclement weather (cold, rain, high wind), maintenance of windows (some are painted or screwed shut, some have damaged fastenings), ability to access window openings, safety and security for pupils, and noise or external air pollution. Even when windows can be opened, there may be substantial variability around the level of ventilation; a cooler windy day will lead to much higher airflow rates than a warm still day.

6.15. CO_2 monitors provide a visual guide to the need for ventilation, however for these to work effectively they need to be installed appropriately, be accurate and for staff to have sufficient training and knowledge to understand how to use them. Experience from our CIVOS study (see paragraphs 4.2 - 4.6 above) suggests that training and guidance is quite limited although sensors are generally easy to use. A key challenge is maintaining engagement over longer periods of time, particularly in classrooms where it is difficult to achieve good conditions. Evidence from schools was summarised in a SAGE paper, indicating that most evaluation studies were carried out over short time periods and there is limited data evaluating acceptability and usability of sensors [CN/22 - INQ000653268].

6.16. Implementing filter-based air cleaning devices in schools is relatively straightforward as most are portable consumer devices which require a plug socket. Many filter-based air cleaners have low energy consumption so are not costly to run. I co-authored a modelling-based analysis of HEPA-filter based air cleaners which suggests that the energy consumption is modest and may even provide acceptable air quality at a lower energy cost than fully opening windows [CN/13 - IINQ000653260]. However, there are a number of important considerations that need to be made including: selecting devices that are robust and safe for use in a classroom; noise from devices particularly where there may be children who have Special Educational Needs and Disabilities ('SEND'); practical considerations around where there is space for the device and whether there are sufficient plug sockets; provision of appropriate guidance to staff on how to use air cleaners and what to do if there are issues; ensuring there is an appropriate plan and budget for maintenance and cleaning including changing filters (typically annually). Adding air cleaning does not improve ventilation, so although there may be wider benefits for health around other air quality exposures, they will be less likely to address challenges with cognitive performance or thermal comfort where ventilation rates are very poor.

6.17. Implementing UV-C based air cleaners may require a more in-depth consideration of the environment. Portable devices or enclosed fan driven devices installed on walls or ceilings are relatively straightforward to implement. However, our experience through the Class-ACT study suggests that some of these devices can consume significantly more energy than filter-based air cleaners and some designs can be noisy or produce heat. The Class-ACT study intended to test the application of upper-room UV-C systems, but we identified that in many UK primary schools the ceiling heights are too low for these to be installed. Such systems have significant potential in some settings as the removal rate for pathogens can be very high but require specialist design and installation to ensure they are safe. The use of UV-C devices has benefits for pathogen exposures but will not have an impact on other particles in the air.

7: Masks in Schools

7.1. Face coverings and masks can be an effective way of reducing both the exhalation of virus by infected people and the exposure to virus for susceptible people. The effectiveness of a mask depends both on the quality of the mask and the wearing, particularly how tightly it fits the face. Laboratory studies show that most types of masks and face coverings have some beneficial effects, but that the most effective masks are FFP2/FFP3 type in terms of both fit and filter. Evidence relating to the science of masks has been covered in previous submissions to the inquiry, particularly in Module 3 and so is not presented here.

7.2. Like ventilation measures, epidemiological evidence relating to the impact of masks on transmission is challenging to acquire and is therefore limited. With respect to school environments the number of studies is small, and most are based on population level data from the USA. An analysis of rescinding a universal masking policy in Massachusetts schools suggested it was associated with an increase in the number of cases CN/36 - INQ000653282] and hence suggested that masking was beneficial. Similarly, an analysis of cases in Arizona in 2021 indicated a lower likelihood of outbreaks when masks were required indoors in school CN/37 - INQ000653283]. A wider analysis in the USA in 2021 also showed that counties without school mask requirements had high increases in COVID-19 cases among children after the start of the school year compared to those that mandated masks CN/38 - INQ000653284].

7.3. Implementation of masks in schools for children or staff is highly dependent on human behaviour and will depend on age groups and capabilities of those concerned. Many older children will accept and tolerate masks well, and indeed during the pandemic wore masks regularly in school environments. However, there are a number of factors that need to be considered, particularly around safety for young children and inclusion for children with SEND, both in terms of being asked to wear masks and the impact on learning and social development through not being able to see the mouths of other children and teachers. I have limited expertise on these aspects so have not commented further.

