Coronavirus

The ventilation problem

Maximising airflow in public spaces is crucial to cut covid-19 transmission, but questions remain about what technology to use and how effective it needs to be, says **Graham Lawton**

AS THE nights begin to draw in and schoolchildren across the northern hemisphere start trooping back into the classroom, there are three words that ought to be inscribed on every blackboard: ventilation, ventilation, ventilation.

"Ventilation is a critically important control measure for covid-19," says Cath Noakes, an environmental engineer at the University of Leeds, UK, and a member of the UK government's Scientific Advisory Group for Emergencies (SAGE).

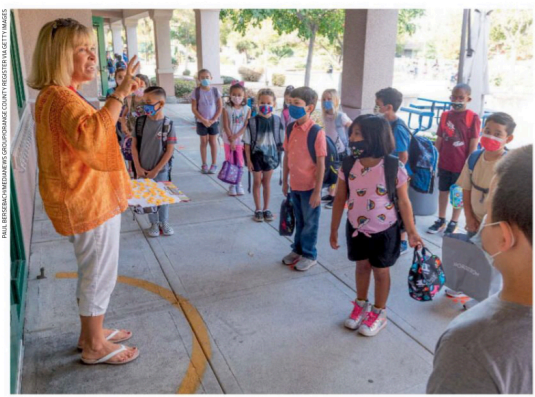
Schools are a particular weak link in controlling the spread of the virus, being crowded with largely unvaccinated children who find physical distancing a challenge. But the mantra should also be repeated in all places where people congregate in large numbers: offices, pubs, restaurants, universities, gyms, healthcare facilities, entertainment venues, public toilets, places of worship and public transport.

This focus on ventilation has come about because of our evolving understanding of how the SARS-CoV-2 coronavirus is transmitted.

In March 2020, the World Health Organization (WHO) issued advice on Twitter stating "FACT: #COVID19 is NOT airborne. The #coronavirus is mainly transmitted through droplets generated when an infected person coughs, sneezes or speaks."

Since then, mounting evidence to the contrary has convinced the WHO to change its position. It now accepts that airborne transmission of the virus is critically important.

In March 2021, the WHO issued new guidance on ventilation. "The risk of getting COVID-19 is higher in crowded and inadequately ventilated spaces... These environments are where the virus appears to spread by respiratory droplets or aerosols more efficiently, so taking precautions is even more important," it said.



PAUL BERSEBACH/MEDIANEWS GROUP/ORANGE COUNTY REGISTER VIA GETTY IMAGES

First day back at Tustin Ranch Elementary School in California on 11 August

"We know now that the virus can be transported across a room in very small particles, and it can build up within the room if ventilation is poor," says Noakes. "And we know that poor ventilation is associated with superspreading."

But ventilation is often an intangible issue. "Ventilation is one of the hardest mitigations to apply well," says Noakes. "Air is very complex. There's not a single, simple rule [like] 'wash your hands for 20 seconds'. Even a rule like 'open a window' has nuance to it: one day you might get good ventilation, the next day you might get different ventilation."

Defining what constitutes good ventilation is up in the air, too. The basic parameter is how many times the air in a space is completely replaced per hour, but how that translates to protection from virus-laden aerosols is hazy. "We don't really know what are the right ventilation rates we need in buildings to manage infection, and every building is different," says Noakes. "I do think we need some new research."

Unknown air quality

That makes it difficult for individuals to gauge whether a space is adequately aired. "For people to act responsibly, they need support from the [UK] government," says Stephen

9%

Maximum fall in productivity due to poor air quality in the office

Reicher at the University of St Andrews, UK. "It's all very well the government advising everyone to 'ventilate', but how can you know if public spaces aren't well-ventilated if we don't have clear standards, if those standards are not publicised and if the spaces are not monitored?"

But there are things that can be done. From an individual point of view, the most effective action is to invest in a carbon dioxide monitor, which estimates the concentration of exhaled air in a room (see "How well ventilated is my local area?", below). "The amount of CO_2 tells you how much of that air in that room was breathed out by other people," says Noakes. "So it's a proxy for the ventilation rate."

