TIME

COVID-19 Is Transmitted Through Aerosols. We Have Enough Evidence, Now It Is Time to Act

Guests play blackjack at tables with only three players allowed at a time at the Red Rock Resort after the property opened for the first time since being closed on March 17 because of the coronavirus pandemic on June 4, 2020 in Las Vegas, Nevada. Ethan Miller—Getty Images

IDEAS

BY **JOSE-LUIS JIMENEZ** AUGUST 25, 2020 7:00 AM EDT

Jimenez is a Professor of Chemistry and a Fellow of the Cooperative Institute for Research in Environmental Sciences at the University of Colorado-Boulder. He is a highly cited researcher and a Fellow of the American Association for Aerosol Research and the American Geophysical Union.

Many months into the COVID-19 pandemic, the coronavirus is still spreading uncontrolled through the U.S. Public health authorities including the U.S. Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO) tell us to remain six feet apart, wash our hands, disinfect frequently touched surfaces, and wear masks. But compliance with these measures—especially masks—is mixed, and daily we hear of cases where people do not know how they were infected. We hear about superspreading events, where one person infects many, happening in crowded bars and family gatherings, but not at outdoor demonstrations. Beaches in cities like Chicago are closed, but gyms and indoor dining at restaurants have reopened. It is no wonder the public is confused.

It is critical to have a clear physical description of the ways in which COVID-19 is transmitted, so that individuals and institutions are able to visualize it and will understand how to protect themselves. Contrary to public health messaging, I, together with many other scientists, believe that a substantial share of COVID-19 cases are the result of transmission through aerosols. The

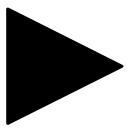
evidence in favor of aerosols is stronger than that for any other pathway, and officials need to be more aggressive in expressing this reality if we want to get the pandemic under control.

There are three possible ways the virus is transmitted, of which two have been emphasized by the WHO and the CDC. The first is through "fomites," objects that are contaminated with the virus (which could include someone else's skin). Early in the pandemic, concern over fomite transmission drove some people to bleach groceries and packages. The CDC now says fomites are a possible means of transmission, but likely not one that is major. For example, an intensive handwashing program in the UK led to only a 16% reduction in transmission. Significantly, other viruses that, like SARS-CoV-2 (the one that causes COVID-19), have a lipid envelope, do not survive long on human hands. That means someone would need to touch their eyes, nostrils, or mouth a short time after touching a contaminated surface in order to contract the novel coronavirus.

The second possibility for how COVID-19 spreads is through droplets, small bits of saliva or respiratory fluid that infected individuals expel when they cough, sneeze, or talk. Droplets—which the WHO and CDC maintain is the primary means of transmission of COVID-19—are propelled through the air, but fall to the ground after traveling 3-6 feet. However, published research, which has been replicated, shows that droplets are only important when coughing and sneezing. But when it comes to talking in close proximity, which appears to play a major role in COVID-19 transmission, droplets are less important than the third potential pathway: aerosols. Many diseases, including COVID-19, infect most effectively at close proximity. Since droplets are visible and fall to the ground between 3-6 feet, we can readily see and understand this route of infection. In fact, it was thought for decades that tuberculosis was transmitted by droplets and fomites, based on ease of infection at close proximity, but research eventually proved that tuberculosis can only be transmitted through aerosols. I believe that we have been making a similar mistake for COVID-19.

“Aerosol” (sometimes referred to as “airborne”) transmission is similar to droplet transmission, except that the bits of fluid are so small that they can linger in the air for minutes to hours. To understand the scale of aerosols, the diameter of a human hair is about 80 microns, and aerosols smaller than about 50 microns can float in the air long enough to be inhaled. SARS-CoV-2 is only 0.1 microns in diameter, so there is room for plenty of viruses in aerosols.

FAQ: Is the COVID-19 Virus Airborne?



