The American Institute of Architects

Reopening America: strategies for safer buildings

COVID-19 emerging research and public health data as of May 2020

Public health briefing summary

Scientific research and public health information as of early May 2020 was the backbone to the team's strategy development. The charettes were informed by a group of public, environmental, and occupational health experts and physicians who provided an independently developed, 90-minute briefing on SARS-CoV-2 infectious disease transmission, epidemiological models, and insights into key research that must be considered when developing modifications for the built environment during COVID-19 re-occupancy.

SARS-CoV-2 transmission

SARS-CoV-2, the virus that causes COVID-19, is spread primarily by person to person[1] airborne transmission through coughing, sneezing, and speaking.[2] Live coronavirus sheds at high concentrations from the nasal cavity even before symptoms develop.[3]

> Large droplets, >100 microns (μm), that are expelled, coughed, or sneezed from an infected person will fall one to two meters (generally, within six feet) due to gravity. Being within six feet exposes a person to direct contact via inhalation.
>
> Large droplets that are expelled may evaporate to form droplet nuclei aerosols, <10 μm, that lack mass; therefore, the coronavirus aerosol may remain airborne for a longer period.
>
> Droplets of respirable size are also expelled during normal speech.[4] An infected person, asymptomatic or symptomatic, will release coronavirus aerosols during normal speech.
>
> Respirable-size aerosols are not visible. Recent studies have also suggested that SARS-CoV-2 can remain infective as an aerosol for at least three hours, though some aerosol physicists argue for much longer estimates.[5]

Transmission generally requires "close contact" and "prolonged exposure." The CDC defines close contact as "within about six feet." "Prolonged exposure" is defined as 10 minutes or longer (recently updated to 15 minutes), noting that if the exposure involves direct contact with respiratory secretions, such as if a sick person coughs directly on another person, that could shorten the time for transmission.[6]

While the CDC recommends that individuals physically distance themselves from others by at least six feet to prevent transmission[7], the distance should be greater if a person shedding the virus is speaking forcefully[8], shouting, cheering, or singing. Evidence suggests such activities will increase the travel distance of respiratory droplets, subsequently impacting physical distancing. In the US, 32 of 61 people were infected with COVID-19 from one symptomatic person who attended a 2.5-hour church choir practice. Twenty other people are believed to have been infected through secondary exposure.[9]

Additionally, airflow around an infected person either from mechanical sources,[10] from wind,[11] or while walking and running[12] could also increase the distance droplets spread. In a confined environment, where there is recirculating airflow from one person onto others with no outside air and filtration, the spread can be enhanced beyond the conventional six feet.[13]

In South Korea, densely packed sports facilities were traced to increased rates of infection. Large class sizes, small spaces, intense workouts, a moist, warm atmosphere, and the turbulent airflow from the activity are believed to have increased transmission of the virus.[14]

Particularly problematic for risk mitigation is that 20–50% of those infected can be asymptomatic,[15] but may also spread the virus. In the small town of Vo, Italy, at the center of the nation's pandemic, two surveys found that approximately 43% of the confirmed SARS-CoV2 infections detected were people who had no symptoms.[16]

It may also be possible that a person can get COVID-19 by touching a surface or object that has the virus on it and then touching their own mouth, nose, or possibly their eyes, but this is not thought to be the main way the virus spreads. Early research indicates that SARS-CoV-2 can survive[17] on inanimate surfaces like metal, glass, or plastic for up to seven days.

The available surface survivability data for studies on SARS-CoV-2 are summarized in Table 1. These studies (van Doremalen et al., 2020,[18] and Chin et al., 2020[19]) were conducted at room temperature (72° F) and relative humidity of 40% and 65%, respectively, in laboratories. The survivability of the virus depends on factors such as temperature, relative humidity, the surface it is deposited on, and the viral concentration.

The study method used in the Chin study resulted in a larger concentration of virus particles deposited than the method employed by van Doremalen. It is not known which of the two studies most closely represents the viral load that could be deposited by an infected person.

In general, the virus appears to be more stable on smooth surfaces, such as plastic, glass, and stainless steel, (Chin et al., 2020) and less stable on paper and copper. The longest survival times reported by Chin and colleagues are on plastic and stainless steel.

