Vox

Coronavirus is in the air. Here's how to get it out.

Brian Resnick 4 days ago

SARS-CoV-2, the virus that causes Covid-19, can float in the air. In particular, it can linger in poorly ventilated indoor spaces, spreading farther than 6 feet from its source. These indoor public spaces are high risk and should be avoided while the virus is still spreading.

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But, increasingly, people are returning to those spaces: Some schools and universities are opening up, restaurants are operating in limited capacity, and, come November, (indoor) polls will open for people to vote in the presidential election. Right now, in August, it's possible to enjoy many activities outside, where the risk of Covid-19 transmission is lower. But cold weather will push many of these activities back indoors.

To make indoor communal spaces safer, experts keep stressing, they need to be "well-ventilated." But what does that mean? In conversations with several air quality experts and engineers, I found ventilation to be simple in concept and potentially fraught in execution.

"It's a huge engineering problem," Shelly Miller, an environmental engineer at the University of Colorado Boulder, says. "We don't have the systems in place for many buildings to be operated appropriately during a pandemic."

As Derek Thompson observes in the Atlantic, a lot of places have put on a big show about cleaning surfaces — what he calls "hygiene theater" — though surface contamination is not thought to be a large source of Covid-19 transmission.

Making places safer, instead, should mean improving air quality. But "have you ever heard a restaurant reopening announce they've improved ventilation or increased ventilation?" Lidia Morawska, an engineer and the director of the International Laboratory for Air Quality and Health at Queensland University of Technology, recently told me. "No."

Ventilation concerns are not limited to restaurants and schools. Recently, a report from the University of California San Francisco noted "exceedingly poor ventilation" at the San Quentin State Prison, which saw a huge outbreak of more than 2,200 cases.

Ventilation efforts could easily fall into the "hygiene theater" trap if not done well. So here's a guide for how to think about safer — but not necessarily "safe" — indoor air, and all the hurdles that may get in the way. We need to think about controlling the source of the virus indoors, about mixing more outdoor air with indoor air, and about air filtration and cleaning devices.

© Johannes Eisele/AFP via Getty Images People social distancing in Times Square on June 22, 2020.

The experts I spoke with agreed: We can't ventilate and air purify our way out of the need to wear masks, reduce occupancy in indoor spaces (or just avoid many of them all together), and physically distance. The indoor space that can't enforce these measures, or allow activities that involve mask removal — like bars and restaurants — probably shouldn't be open. And, still, the most important way to make indoor spaces safer is to decrease community Covid-19 spread as much as possible. It may not be easy for all spaces to achieve ideal ventilation.

There are no perfectly safe indoor environments during the pandemic, but there are clear goals to have in mind when trying to make them safer with ventilation. Here's where to start.

First: Limit the amount of virus in the air in the first place

Intuitively, I think we all know how to think about cleaning surfaces: Wipe them down with a disinfectant, or scrub with good old soap and water. Cleaning the air is an entirely different challenge. You can't just spray it with chemicals and call it a day.

"Cleaning the air is at least as important as cleaning surfaces, but you do it very differently," says Linsey Marr, a Virginia Tech engineer who studies the airborne spread of viruses. "We end up having to breathe whatever it is we spray. And if it's harmful to the virus, it's likely it's also harmful to us. So we need to take a totally different approach."

There are other challenges to cleaning the air, too. One big one: Floating particles can move. If you clean one section of air in a space, new dirty air can move in and replace it. Also, air cleaning needs to be continuous in the spaces we inhabit. As long as there are living, breathing people in a space, we're potentially contaminating it with virus.

The first thing to do in thinking about cleaning the air, says Jeffrey Siegel, an air filtration expert at the University of Toronto, is to think about limiting the source of the contagion in the first place (i.e., living, breathing people). There's an old saying in his line of work: "If you've got the odor of manure, don't try and ventilate to get rid of it, get rid of the manure," he says. "That's the exact idea, right? Get rid of the source or manage that source."