Building owners and managers also have a key role to play. "How buildings are managed makes a big difference," says Peter Guthrie, vice president of the Royal Academy of Engineering in London.

Unfortunately, says Guthrie, ventilation is often near the bottom of their to-do list. "Ventilation is particularly likely to be neglected. It can be difficult to get right, people tend not to notice it and unlike other important issues, such as hand hygiene and cleanliness, which are visible signs you are taking your responsibility seriously, ventilation is an invisible feature," he says.

"Building management is sometimes seen as a bit of a chore, and a cost that's got to be met," says Hywel Davies at London's Chartered Institution of Building Service Engineers. "Nobody is very enthusiastic about it and building managers are often given incentives to focus on the more eye-catching activities, such as one-way systems, hand sanitiser and frequent cleaning."

But this "hygiene theatre" does little to address the risk of spreading covid-19, says Gabriel Scally, president of the Royal Society of Medicine's Epidemiology & Public Health Section in London.

Even where buildings have adequate ventilation systems, they are often poorly maintained and managed. In the UK, top-class ventilation is found in a small percentage of buildings, says Guthrie. "Most people spend most of their time in buildings that have far less sophisticated ventilation systems," he says.

Companies often regard good indoor air quality as an expensive luxury, but that is a false economy, says Shaun Fitzgerald at the University of Cambridge. He points to research from Denmark showing that poor office air quality cuts productivity by up to 9 per cent, or about half a day a week per employee. "That's what I would call a seriously good investment," says Fitzgerald. "Businesses should think about how much their poor air quality is already costing them."

Air conditioning can make the problem worse. "Sometimes air conditioning is part of the mechanical ventilation system and that is probably OK because it's cooling the air and supplying fresh air at the same time," says Noakes. "But many buildings have recirculating units. Those are the worrying ones because they mask the fact that the ventilation's poor. They make you feel comfortable, but all they're doing is recirculating the same air over and over and over again."

Buildings without mechanical ventilation systems that rely on natural sources of fresh air such as windows are another headache.

"Everyone perceives the Tube in London as badly ventilated, but there's quite a high flow rate"

"Do all the windows which are supposed to open actually work?" says Fitzgerald. "It is a fact of life that many windows which are at a low level and easily accessed by occupants are better maintained than higher windows. Top windows get painted shut and then they're out of action. Losing a few windows really is a problem in winter. By cracking open all the high-level windows a small amount, you can get rather good levels of ventilation but without cold draughts: the incoming cold air will mix with the air in the space and be warmed before it hits the nearest occupant."

Bringing in fresh air from low-level windows can make a space intolerably cold, so people shut them, says Fitzgerald. "Last winter, some buildings in the UK were very cold, particularly schools," says Noakes. "This is what we need to avoid," says Fitzgerald.

Public transport in the UK, and elsewhere, can also be problematic. "Trains and buses are designed for comfort not for ventilation," says Guthrie.

However, while research is limited, some public transport systems appear well-ventilated, says Noakes. In the UK, mainline trains often have good mechanical ventilation and they usually open their doors frequently, she says. Also, many station concourses ›

How well ventilated is my local area?

The easiest way to check whether a space is well ventilated is to use a carbon dioxide monitor. The amount of CO_2 tells you how much of the air present was breathed out by other people, providing there is no other source like a gas stove. Outdoor air has a CO_2 concentration of about 410 parts per million (ppm). While there is no specific data on how ventilated a space must be to prevent coronavirus transmission, below 800 ppm is cause for concern and above 1500 ppm screams "get out". *New Scientist* tested the air in various environments around London.

Space	Details	Highest reading (ppm)
Outdoors		413
Bus	Upper deck, half full, windows open	741
	Lower deck, full, doors opening at stops	724
London Tube	Platform, between trains	783
	Platform, after train departs	419
	Empty carriage with open windows	542
	Half-full carriage with open windows	976
	Full carriage, standing room only	1076
Overground train	When doors are open / closed	413 / 720
Private car	Two people, windows closed	1740
	Two people, recirculating air con on	1589
	Two people, windows open	413
	Two people, non-recirculating ventilation on	413
Supermarket	Large, empty	413
	Small, busy	1100
Restaurant	Busy, by open door	739
Office	*New Scientist* office, less than half full	477
Pub	Main bar, full, doors and windows open	420

are large enough to dilute any airborne virus to low levels.

