Testimony of

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Subcommittee on Workforce Protections

Committee on Education and Labor

United States House of Representatives

March 11, 2021

Protection Against Transmission of COVID-19

Chairwoman Adams, Ranking Member Keller, Chairman Scott, Ranking Member Foxx, and Members of the Subcommittee. My name is Linsey Marr, and I am a professor of civil and environmental engineering at Virginia Tech. I have studied airborne transmission of viruses for the past 12 years, and have published more than 30 scientific papers on the topic, among more than 100 papers total on topics related to air pollution and health. I co-authored the recent letter to the Biden Administration and the CDC calling for immediate action to address inhalation exposure of SARS-CoV-2 to prevent COVID-19 infections and deaths.

Today, I will address three major points: (1) how COVID-19 is transmitted mainly by breathing in aerosol particles carrying the virus, (2) how best to protect workers and the public through the use of appropriate face coverings and other controls, and (3) what updates are needed to CDC's guidance. I will conclude by stating what needs to be done to protect workers and the public from becoming infected.

1. How is COVID-19 transmitted?

In theory, there are three possible ways for the virus to be transmitted:

1) You could touch a sick person or an object that has been contaminated with the virus and transfer it to your eyes, nose, or mouth.
2) You could be hit by large, respiratory droplets that fly like mini cannonballs out of a sick person's mouth and land directly in your eyes, nose, or mouth. These droplets may contain virus.

3) You could breathe in small aerosol particles from the air. These are much smaller than large respiratory droplets, so small that we cannot see them. They float around in the air like cigarette smoke. These aerosols may contain virus.

At the beginning of the pandemic, most of the emphasis was on wiping down your groceries to avoid transmission by touching contaminated surfaces. However, all evidence suggests that transmission from contaminated surfaces is rare. It is possible, but there are zero documented cases involving this type of transmission. Although laboratory studies have shown that this coronavirus can survive for many hours on different types of surface materials, the experiments used unrealistically large amounts of virus in unrealistically large droplets.

For over a century, physicians and many scientists have believed that colds and the flu are spread mainly by large droplets released during coughing. The droplets could land on your eyes, nose, or mouth, and they are large enough that, if they don't hit anybody, they fall to the ground within 3 to 6 feet of the sick person. Many cases of COVID-19 have been traced to "close contacts," and this was incorrectly interpreted to mean that large droplets were responsible for transmitting the disease.

However, this assumption ignores the fact that when people breathe, talk, sing, laugh, cough, or sneeze, they release far more aerosols than large droplets, as shown in Figure 1. When we speak, we release hundreds of aerosols for every one large droplet. These aerosols are most concentrated close to the sick person, and they don't fall quickly to the ground. Instead of falling like cannonballs, they remain floating in the air and follow air currents like cigarette smoke.

Thus, when you are close to someone, you are in the most concentrated part of their exhaled air, as shown in Figure 1. When people are talking in close proximity, it is much more likely that they will breathe in each other's respiratory aerosols than shower each other with large droplets of spittle. Because aerosols can float in the air for long periods of time, they can easily travel more than 6 feet, filling a room and building up over time if the space does not have good ventilation, as also shown in Figure 1.