SARS-CoV-2 gets into the air via human breath. So we should start by reducing the number of humans in a space, masking those who have to enter, and limiting activities like singing or shouting that can propel even more virus-laden particles into the air.

From contact tracing studies, we know the virus spreads most readily through close contact, with the risks increasing with the amount of time spent in close proximity. However, there are some situations in poorly ventilated indoor spaces where the virus may be able to float in the air for an extended period (tens of minutes or more), or spread in a gaseous cloud over an area larger than 6 feet (some of that long-range floating virus may still be able to infect people, some of it may not). Ventilation *may* help decrease the chances of transmission in these indoor environments.

"Ventilation may be able to help reduce indoors transmission, but it's never going to be as effective as simply not having lots of people in a single indoor space," Boston University epidemiologist Eleanor Murray says in an email. "If a workplace can function with employees working remotely, then it will be safer for them to do so than to have all employees come back to work even with better ventilation. But there may be a few employees who would be better served by being at the office, and for those, improving ventilation will help make the office as safe as possible."

Second: Ventilate

Outside of source control, there are three basic ways to clean the air and reduce the concentration of airborne virus. The first is to simply ventilate, or increase the amount of outdoor air in indoor spaces, and to make sure the inside air is replaced by outside air several times per hour.

"So the air in your home probably changes over once every hour or two hours," Marr says. "We're aiming for an air exchange rate of, like, six per hour." That recommendation, she says, comes from studies of tuberculosis transmission. (Tuberculosis is not SARS-CoV-2. TB is much more contagious and is thought to be able to spread farther and stay longer in the air.)

It's important to remember, too, that scientists still don't really have a specific figure on what amounts to a dangerous, infectious concentration of virus in the air. "There's no perfectly 'safe' level of ventilation because we don't actually know what 'safe' is, since we don't know how much exposure leads to transmission," Angela Rasmussen, a Columbia University virologist, says in an email.

Six air changes an hour is a baseline. "If you want the risk down to zero, you've got to get to an infinite number of air changes per hour," Marr adds. Which is impossible.

Again, more ventilation may be "safer," but it's not "safe."

The easiest way to increase ventilation: open windows. This will increase the amount of outside air (which does not have virus in it) coming in to dilute indoor air (which may have virus in it). The less concentrated the virus is in the air, the less likely it is to infect people.

It seems simple, but it's not foolproof. There are some specific scenarios where opening windows can be counterproductive and yield unpredictable effects, as Siegel explains.

Let's say you have a bathroom. It would be a good idea to keep the bathroom air in the bathroom. After all, many types of viruses can spread in bathrooms, and in the case of Covid-19, it's possible for the virus to be sent into the air via toilet flushes (though it's less clear if someone can be infected this way). So it's ideally best to not let that bathroom air get out into other spaces.

To keep the air in the bathroom in the bathroom, it needs what engineers call "negative pressure," meaning that air can flow into the bathroom but not out.

"And then you open a window in the room beside the bathroom," Siegel says. "And once you open windows, you give up on any idea of controlling pressurization or depressurization." When this happens, the potentially contaminated air in the bathroom will start flowing out.

The point of this example isn't to make people scared of opening windows. It's just that indoor spaces are complicated, and airflow can be hard to predict.

"No one I know — even some of the best building modelers in the world — can accurately model a building with open windows," he says. "It's just way too dynamic of a system. We know that, in general, ventilation rate increases. And I'm not going to tell anyone not to open the windows. But really we can't tell you what it's doing to airflow in the space."

© Scott Strazzante/The San Francisco Chronicle via Getty Images An employee cleans the windows at True Sole as the shoe store prepares to reopen in San Francisco on May 18, 2020.

This is one of the potential pitfalls with ventilation: "Ventilation pathway matters too," Siegel explained on Twitter. If a fan meant to increase

ventilation ends up blowing virus across people's faces, it's self-defeating. This is what's believed to have happened in a restaurant in China, where people sitting in the path of an air conditioning fan got sick. Later, researchers also said that the restaurant A/C system pulled in *no* outdoor air, and the air in the restaurant wasn't replaced even once in an hour, let alone six times, which likely contributed to the outbreak there.