Fomites and droplets have dominated our everyday understanding of COVID-19 transmission. While the WHO and CDC both state that aerosols *could* lead to transmission under highly specific situations, both organizations maintain that they are less important. I believe this is a significant mistake and on July 6 I, along with 239 scientists, appealed to the WHO to reevaluate their stance.

WHO updated its position in response, but the agency's language continues to express skepticism of the importance of this pathway.

The unwillingness to acknowledge the likelihood that aerosols are a major means of COVID-19 transmission can be traced to the legacy of Dr. Charles Chapin, an American public health researcher. Trying to bury once and for all the theory of miasmas, ghostly clouds of disease, he argued in his seminal 1910 book *The Sources and Modes of Infection* that aerosol transmission was nearly impossible. "It will be a great relief to most persons to be freed from the specter of infected air, a specter that has pursued the race since the time of Hippocrates," Chapin wrote. The impact of his book was fortuitous in a way: it came at a time when enough evidence about the transmission of different infectious diseases had accumulated since the discovery of germs by Pasteur in the 1860s, but before we had the technology to measure aerosols. Chapin's notions became the paradigm of infectious disease transmission, which has dominated until now.

Given this deeply held disbelief of aerosol transmission, just a few diseases, including measles and chickenpox, have been accepted as being transmitted through aerosols—and only because these are so transmissible that the evidence could not be ignored by the medical community. Some less-contagious respiratory diseases, like influenza, were described as due to droplet and fomite transmission, even when they clearly had an aerosol component. That stance has, over the years, created an unfounded perception in health care that any disease that is transmitted through aerosols has to be extremely contagious. But 110 years later, the nuances and importance of aerosol transmission of respiratory diseases are finally becoming mainstream.

When it comes to COVID-19, the evidence overwhelmingly supports aerosol transmission, and there are no strong arguments against it. For example, contact tracing has found that much COVID-19 transmission occurs in close proximity, but that many people who share the same home with an infected person do not get the disease. To understand why, it is useful to use cigarette or vaping smoke (which is also an aerosol) as an analog. Imagine sharing a

home with a smoker: if you stood close to the smoker while talking, you would inhale a great deal of smoke. Replace the smoke with virus-containing aerosols, which behave very similarly, and the impact is similar: the closer you are to someone releasing virus-carrying aerosols, the more likely you are to breathe in larger amounts of virus. We know from detailed, rigorous studies that when individuals talk in close proximity, aerosols dominate transmission and droplets are nearly negligible.

Read More: *How to Make Homemade Face Masks More Effective—and How to Wear Them Right*

If you are standing on the other side of the room, you would inhale significantly less smoke. But in a poorly ventilated room, the smoke will accumulate, and people in the room may end up inhaling a lot of smoke over time. Talking, and especially singing and shouting increase aerosol exhalation by factors of 10 and 50, respectively. Indeed, we are finding that outbreaks often occur when people gather in crowded, insufficiently ventilated indoor spaces, such as singing at karaoke parties, cheering at clubs, having conversations in bars, and exercising in gyms. Superspreading events, where one person infects many, occur almost exclusively in indoor locations and are driving the pandemic. These observations are easily explained by aerosols, and are very difficult or impossible to explain by droplets or fomites.

Furthermore, droplets move ballistically—they fly like a cannonball from someone's mouth and then travel through the air until they either hit something (worst case someone else's eyes, mouth or nostrils) or fall to the ground. Aerosols on the other hand, act like smoke: after being expelled, they don't fall to the ground, but rather disperse throughout the air, getting diluted by air currents, and being inhaled by others present in the same space. Contact tracing shows that, when it comes to COVID-19, being outdoors is 20 times safer than being indoors, which argues that aerosol transmission is much more important than droplets; outdoors, there's plenty of air in which aerosols can become diluted; not so indoors. In addition, researchers have demonstrated aerosol transmission of this virus in ferrets and hamsters.