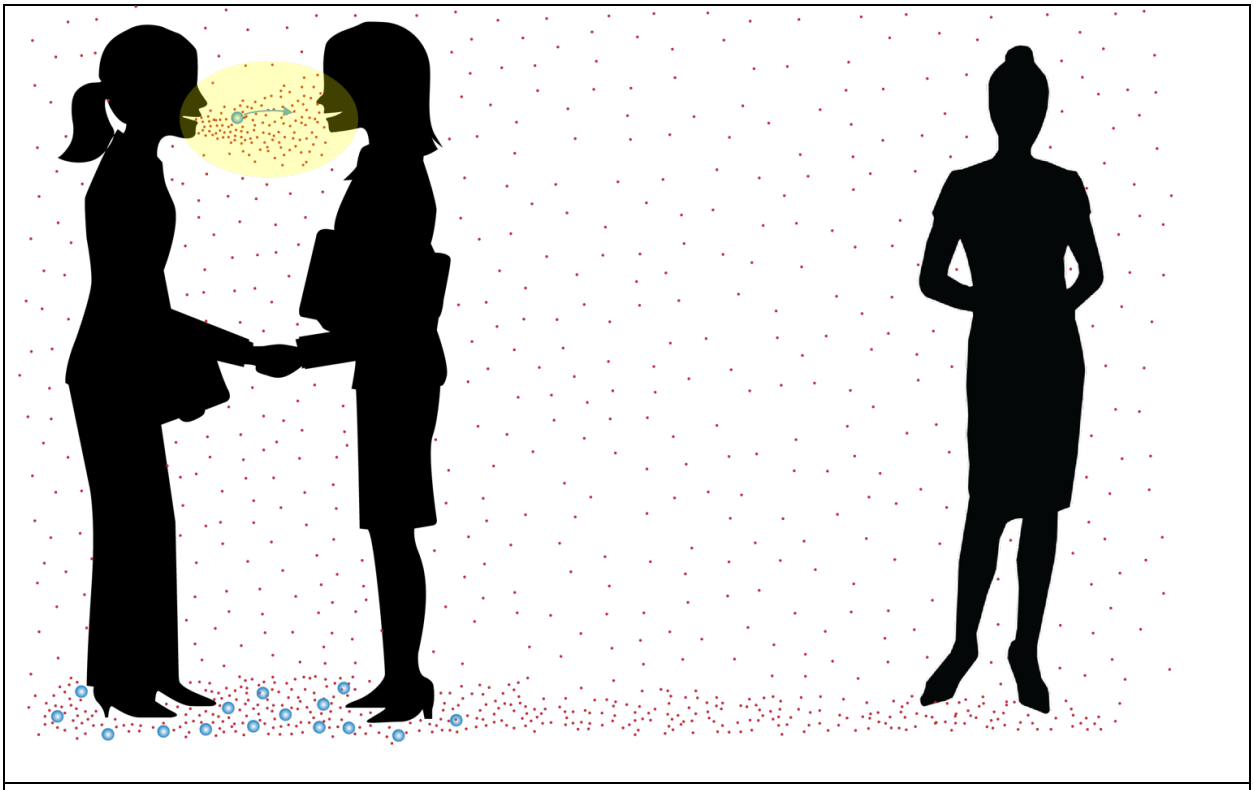

Figure 1. Exposure to large droplets (blue) and aerosols (red) at close proximity and farther away. When we speak, we release hundreds of aerosols for every one large droplet, as shown in the respiratory plume shaded in yellow. At close proximity, you are exposed more by breathing in aerosols than by having droplets land on your eyes, nostrils, or mouth. Aerosols can travel well beyond 6 feet. They can easily spread throughout a room and can accumulate in the air if the room is poorly ventilated. People far away from the infected person can breathe in the aerosols.

There is overwhelming evidence that inhalation of virus-containing aerosols is the main route of transmission for COVID-19.

1) **Superspreading events.** Examples include the choir practice at which 53 out of 61 attendees became sick and two died,[1] and the gym classes where 55 out of 81 people became sick, even though they were at least 6 feet apart.[2] Inhalation of aerosols in shared air is the best explanation for superspreading events, as clearly not everyone has spent 15 minutes close to the infected person.
2) **Asymptomatic/pre-symptomatic transmission.**[3] If people can transmit the virus without coughing, then the virus must be transmitted by just talking and breathing, which produce aerosols but few large droplets compared to coughing.[4]
3) **Indoor transmission.** There is much less transmission outdoors than indoors. Aerosols are rapidly diluted in outdoor air, so it is much less likely that someone will breathe in enough viruses outdoors to become sick. In a study that traced over 7000 cases of disease, there was only one instance of transmission that occurred outdoors.[5]
4) **Scientific studies.** Infectious coronavirus has been found in aerosol samples collected in hospitals.[6] The virus can survive for many hours in aerosols.[7] A careful study of droplets and aerosols traveling through the air demonstrated that the greatest exposure at close

[1] https://onlinelibrary.wiley.com/doi/10.1111/ina.12751
[2] https://www.cdc.gov/mmwr/volumes/70/wr/mm7009e2.htm
[3] https://www.nature.com/articles/d41586-020-03141-3
[4] https://www.sciencedirect.com/science/article/pii/S0021850211001200
[5] https://onlinelibrary.wiley.com/doi/10.1111/ina.12766
[6] https://www.ijidonline.com/article/S1201-9712(20)30739-6/fulltext; https://www.medrxiv.org/content/10.1101/2020.07.13.20041632v2
[7] https://www.nejm.org/doi/full/10.1056/nejmc2004973

contact comes from breathing in the aerosols, not by having large droplets land on you.[8] Transmission in animals has been shown to occur by breathing in aerosols.[9]

2. How to prevent transmission

If you spend a long time around other people indoors and do not wear a "good" mask (which I describe below), you could breathe in enough virus-containing aerosols to become sick with COVID-19. The simplest way to prevent transmission is to limit exposure to the virus. One way of accomplishing this is by avoiding crowded indoor spaces and limiting the amount of time spent indoors with those who are not part of the same household. When contact with others cannot be avoided, as is the case for essential workers, it is critical to reduce exposure to virus in the air by ensuring good ventilation—this reduces the amount of virus in the air—and wearing high-performance masks or respirators.