How to monitor ventilation

So how do you know if you're doing ventilation right? Is there any way to monitor your airflow and know the air exchange rate? Here, things get tricky. One indirect way to do this is to purchase a carbon dioxide detector (which are around $100 online) to give you a *rough* sense of air quality. When we exhale, we exhale CO2. "How much CO2 is in an indoor space is basically a metric of how much air other people have expelled in that space," Jose-Luis Jimenez, a chemistry professor at the University of Colorado Boulder, says. So high and rising CO2 levels in a space can be a sign it's not properly ventilated.

"The relationship between CO2 and outside air ventilation is really complicated and not something I'm advocating the public try to figure out," Miller says. But, as a general benchmark, the average C02 concentration of outdoor air is around 400 ppm (parts per million). So indoor spaces should ideally have a CO2 concentration of under 500 or 600 ppm in a room where people are breathing. That will tell, roughly, whether outdoor air is being mixed with indoor air at a reasonable level.

Building managers, though, shouldn't depend entirely on a CO2 monitor. Again, it's an indirect measure. If there are only a few people in a space, they may not generate enough CO2 to make the sensor rise that much even in a stagnant environment. And it only takes one person to start an outbreak.

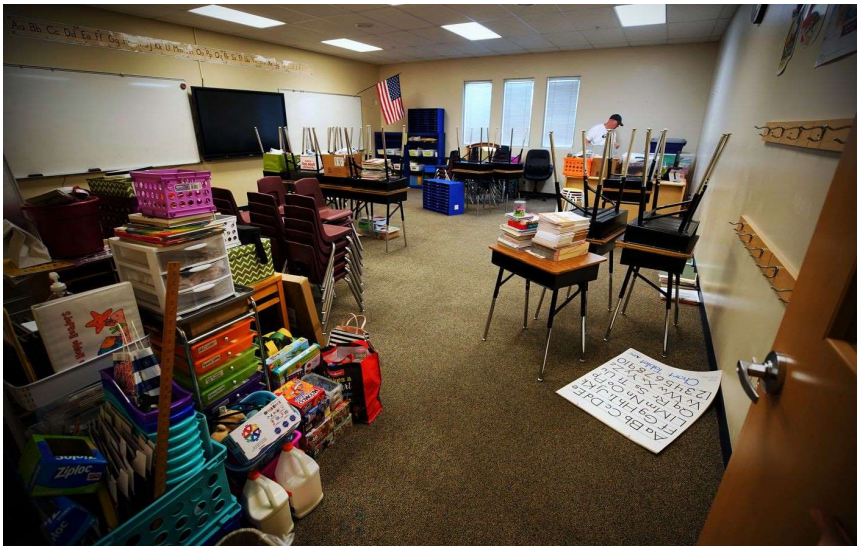
(There's also some room for commonsense measurements, too: Use your nose. If you can smell odors wafting through a building coming from indoor sources, the space may not be adequately ventilated. "If you walk into a place and it feels stuffy and the windows aren't open, then that's an indicator that there's not good ventilation there," Marr says.)

In commercial settings, some building operators might be able to adjust the amount of fresh air pumped into a building's ventilation system. During the pandemic, they should do this. But, as Miller explains, "many [commercial HVAC] systems don't run on 100 percent outside air." It's too energy-intensive. "You can't provide air conditioning and heat with 100 percent outside air," she says. So, in some cases, there is a limit to how much outside air an HVAC system can mix into a building.

Other systems might be in disrepair and unable to ideally ventilate buildings, even if their systems are cranked up. Particularly in schools, ventilation systems can be old and in disrepair. In June, the Government Accountability Office published a survey of 65 school districts that receive aid from the federal government. It found 41 percent of the districts needed to update HVAC equipment in half of their schools. Separately, in New York City, a Daily News investigation found that "roughly 650 of the 1,500 buildings surveyed in 2019 by city inspectors had at least one deficiency in their exhaust fans."