While, as of early May 2020, there were no data on the survivability of SARS-CoV-2 on finishes in occupied buildings, it is clear that the virus can survive for various periods of time on a range of common materials. Note that surface survivability in a laboratory study does not equate to infectivity under normal conditions. For architects, one obvious strategy to avoid infectivity is to specify touchless fixtures and appliances to eliminate contact with high touch points (e.g., doors, poles, doorknobs, railings, faucet handles, stairway railings, elevator buttons, escalator railings, toilet handles, etc.).

Stability of SARS-CoV-2 on surfaces

Table 1.

SURFACE	REFERENCE 1	REFERENCE 2
Plastic	3 days 🔴	7 days 🔵
Glass		4 days 🔵
Stainless steel	3 days 🔴	7 days 🔵
Copper	4 hours 🔵	
Wood		2 days 🔵
Cloth		2 days 🔵
Cardboard	2 days 🔵	
Paper		3 hours 🔵
Tissue		3 hours 🔵
Bank note		4 days 🔵
Surgical mask		7 days 🔴

🔴 Detectible but greatly reduced

🔵 None detected

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2. Chin WH, Chu JT, Perera R, Jui K, Yen H, Chan M, Peiris M, Poon L. April 2020. Stability of SARS-CoV-2 in Different Environmental Conditions. *Lancet Microbe*.

Fortunately, the virus is susceptible to cleaning and disinfection protocols,[20] such as those recommended by the CDC. The virus is enveloped by a covering of oily lipid molecules that falls apart on contact with soap. Then, disinfectant[21] is used to inactivate the virus.

Frequent handwashing,[22] using the proper World Health Organization technique with soap and water for a minimum of 20 seconds is one of the most effective ways to reduce infection. Hand sanitizers are not essential. Prior to the COVID-19 pandemic, there was a concern that alcohol-based sanitizers could promote antimicrobial-resistant microbes, such as some *Clostridioides difficile* bacteria.[23] Only when soap and water are unavailable or impractical does the CDC recommend[24] use of alcohol-based hand rubs, which must have greater than 60% ethanol or 70% isopropanol to be effective.

Scientific evidence is still evolving about airborne transmission.[25] Past experience with the SARS pandemic in 2002 and a study from the University of Nebraska Medical Center[26] suggest aerosol transmission (virus within a very small respiratory droplet that stays suspended in the air) may also be possible. Although at this time there is minimal published scientific evidence concerning airborne transmission via mechanical systems such as HVAC, WHO "recommend[s] airborne precautions for circumstances and settings in which aerosol generating procedures and support treatment are performed, according to risk assessment."[27]

The American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE) position aligns with WHO but extends beyond just aerosol-generating procedures, etc.:

1. airborne transmission of SARS-CoV-2 is sufficiently likely, and operation of the HVAC system can reduce airborne exposures; and
2. operation of HVAC can reduce the airborne concentration of SARS-CoV-2 and thus the risk of transmission. In general, disabling HVAC systems is not recommended.[28]

ASHRAE's position responds to information from multiple studies, including those referenced above and other studies that found:

- » The virus may remain stable for weeks in cool, dry conditions.[29]
- » Particulate pollution is associated with higher death rates.[30]
- » Sunlight reduces the half-life of SARS-CoV-2 from six hours to two minutes on non-porous surfaces.[31]
- » Outdoor transmission appears to be less likely.[32]

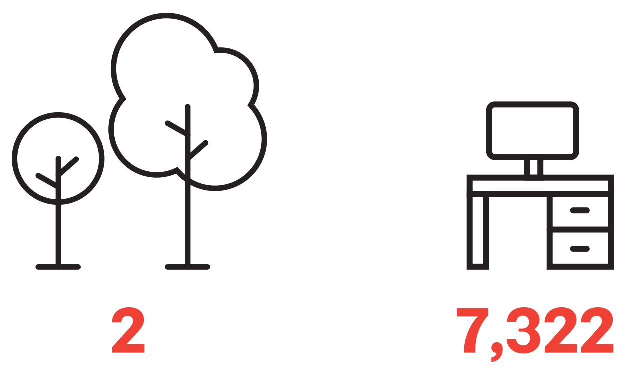

Figure 1: Majority of the COVID-19 transmissions happened indoors.[43]

If recirculation air has no filtering, minimizing air recirculation may reduce the risk of spreading the virus. Making outdoor spaces readily available, introducing natural ventilation/increased ventilation rates, enhanced filtration (from MERV 8 to MERV 13)[33], and UV treatments are also worth serious consideration. Natural ventilation dilutes the air, so introducing outdoor air through operable windows, especially when no mechanical ventilation is available, is useful. Similarly, increasing fresh air intake can be helpful if the outdoor air quality and thermal conditions are acceptable. Air pollution is a complication; microbes can be found on particulate matters in the air and can travel with the particulate matters.[34]

Current ASHRAE guidelines recommend an indoor relative humidity range of 40–60%.[35] ASHRAE's recommendation takes multiple factors into account, yet if the focus is reducing viral load, a range of 50–70% RH appears to be more effective.