2a. What this means for workers

The total amount of virus that someone breathes in depends on both the concentration of the virus in the air and the amount of time spent breathing that air. Thus, someone who spends 8-12 hours in a poorly ventilated workplace where they share the air with other people is at much greater risk for transmission than a customer who passes through the space for a short period of time.

2b. Cloth masks vs. respirators

[8] https://www.sciencedirect.com/science/article/pii/S0360132320302183
[9] https://www.nature.com/articles/s41586-020-2342-5

I will now discuss different types of face coverings and how they work. Face coverings work in both directions. They reduce the amount of virus that an infected person spreads into the air. We call this "source control." Face coverings can also reduce the amount of virus that the wearer breathes in from the air around them. Some types of face coverings are much more effective than others against aerosols. The performance of a face covering depends on the filtration efficiency of the material and the fit.

Cloth masks are better at source control than at protecting the wearer from breathing in viruses from the air around them, as shown by studies in my laboratory and others.[10] Cloth masks are only partly effective against aerosols and have wildly varying efficiencies. A good cloth mask might have a filtration efficiency of 50%, but there are some that have an efficiency of only 10%. The actual protection afforded to the wearer may be further degraded if the mask does not fit well. Most cloth masks are not sufficient to protect, for example, a worker in a grocery store who spends 8-12 hours surrounded by unmasked shoppers.

Surgical masks fit loosely and are not designed to protect the wearer from inhaling aerosols. They are designed to protect the patient from large droplets released by a healthcare worker. The material they are made out of—meltblown, non-woven polypropylene—can filter out aerosols very efficiently, but surgical masks do not fit well. Large gaps around the sides allow aerosols to easily circumvent the mask, like having a dam with holes in it. Surgical masks are good at filtration efficiency but bad at fit.

[10] https://www.tandfonline.com/doi/abs/10.1080/02786826.2021.1890687

In contrast to masks, respirators are designed to be tight fitting and to filter out aerosols with very high efficiency. They are required by OSHA to protect workers from respiratory hazards. An N95 is one type of respirator that filters out at least 95% of aerosols, and OSHA requires the wearer to undergo a fit test to ensure the N95 does not leak. N95s offer much greater protection compared to cloth and surgical masks. Likewise, elastomeric respirators, which look like gas masks, are designed to seal to the face, and they have replaceable filters that are at least 95% efficient. Another option is a powered air purifying respirator (PAPR), which consists of a hood that is supplied with air that has passed through a high-efficiency filter that removes all aerosols.

2c. Protecting workers

Because workers may spend 8-12 hours in a poorly ventilated workplace with frequent contact with co-workers, patients, and members of the public who may be unmasked, workers require special considerations. According to the hierarchy of controls, the first priority is to control the source. Unfortunately, workers may be exposed to members of the public who are unmasked, especially in restaurants and localities where masks are not required.

The next priority is to use engineering controls, such as ventilation, to reduce the amount of virus in the air. Fresh air dilutes the virus, so it cannot build up to dangerous levels. Opening windows and doors is an easy way to improve ventilation. Workplaces should ensure that HVAC systems are running with as much outdoor air, rather than recirculated air, as possible. Improved filtration also helps remove viruses from the air. Filters in HVAC systems should be upgraded if possible.

Portable air filters are an alternative way to reduce virus concentrations in the air. Upgrades to HVAC systems can be costly and take time to implement.

Personal protective equipment (PPE) is considered the final line of defense. Because SARS-CoV-2 is transmitted mainly by aerosols, the appropriate PPE for workers at elevated risk is a high-performance mask (e.g., filtration efficiency of at least 80% according to the new ASTM standard) or a respirator (e.g., N95, elastomeric respirator, or PAPR), depending on the level of risk. This intervention can be implemented quickly, and supplies are readily available.

3. Problems with CDC's guidance

Unfortunately, most CDC guidance and recommendations have not yet been updated or strengthened to address and limit inhalation exposure to aerosols. The failure to address inhalation exposure to SARS-CoV-2 continues to put workers and the public at serious risk of infection and undermines the effectiveness of an OSHA standard.