A huge part of the challenge of increasing ventilation is that different buildings, built in different eras for different purposes, will need potentially different solutions. Older buildings might not have any central HVAC systems at all. And some with HVAC systems may operate well for some rooms but less well in others.

"When I think about my daughter's school," Siegel says, "I don't worry about the school as a whole as much as I worry about that classroom where they can't open the windows because there's a construction site right nearby."



© George Frey/Getty Images Classrooms at Freedom Preparatory Academy are reconfigured as they begin to prepare for reopening in Provo, Utah, on August 5, 2020.

It's important to know here that ventilating schools has benefits that are broader than its pandemic applications. Kids need to breathe healthy air (the dangers of air quality for children's' health and cognitive well-being are as clear and critical as ever). And allowing them to do so will require huge investments.

"We can't even get the Congress to allocate, you know, $600 a week in unemployment, let alone a billion dollars to schools to upgrade their HVAC," Miller says.

"We have systematically neglected our HVAC systems for a very, very long time," Siegel says. "Schools are one classic example of that. But also every building. And so now all of a sudden, we've got a pandemic, and we say, well, we want to increase ventilation ... you don't get there without some amount of investment."

(Hospitals, you might be curious to know, already have extensive requirements in place for ventilation, which comes at a great cost and takes lots of energy to use.)

Air filters can work too — if used properly

The goal in ventilation is to replace potentially virus-laden air indoors with virus-free air. One way to do this is to bring more outdoor air inside. The other way is to filter the indoor air itself.

This also is simple in theory, but the implementation can be tricky.

It starts with getting a good air filter. For this, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers suggests using filters with a MERV-13 designation or higher. Or use a portable HEPA filter (there are some DIY versions you can try on the cheap).

MERVs are based on a filter's performance in filtering out particles between 0.3 and 10 microns. SARS-CoV-2 could very well be found in respiratory droplets in this size range; the higher the MERV number, the higher the probability that the filter will remove these droplets.

HEPA filters, more common in portable air filters, are slightly different. The "HEPA" designation means they filter out at least 99.97 percent of particles that are 0.3 microns. Which is to say, they filter out practically everything. (A quirk of the physics of filtration is the very smallest particles are actually easier to filter out than the 0.3 micron ones. The smallest particles get pushed toward filter fibers because of their collisions with gas molecules in the air, Siegel explains.)

But installing higher-quality filters isn't enough.

"I can't just tell you in good conscience, 'This is the filter you should use to protect against Covid-19 transmission,' because it really depends how you use that filter," Siegel says. "We much more often have an implementation problem than a lack of technology problem."

Often, he says, in buildings, a filter will be improperly sealed so that some unfiltered air sneaks past it and recirculates in the building; this downgrades its filtering ability. Also, not all systems can run these higher-efficiency filters, which can be quite dense. They often require more powerful fans to push air through.

For instance, Siegel says that, typically, home window AC units don't operate with very powerful fans. So if you put a good filter in the unit, "you would not move any air, your air conditioner would cease to perform as an air conditioner, the coil would ice up very rapidly, and you'd have a nice block of ice with no air blowing across it."

The other consideration: These higher-quality filters need to be replaced more frequently as they "fill up" with more stuff more quickly and it becomes harder to push air through the filter. Also (this list of caveats and considerations is getting long, right?) you need to buy a unit that's sized correctly for the space you are in. The filtering unit should ideally, along with ventilation, lead to six or more air exchanges per hour.

© Michael Ciaglo/Getty Images The co-owner of Brick House Salon switches out an air filter as she prepares to open for business in Greeley, Colorado, on April 28, 2020.

"You want something that's good for the size of your room or bigger; bigger will give you better cleaning power," Marr says. "But, you know, even if you get something that's smaller, it's not going to harm you." She adds that you also need to be careful when changing the filters because they could be contaminated with virus.

And finally: Air filters have to be constantly running to work.