8: Future Recommendations

8.1. The Inquiry has asked me to consider future approaches to enabling safer environments in schools, and particularly to expand on two recommendations that I made in my Module 2 statement and elaborate on what these could entail in practice for schools:

"Putting a greater level of investment into mitigating environments which contribute so much to long term societal equality and long-term economic growth such as schools could be better prioritised. (Module 2 para 14.27)

A programme to improve environments in buildings, alongside other public health system interventions, would likely improve resilience to future pandemic risks including reducing inequalities, as well as also bringing wider health benefits. (Module 2 para 14.28)"

8.2. My view is that, while the evidence base around infectious disease is still weak, there is a growing body of evidence that indicates enabling better ventilation and indoor air quality in school environments will have a positive effect on the health of children. This is in terms of exposure to communicable pathogens and other microorganisms such as mould, exposure to air pollution, and enabling thermally comfortable environments. While ventilation or air cleaning is not a silver bullet and will not reduce transmission of COVID-19 or other respiratory infections to zero, there is some evidence to indicate a positive impact in schools and may enable environments to be more resilient to both seasonal infections and future pandemics. In addition, there is clear evidence that air pollution is associated with health effects such as asthma and allergic responses CN/41 - INQ000653287 and CN/42 - INQ000653288] and therefore providing better quality environments with better air quality is likely to have wider health benefits. There is also evidence from a number of studies that better ventilation is likely to have a positive impact on learning for children CN/43 - INQ000623467 and CN/44 - INQ000653290], such as reducing asthma exacerbations, as well as have a positive impact on learning for children. School absence has remained high since the pandemic and absence due to illness is the biggest reason, hence actions which can contribute to reducing risks are beneficial.

8.3. There is no one-size-fits-all solution to improving indoor environments in schools. Some schools already have good or acceptable ventilation across their classrooms and other spaces, while others have significant challenges with large numbers of spaces experiencing poor conditions on a regular basis. Identifying appropriate solutions will be school specific depending on the age and design of the existing buildings, the number of pupils, the local external environment and weather conditions and the vulnerability of the particular pupil cohorts.

8.4. Over the past five years I have contributed to several reports which have brought together expertise from academia, industry and the public sector to examine the importance of indoor environments to both mitigate infection transmission and to improve indoor air quality. These include a body of work from the Royal Academy of Engineering on Infection Resilient Environments, in particular reports from 2022 [CN/39 - INQ000653285] and 2024 [CN/40 - INQ000653286], the 2022 Chief Medical Officers report on Air Quality [CN/41 - INQ000653287], and the 2025 report from the Royal College of Physicians [CN/42 - INQ000653288]. Although these reports do not explicitly focus on schools, I have drawn the following recommendations from these bodies of work as well as my own experience of working with school environments:

(1) **Strategic approach:** Improving school environments for infection prevention cannot be carried out in isolation. It is important that both a policy approach and specific actions in schools are aligned with other relevant priorities including improving air quality, ensuring thermal comfort including resilience to increased overheating risks, building safety, net-zero, and enabling inclusive environments particularly for children with SEND. Changes to address one aspect may have a knock-on effect, and therefore a joined-up approach will reduce the risk of unintended consequences. This should be strategic across both capital investment in school buildings and any communication campaigns to schools.

(2) **Development and application of appropriate school building standards**: School ventilation in new buildings or major retrofit is covered by Building Bulletin 101 ['BB101'] [CN/43 - INQ000623467] which was last updated in 2018. This guidance includes recommended CO_2 levels as a proxy for ventilation, yet the values are considerably higher than recommended for other buildings. The guidance should be revised to both reflect new evidence (including changes to the building regulations and new research) since the last revision and to ensure that children and staff in schools are able to access ventilation that is designed to be at least comparable to standards for other environments such as workplaces. There is a risk that if standards are not updated, that any new school building programme will "lock in" outdated requirements. It is also well recognised in the construction sector that there is a substantial challenge with compliance, with large numbers of buildings across all sectors not performing to the design standards. Addressing this requires both data on performance and better enforcement of regulations to ensure that building standards are met.