CDC's stance on how the virus spreads is as clear as mud. CDC's FAQ on "How does the virus spread?"[11], emphasizes close contact and says nothing about inhaling the virus. The Scientific Brief entitled "SARS-CoV-2 and Potential for Airborne transmission"[12] obfuscates by incorrectly equating all transmission at close proximity with exposure to droplets. This is wrong because transmission in close contact is dominated by inhalation of aerosols. The webpage

[11] https://www.cdc.gov/coronavirus/2019-ncov/faq.html, updated on March 1, 2021
[12] https://www.cdc.gov/coronavirus/2019-ncov/more/scientific-brief-sars-cov-2.html, updated on October 5, 2020

downplays aerosols and airborne transmission, a position that is exactly opposite the best scientific evidence.

Why doesn't CDC just say that COVID-19 is spread mainly by breathing in the virus from the air? First, there has been a limited understanding of aerosols in the medical community. When different transmission routes were first identified in the early 1900s, there was no way to detect the invisible aerosols, so researchers focused their efforts on pathogens carried in large, visible droplets. Therefore, there has been a longstanding bias against transmission of viruses through the air, leading to a higher burden of proof required before this route of transmission is accepted for a particular disease. Transmission by large droplets is automatically assumed, even though there is no direct evidence that this actually occurs for any disease.

Second, there has been reluctance to describe the coronavirus as "airborne" because the word has a specific meaning in hospitals. If a disease is labeled "airborne," then hospitals must use negative-pressure rooms for patients, in addition to N95s; and these precautions are resource-intensive. Initially, it was not clear whether healthcare workers were becoming infected, but studies have now shown that they are at increased risk compared to the general public.[13]

Third, early in the pandemic, concerns about limited supplies of N95s influenced recommendations. Government officials seemed reluctant to identify hazards and make

[13] https://www.thelancet.com/journals/lanpub/article/PIIS2468-2667(20)30164-X/fulltext; https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-020-05587-2

recommendations that could not be achieved due to shortages of supplies. However, to my knowledge, there is no longer a shortage.

4. What needs to be done

CDC must update and strengthen its guidelines to fully address transmission via inhalation of aerosols at both close distances and farther away. Most CDC guidance and recommendations continue to emphasize distancing and surface cleaning, which are important, but less important than using high-performance masks and sufficient ventilation to clean the air. CDC is moving in the right direction, for example with its web pages "Improve How Your Mask Protects You"[14] and "Ventilation in Buildings,"[15] but clear and explicit explanation of why these actions help protect against inhalation of aerosols is needed so that people understand why certain interventions work better than others. Improved guidance is sorely needed so that people can better protect themselves against infection, especially workers who may be exposed to elevated levels of virus in the air for long periods of time.

In a letter to the Biden Administration and CDC that I co-authored with 12 other leading medical and scientific experts, many of whom were members of President Biden's Transition COVID-19 Advisory Board, we call for CDC and OSHA to issue recommendations and requirements that address transmission of COVID-19 by inhalation of aerosols. Specifically, we urge OSHA to issue an emergency standard on COVID-19 that requires implementation of control measures, including effective respiratory protection for all healthcare workers and other workers at high

[14] https://www.cdc.gov/coronavirus/2019-ncov/your-health/effective-masks.html, updated February 13, 2021
[15] https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html, updated February 9, 2021

risk, including those in meatpacking, corrections, and public transit. Similar letters have been sent by other experts to governments and public health agencies in Australia, Canada, Colombia, Spain, and the UK.

Calling the virus "airborne" is the clearest way to convey how it is transmitted. Airborne, meaning "borne by air," is directly analogous to the terms waterborne, foodborne, bloodborne, and vector-borne for describing how pathogens are transmitted. For now, the word "airborne" can continue to retain its special meaning in hospitals, just like the word "chart" means something different in hospitals than among the general public.

While CDC has been reluctant to call the virus "airborne," in my experience, the general public appreciates learning how the virus really spreads. This knowledge empowers them to make the best decisions to protect themselves and others. My colleagues and I have received numerous messages from the public, thanking us for delivering the clear and simple message that airborne transmission of COVID-19 is most likely the main way it spreads. This message has saved lives.

Summary

There is overwhelming evidence that inhalation of virus-containing aerosols is the main way that COVID-19 spreads. It is critical for the CDC to state this clearly and to provide appropriate guidance and recommendations. It is equally critical for OSHA to base its standards on this evidence. Improved guidance is sorely needed so that people can better protect themselves against infection, especially workers who may be exposed to elevated levels of virus in the air for long periods of time. We know how to protect people from aerosols: using high-performance

masks and respirators and cleaning the air by ensuring good ventilation and/or filtration. Strong CDC guidance and OSHA standards that are based on the best available science will enable us to safely reopen workplaces and schools, while ending this pandemic and better preparing us for the next one.