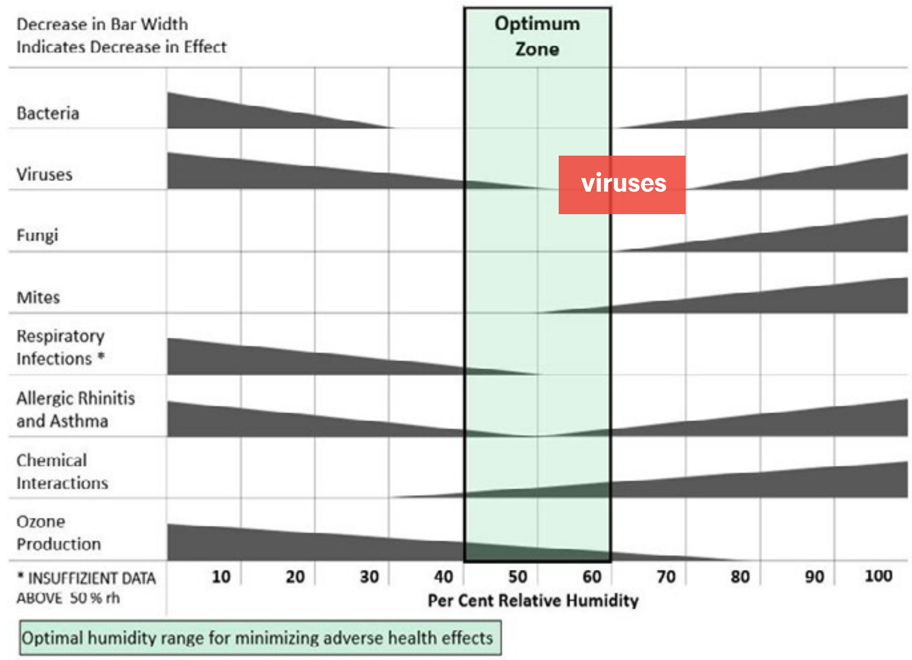

Figure 2: Optimum Humidity Range for Human Comfort and Health (Source: Sterling et al. 1985) Sterling EM, Arundel A, Sterling TD. 1985. Criteria for human exposure to humidity in occupied buildings. *ASHRAE Transactions, 91(1B): 611-622.*

A MERV 13 filter reduces pass-through of small infectious particles more than the MERV 8 filter. However, if not installed and sealed properly, the virus can bypass the filter. Additionally, system fans must be able to handle the higher pressure in the air stream resulting from use of the higher MERV filter. Another air filtration option is portable room air cleaners with HEPA filters.

Particularly with high-risk situations, using upper-room UVGI (ultraviolet germicidal irradiation) with UVC (UV light wavelength at 254 nm) fixtures or lamps or installing UVGI in the HVAC system (ductwork or air handling unit) is worth considering. A study from the 1940s[36] demonstrates a reduction in transmission of the measles virus using upper-room UV lights—with UV, only 10% of the subjects contracted the virus; without UV, 40% contracted it. A more recent study shows reduction in absenteeism during the common flu season with use of upper-room UV as well.[37]

As many as half of the people with COVID-19 also have diarrhea and shed the virus via their stool, raising concern about fecal-oral transmission.[38] Sufficient handwashing and other good personal hygiene along with touchless operations in and regular cleaning and sanitization of bathrooms are important interventions in preventing this transmission, but there are additional concerns. Toilet flushing may cause aerosolization of the virus, generating a plume of droplets that can subsequently be inhaled or deposited on surrounding surfaces. Therefore, toilet lids are beneficial to reduce virus transmission. The well-documented case of the Amoy Gardens apartment complex in Hong Kong[39] during the SARS pandemic of 2002 demonstrates the potential for transmission of virus-laden aerosols spreading through poorly ventilated plumbing systems from bathroom to bathroom in a single building. These aerosols also have the potential to spread from building to building via prevailing winds.