"Forced air systems [like centralized heating and cooling] in most residential contexts and in some commercial context only come on when there's a need for conditioning," Siegel says. That is, they only turn on when it gets too cold or too hot. For a filter to work at its best, air needs to be constantly running through it. Some systems may need to be tinkered with to get this to happen.

Again, it's hard to know, exactly, what impact air purifiers will have on transmission. "My main concern with these ventilation systems is that we do not know really whether they will decrease transmission risk substantially," Muge Cevik, a physician and virology expert at the University of St. Andrews, says in an email. After all, there aren't randomized controlled studies of using air cleaners during this pandemic to decrease transmission.

In theory, air purifiers should help. "It's not rocket science," Jimenez, who strongly advocates for their use, says. "If you pass air through the filter, it will catch the particles."

Watch out for snake oil air-cleaning products

There's yet another option for removing virus from the air: killing it with ultraviolet lamps. That said, Miller — who specializes in studying devices that do this sort of thing — doesn't recommend these for the average consumer.

"While they can be effective, there is not enough testing/certification for these devices," she says. "These are pretty complex, and there are a lot of great applications and some really good companies that can help with design and install." But, she says "there are also a lot of bad lamp manufacturers and people selling devices that don't work. Best left to engineers and reputable companies to support these installations."

If you look at air cleaning products, you'll find a lot of gimmicks: ionizers, plasma generators that claim to amp up the power of filters. "There's very little science behind them," Siegel says. "It's not only that the devices are ineffective and maybe lull people into a false sense of security, but in some cases they're actually harmful."

Watch out, in particular, for machines that can generate ozone. Ozone is a pollutant that can interact with a lot of different products in your home and create harmful chemicals to breathe in. "It reacts with carpets and skin oil and all kinds of things inside of buildings," Siegel says, "forming all kinds of harmful byproducts, ultra-fine particles, formaldehyde, all kinds of other things that we would worry about indoors."

So stick with HEPA or MERV-13+ rated filters. Or just open windows.

Remember: Hygiene theater is possible when it comes to air quality as well. If a school or any indoor space says it has improved ventilation, ask how. Marr suggests asking building operators what the air exchange rate is (if they don't know it, maybe be wary about the space). Ask about what filters have been put in place. Ask if their HVAC systems have been routinely maintained.

"Even if you can't reach the target — six air changes per hour — if you can improve, that will still be helpful," Marr says. "Do what you can, because that will reduce the risk of transmission. Don't give up."

We need to invest in cleaner air, period. Pandemic or not.

There are no risk-free situations in a pandemic. Again, good ventilation is meant to supplement the other precautions we have in place. The hope is "if we can take this whole suite of stopgap measures from the ventilation standpoint and add it to masks, social distancing, reduced occupancy, limited time indoors, the whole package could reduce our risk substantially to help get the case rates down," Miller says.

This is particularly important heading into the fall and winter seasons, when more people will be spending more time indoors in potentially risky environments.

Experts also worry that the US Centers for Disease Control and Prevention is not being helpful enough in its air quality recommendations. For instance, the CDC recommends that schools "ensure ventilation systems operate properly and increase circulation of outdoor air as much as possible, for example by opening windows and doors." But they don't even weigh in on the merits of putting a HEPA air purifier in each classroom.

"It would carry more credibility," Jimenez says, if the CDC would discuss their use rather than leave the conversation in the hands of independent scientists speaking for themselves. "When I was talking to a school district, they were all saying, 'Well, the CDC doesn't recommend air cleaners.'" In Jimenez's mind, air cleaners are essential. But it's hard to get the message across without a huge institution like the CDC echoing it.

So much of the pain of the pandemic builds on preexisting problems. Too many schools and other buildings have overlooked their ventilation and indoor air quality to begin with. Addressing ventilation can't just be a one-time Band-Aid during the pandemic. It's an investment. And not just for future pandemics but for our overall health.

"The best possible case is that you reduce risk of Covid-19 and you make your indoor air quality better," Siegel says. "The worst possible case is that you make indoor air quality better but don't appreciably change Covid-19 risk."