(3) **Development of approaches to upgrade existing schools**: BB101 applies to new schools and major retrofit, but the quality of the environment in existing schools will depend on both the standards at the time of construction/retrofit as

well as the level of maintenance in that school. While requiring all schools to meet a particular new standard is not feasible, setting out guidance to enable schools to better identify where their environments are below par and to take reasonable steps towards improving them could be very valuable. This would require collaboration across policy makers, built environment professionals and schools to produce guidance that is realistic and effective. It would also require support with funding to both carry out maintenance effectively and support upgrading systems in some schools.

(4) **Better technology standards**: Air cleaning appears to be a valuable tool, particularly for addressing short term challenges where there is not sufficient resource to upgrade environments. However, there are a raft of technologies on the market with little regulation around their performance and safety. During the pandemic, technologies were marketed aggressively across the public and private sectors without evidence of effectiveness. Better standards would support more reliable and cost-effective selection of technologies. Our experience in the Class-ACT study is that many air cleaning devices are not designed with schools in mind. There is a need for devices that are robust, quiet, low-maintenance, not reliant on wi-fi connections for operation, and safe for children.

(5) **More effective monitoring with long term data collection:** Stand-alone CO_2 monitors as provided to schools give a visual guide which can enable school staff to respond to environmental conditions in classrooms, but do not provide any long-term data on the quality of school environments. The SAMHE study has shown the value of remote data collection, and projects such as the Boston Schools study in the USA have shown that this can be done at scale [CN/44 - INQ000653290]. Better data collection across public buildings would support building the evidence base for environmental impacts on health and could support better targeting of resources to tackle issues with ventilation and air quality, support energy efficiency measures, and provide baseline data to inform response to future risks including pandemics.

(6) **Improving schools' knowledge base on environmental impacts on health and wellbeing:** The first step to improving environments is awareness. While some school environments are very challenging to improve, many can be improved with simple measures. Better guidance and support provided to schools to increase the knowledge base among teachers and senior leaders,

could enable small changes to improve environments both for infection control and for wider health, wellbeing and learning. This includes enabling an inclusive education system which supports children who may have health conditions or are neurodiverse and are more impacted by the environment that they are in. Such guidance should be supportive, and rather than expecting teachers to become experts in building systems, provide practical support to enable them to get the best out of their learning environments.

(7) **Improving knowledge base among built environment and school policy professionals:** Improving training and expertise around health and wellbeing among professionals who support the development and delivery of school environments could enable spaces to be better designed and maintained in a holistic way. Aspects such as sustainability and energy efficiency are well embedded in training for engineers, architects and estates managers, but there is less understanding around health impacts, particularly infectious diseases. Enabling this through apprenticeships, degree courses and CPD could build a knowledge base and enable better maintenance and response to risks in the future.

(8) **Addressing research knowledge gaps:** Despite clear understanding that better ventilated environments are good for health, there is still limited data on the extent of the benefits, holistic evaluation of strategies undertaken during COVID-19, and the cost-benefit of different approaches. There is a particular gap around the impact on infectious diseases which requires well designed studies that are not easy to carry out. Cross-disciplinary research studies to provide clearer evidence would significantly support future decision making both in terms of planning for resilient environments and enabling a more effective response in the event of another pandemic.

8.5. Addressing the quality of school environments is by no means free and would require investment. The scale of investment will depend on the level of change. For example, installing mechanical ventilation into all schools would be very costly, but improving training and standards are much lower cost and can effectively support improvements going forward as well as building the knowledge base for a more informed response to future risks.

8.6. I believe that addressing child health is an important preventative strategy for society. Exposures to infection or poor air quality early in life or disruption to learning can leave a lasting impact and influence health and economic life chances for decades. While there are benefits to providing good environments for all buildings, those which support children have the potential to have the biggest long-term impacts.

Statement of Truth

I believe that the facts stated in this witness statement are true. I understand that proceedings may be brought against anyone who makes, or causes to be made, a false statement in a document verified by a statement of truth without an honest belief of its truth.

Signed: Personal Data

Dated:___24/09/2025__