The visual analogy of smoke can help guide our risk assessment and risk reduction strategies. One just has to imagine that others they encounter are all smoking, and the goal is to breathe as little smoke as possible. But COVID-19 is not very contagious under most situations, unlike, for example, measles: the CDC says that 15 minutes of close proximity to a COVID-19 infected person often leads to contagion, which provides an estimate of how much "exhaled smoke" one may need to inhale for infection. Inhaling a little whiff of "smoke" here and there is OK, but a lot of "smoke" for a sustained period of time and without a mask is risky. (To be clear, actual smoke does not increase the probability of infection.)

We should continue doing what has already been recommended: wash hands, keep six feet apart, and so on. But that is not enough. A new, *consistent and logical* set of recommendations must emerge to reduce aerosol transmission. I propose the following: **A**void **C**rowding, **I**ndoors, low **V**entilation, **C**lose proximity, long **D**uration, **U**nmasked, **T**alking/singing/**Y**elling ("A CIViC DUTY"). These are the important factors in mathematical models of aerosol transmission, and can also be simply understood as factors that impact how much "smoke" we would inhale.

A CIViC DUTY first suggests that we should do as many activities as possible outdoors, as schools did to avoid the spread of tuberculosis a century ago, despite harsh winters. Given how much being outside reduces COVID-19 transmission risk, it is mind boggling that the U.S. National Guard is not busy setting up open canopy tents at every school around the country. That said, stepping outdoors is not a magical protection against contagion: a windy day in an open area while keeping our distance is very safe, but an unmasked close conversation with still air in a narrow passage between tall buildings is risky.

Second, masks are essential, even when we are able to maintain social distance. We should also pay attention to fitting masks snugly, as they are not just a parapet against ballistic droplets, but also a means to prevent "smoke" from leaking in through gaps. We should not remove masks to talk, nor allow someone who is not wearing a mask to talk to us, because we exhale aerosols 10

times as much when talking compared to breathing. Everyone should be careful to not stand behind someone with a poorly fitting mask, as the curvature of an ill-fitting mask can cause aerosols to travel behind the person wearing it.

It is important to think about ventilation and air cleaning. We take operable windows and HVAC systems for granted, rarely paying attention to how they work. Times are different now, and we need to learn how to best use these systems to decrease risk. We need to increase the amount of indoor air that is replaced by outdoor air, by opening windows or adjusting mechanical systems. We need better filters installed in many ventilation systems that recirculate some of the air. These interventions can get costly, so it is very important to think carefully and prioritize objectively—we can, for example, use affordable CO2 measurements to identify the most dangerous, underventilated frequently occupied public spaces, and prioritize them.

Read More: *A New Study Suggests COVID-19 Reinfection Is Possible. Here's What to Know*

Portable HEPA air cleaners work well to remove virus-laden aerosols, but unfortunately they are costly. Makeshift fan-filter cleaners can be made for less than $50, have been shown to work in multiple tests including peer-reviewed papers, and have been used for years in China to reduce the impact of pollution in homes. They can be noisy and are not a long-term solution, but they may help us get through the next few months. Germicidal UV systems can help in some situations, but only if ventilation and filtering cannot do the job. We should also remember that air cleaning is not a silver bullet: if we simulate the Skagit choir outbreak with an added large amount of air cleaning, the infection rate only drops by half. Spending as much time as possible outdoors, wearing masks, and reducing density will remain critical no matter how well we ventilate and clean the air.

In a fast-moving viral pandemic, scientific understanding will inevitably change as research catches up to the speed at which the virus spreads. However, it seems clear that aerosols are more important when it comes to

transmitting COVID-19 than we thought six months ago—and certainly more important than public health officials are currently making them out to be. The WHO and CDC, among others, must begin communicating the science suggesting aerosol spread of COVID-19—and the risk reduction strategies necessary as a result. If not, we hamper our ability to counter the growing health consequences and increasing death toll of COVID-19.