Medical Xpress

Measuring ventilation to quantify COVID-19 risk

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Credit: California Institute of Technology

There are many factors that play into models of COVID-19 transmission: How much viral load is present in a person's cough? What kinds of materials are most effective for masks?

One of these factors is ventilation of indoor spaces: A well-ventilated space decreases risk of COVID transmission in that room, but what is the best way to measure ventilation? Now, a cross-disciplinary group of

Caltech researchers as well as members of the Institute's facilities team are adapting technology used by geochemists and atmospheric scientists to survey ventilation rates in buildings across campus.

We spoke with Professor of Geobiology Alex Sessions about this project.

The World Health Organization (WHO) recently released a report giving guidance for ventilating spaces. Can you discuss those recommendations?

The WHO report reaffirms the importance of good indoor ventilation in limiting the spread of COVID, and then provides more specific guidance about how to achieve that goal. This includes the use of air conditioners, fans, filters, and other mechanical devices in addition to natural ventilation like windows. It's sort of a common-sense roadmap to achieving healthy indoor ventilation. We're lucky to have a team of HVAC professionals on campus in Facilities Operations, so Caltech was already doing most of what they recommend.

Most useful for us is that, for the first time, they put a number on what adequate air flow with respect to COVID looks like: 10 liters per second per occupant in a non-healthcare setting.

Early in the pandemic, the World Health Organization had said that SARS-CoV-2 did not spread by aerosols: tiny liquid particles that are produced when a person exhales. Their recommendation was just wash your hands, keep six feet away, you'll be safe. But now, the evidence clearly shows that aerosol spread is happening, and may even be the most likely transmission route. So if you're just in the same room with someone, you might be at risk. When you tell people that, it can be very scary. People are wondering, "I'm in the same building with someone, could I get sick? How likely is it?" No one can calculate with absolute certainty whether you will get sick or not, but we're starting to make measurements that will contribute to numerical probabilities regarding risk.

You normally study the geochemistry of Earth environments; how did you get involved in measuring airflow in campus buildings?

Last March, campus shut down and we were all sitting at home wondering how to do research without our labs. It seemed pretty important to understand certain [things], like how well-ventilated a particular classroom or lab is, in order to eventually be able to return to campus safely.

Paul Wennberg [R. Stanton Avery Professor of Atmospheric Chemistry and Environmental Science and Engineering] and I were both sitting at home texting each other, and we came up with the idea of using methane as a tracer to measure ventilation in a room. The idea is simple: You put some amount of gas into a room, and then watch how quickly it goes away. Because methane is inert, we know it's not going away due to chemical reactions or adsorption, so its disappearance tells us how quickly the whole room is being flushed with fresh air. The hard part is how to easily measure this inert, invisible trace gas at part-per-million concentrations.

A company, Picarro, makes portable methane detectors that we've used in the field before to study methane seeps and methane-producing sediments. The divisions of GPS [Geological and Planetary Sciences] and CCE [Chemistry and Chemical Engineering], along with the Provost's office, each chipped in a third to cover the cost of us buying our own. While they were manufacturing our portable detector, the company loaned us a non-portable version. Nathan Dalleska [director of the Resnick Water and Environment Laboratory of Caltech's Resnick Sustainability Institute] cleverly strapped the analyzer, its pump, and a computer monitor to a cart so we could wheel it from room to room, along with a tank of methane and a fan to blow it around a room. And presto, we were up and running.

We didn't invent this trace gas decay method, but we adapted it to work with methane and this portable sensor. Interestingly, last summer I got in touch with a Caltech alumnus named Peter Lagus. He has a company that does airflow ventilation testing in nuclear power plants—that's one place where you really want to make sure that there's no air coming in or out, in case there's a leak. They are huge buildings, so it's hard to do accurately. Peter worked out this trace-gas approach to measuring ventilation several decades ago. He gave us some great advice and encouragement on our project.

Who else has been involved in this project?

This has been a real team effort, across Caltech, from the beginning. David Tirrell, John Grotzinger, and Dennis Dougherty financed the effort. Along with Paul Wennberg, John Crounse helped design the measurements, check our calculations, order equipment, and get us started. Several other people from GPS volunteered their time to make measurements in our labs and classrooms, including postdocs Ted Present and Elizabeth Niespolo, and staff scientists John Magyar and Ma Chi. A number of people in other divisions have also helped to make measurements in their own labs, I'm afraid I don't even know all their names; this has kind of taken on a life of its own.

This fall, after our portable methane detector arrived, we trained a crew from the campus Facilities Operations group to make the measurements, and they have been going all over campus trying to test rooms without disrupting the occupants, which is a real logistical challenge. If you see them with their cart and gas tank, give them a shout-out. Throughout all of this, Nathan has really done the yeoman's work of organizing all the different users, keeping the equipment running, and helping everyone interpret their data. At this point, thanks to everyone's efforts, we have collectively tested many hundreds of rooms across campus. It's been very gratifying to me to see so many people giving so much of their time to this project.