Aeroplanes and many underground trains are also surprisingly airy. "Everybody perceives the Tube [in London] as really badly ventilated," says Noakes. "The air quality is poor, but there's actually quite a high ventilation flow rate in an underground train. Planes also have quite good ventilation systems on the whole: although they recirculate the air, they recirculate it through good filters."

New Scientist used a CO_2 monitor to assess the ventilation rate on the London Underground and found it varied enormously depending on the position in the carriage and, unsurprisingly, how busy it was. On a train with standing-room only, the CO_2 levels quickly rose, but on a quiet train next to an open window between carriages, it dropped back to an acceptable level of ventilation.

Prompting a revolution

Filters might also be the answer for some buildings. Various high-tech solutions such as HEPA (high-efficiency particulate absorbing) filters and UV disinfectors are available. But they shouldn't be seen as magic bullets, says Noakes. "Some are potentially very beneficial, but just because you've got one doesn't suddenly mean everyone is safe. Air cleaners will work well in some spaces, but not in others. It's all about the right tech in the right environment. There's a real gap here in understanding how we actually deploy these technologies."

There is also a risk of building owners and managers squandering money on high-tech solutions when maintenance of existing systems would pay higher dividends, says Fitzgerald.

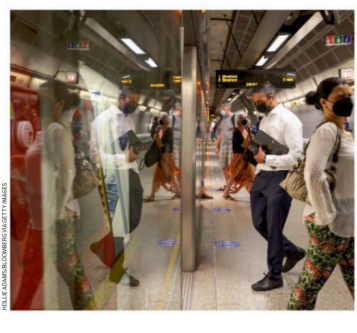
We may have more clarity on how useful filters are soon. Last week, it was announced that 30 primary schools in Bradford, UK, would take part in research testing whether HEPA filters or UV can help cut covid-19 transmission.

Overall, says Noakes, there are no easy answers, and ventilation alone won't keep us safe. "We have to remember that ventilation only mitigates airborne transmission beyond about one-and-a-half metres from a person," she says. "We need to therefore make sure there are also other measures in place at the same time: masks, distancing, surface cleaning and hand hygiene."

But once the northern hemisphere gets through the next winter, there may be a revolution in the air. The pandemic has focused minds on the wider problem of unsafe indoor spaces, and in May an international team of researchers published a call in the journal *Science* for a fundamental rethink.

According to lead author Lidia Morawska at the Queensland University of Technology in Australia, today's indoor air quality standards fail to protect us from airborne pathogens such as viruses and bacteria, and must be upgraded to deliver better ventilation, filtration, disinfection and public displays of the state of indoor air quality.

"We wouldn't tolerate our children drinking dirty water, but we seem to tolerate dirty air"



Commuters board a Jubilee line Underground train in London on 19 July

KELLE JEAN/BLOOMBERG VIA GETTY IMAGES

Even the recent guidelines from the WHO don't go far enough, says Morawska. The scale of the change required is equivalent to the sanitary revolution of the 1800s, she says, when cities such as London realised that contaminated water was a deadly public health problem and began work to build clean water supplies and sewage systems.

In some places, change has begun. In New York City, for example, the ventilation status of every classroom in the public school system is published on a website, and classrooms must have at least two functioning methods of ventilation. Belgium has begun the process of mandating that all public buildings display their CO_2 levels.

Scientists say that action cannot come soon enough in the UK, especially given the government's decision not to mass vaccinate the under 16s.

"This is an airborne disease," says Scally. "If it was coming through our water supply we'd take action, and we should be taking action with our air supplies." Just as restaurants have to be regularly inspected for their food hygiene, public spaces should be regularly inspected for ventilation, he says.

Reicher agrees. "We wouldn't tolerate our children having to drink water which infects them, but we seem to tolerate dirty air. There's got to be a fundamental change in attitude." ▮