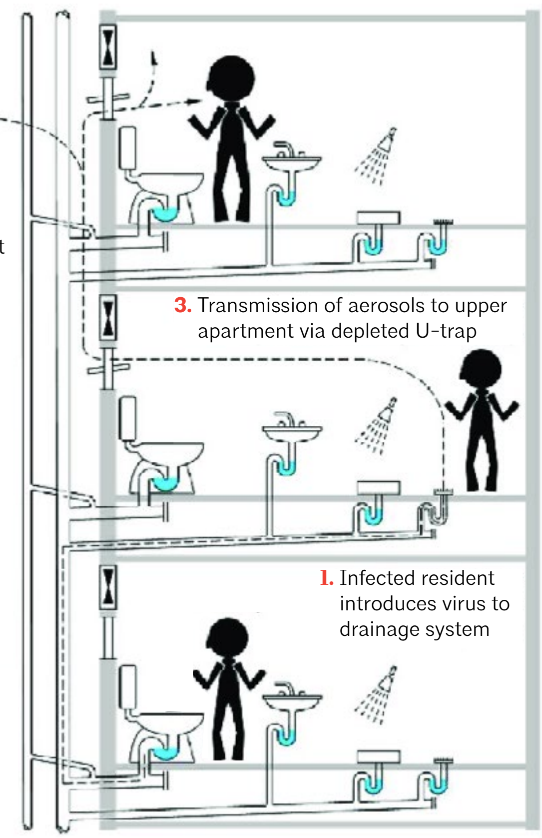

Figure 3: SARS transmission route at Amoy Gardens via the sanitary plumbing system. doi:10.1371/journal.pone.0171556.g001

Human behavior, compliance, and compliance fatigue also play an important role when considering perception of the risk of SARS-CoV-2 virus/COVID-19 disease transmission. Risk assessment generally involves acknowledging the hazard, assessing the potential extent of exposure, and characterizing risks. Individuals vary in their risk tolerance; some may agree to take steps to mitigate the risk to obtain a safe outcome, while others are willing to take their chances and find the risk tolerable. This may create difficulties in controlling the COVID-19 incidence rate and possible resurgence of the virus. Some of the reasons for underestimating the risk are:

- overconfidence in facilities, operations, and people
- underestimating the seriousness of the potential outcome
- difficulty overcoming habits and/or a yearning to return to normal
- lack of personal experience with severe cases of COVID-19
- leadership demonstrating high tolerance to risk
- expectation that, if all else fails, a vaccination will be discovered to change everything

The goals then are to break the routes of exposure through careful design to minimize reliance on voluntary behavior (e.g., by promoting unidirectional workflow, designing for cleaning, minimizing potential for splash and touch, and optimizing opportunities to practice good hand hygiene).

There are also concerns about buildings that have remained unoccupied with building systems shut down.[40] Air and water safety in buildings that have incurred low or no occupancy (30+ days) is another critical issue. Building water distribution systems, including equipment with water reservoirs (i.e., anything utilizing water, such as water heater storage, ice machines, drinking fountains, decorative fountains, and coffee machines), must be recommissioned. Water stagnates over extended periods of time, losing its disinfectant residual. Once disinfectant residual (e.g., chlorine or chloramines) dissipates, bacteria can grow and spread. Stagnated water may contain waterborne pathogens (e.g., *Legionella*), leading to disease cases and death. Also, depending upon existing piping materials for municipal service lines or building piping distribution, the lack of water flow allows for the buildup of potentially toxic metals, such as copper and lead, and disinfectant byproducts that can lead to illness or injury from exposure. The CDC, EPA, and AWWA have all developed guidelines specific to dormant buildings related to COVID-19 building re-occupancy.

Beyond the impact of COVID-19 response, there are additional public health concerns that must also be considered. The risk of future pandemics is increasing,[41] making design considerations for controlling infectious disease transmission paramount even after the current health crisis. Due to the varying nature of virus transmission and that guidance commonly refers to minimum recommendations, there is no one-size-fits-all approach to controlling pandemics. However, influenza and other pandemics (SARS, H1N1, Ebola) are not new either. Design professionals have the opportunity to strengthen their knowledge about person-to-person, air, water, surface, and fecal/oral transmission in order to consider effective design solutions to protect the health, safety, and welfare of the public. Even in the current pandemic environment, the highest causes of death in the US[42] are related to disease that emerge from tobacco use, poor nutrition, and lack of exercise. Continual advancement of building design to promote equity, health, and well-being remains imperative.

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