Can you describe the process and how it works?

The first thing we do when we go into a room is turn our methane detector on and measure how much background methane is present, just at baseline, which is usually one to two parts per million. Then we release some methane gas into the room, and turn on a fan to blow it around and make it homogenous throughout the space. The detector registers a spike in the methane concentration—typically about 10–20 parts per million. This happens within just a few minutes.

Then we turn off the gas and watch the concentration gradually drop over the course of 20-40 minutes as methane gets diluted out of the room by fresh air. We fit an exponential decay equation to the curve and get a number that reflects the air-changes-per-hour, or ACH. This value tells you exactly what you want to know about ventilation: how fast indoor air is being replaced by fresh air. We saw that, for example, in a "clean room" that has many fans and hoods, the methane went back to baseline within around 5 minutes. Occasionally, we find a room that takes more than an hour to flush out all the methane. We measured certain classrooms with and without windows open, and saw that opening the windows more than doubled the ventilation rates.

What is considered a good ACH number to be safe

from COVID infection?

That's a more complicated question than most people realize. There is no ACH number that will make you 100 percent safe from infection; there is always some very small risk. So you have to first decide what level of risk you are willing to tolerate before you can calculate what ACH number will get you there. That said, the WHO's new recommended minimum of 10 liters per second per person corresponds to about 1.6 ACH per person in a small, 8-by-10-foot office. That's probably pretty close to where many of our offices are at on campus, so would be considered safe with 1 occupant but not 2. In contrast, labs tend to have very good ventilation, often 6 ACH or higher. If we put one occupant in every 400 square feet of a lab (Caltech's current guideline) with 6 ACH, that translates to about 225 liters per second per person.

The other thing that ACH numbers do is let you make informed decisions about relative risk. For example, we measured ventilation rates in certain classrooms with the air conditioner off, and then on. We found that the air conditioning made only a small difference in the ventilation rate. Then we opened the windows and found that ventilation doubled, so you would be roughly twice as safe in that second scenario. That kind of information is very helpful, for example, in supporting a policy decision that says the windows will all be open, the improved safety is worth being a little cold. We still can't say exactly how safe you are, but we can say you are twice as safe by opening the windows.

How well does the trace gas method describe the behavior of COVID aerosols?

The amount of virus particles in a room reflects a balance between the sources and the sinks. The sources are people exhaling the virus into the air. The sinks are where the particles get deactivated or pulled out of the air: whether by sticking to surfaces, filtering through an air filter, or being diluted out of the room by ventilation. Ventilation is the major sink we focus on; the others are fairly small in comparison.

When we use a trace gas like methane, the gas tank is the source. Filtering doesn't do anything to gases, and methane doesn't decay or stick to anything. So that allows us to focus solely on ventilation, and watching methane disappear from a room gives us just the rate of ventilation by outside air. COVID aerosol particles do of course get filtered and decay and stick to things, so our trace-gas measurements are a conservative underestimate of how quickly aerosols will disappear. One of the things we have done when we find rooms with poor ventilation is to bring in portable air-filtration units. These can be really helpful in removing aerosols from rooms and making them safer for the occupants.

What does it mean to calculate "risk"?

Understanding risk is really important, because it doesn't look like SARS-CoV-2 is going to go entirely away. Even if everyone gets vaccinated, and I hope they do, different vaccines may work better against some variants than others, and so on. So there is still going to be some risk. Learning how to quantify that risk, so that people can put it into perspective and decide whether they are willing to accept it, is I think a really important first step in us getting back to normal life. After all, we already live comfortably with all sorts of other risks, like when we get into our car and drive.

People tend to be more terrified of dying in an airplane crash than in a swimming pool. But we're way more likely, statistically, to die in a swimming pool. Understanding risk is critical for making informed choices, but humans are notoriously bad at putting risks into proper perspective.

One of the leading researchers working on quantifying risk associated with COVID aerosol transmission is Jose-Luis Jimenez. He was a Caltech postdoc with John Seinfeld studying aerosols and air pollution; now he's at CU Boulder. He's built this online spreadsheet that lets you type in how big is the room, how good is the ventilation, how many people are there, and so on, and it comes out with actual numbers, like one in a thousand or one in a million, quantifying the risk that you would get infected. There are still pretty big uncertainties, mostly how many infectious particles each sick person emits, but even order-of-magnitude numbers are helpful for making decisions. One in a million is like getting on an airplane; one in a thousand is more risky than drunk driving. The public is super interested in this model, for obvious reasons.

We're still studying the question of how best to use these risk assessment tools at Caltech. On the one hand, I find that most people's perception of COVID transmission risk (while working in the labs at Caltech) is much worse than reality. On the other hand, there are still big enough uncertainties in these calculations that we don't want to give anyone a false sense of security. I expect these models to get better over time as the epidemiologists collect more data about transmission, so stay tuned.

Provided by California Institute of Technology