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Reducing SARS-CoV-2 in Shared Indoor Air

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SARS-CoV-2 replicates in the respiratory tract and spreads through exhalation of infectious respiratory particles. The chances of transmission increase the longer an uninfected person stays in an enclosed space with an infected person. Infection can occur not only through short-range transmission of exhaled respiratory particles from an infectious person resulting in mucous membrane deposition or inhalation of exhaled respiratory particles by an uninfected person. Infection also can occur through long-range transmission from inhalation of infectious respiratory particles that remain suspended in air for longer periods (potentially after the infectious person is no longer present) and across longer distances (greater than a few meters).

Because no single approach is 100% effective in preventing COVID-19, prevention measures work best when layered, including vaccination and nonpharmacologic interventions that reduce inhalation of infectious particles. Community masking and physical distancing, both of which can reduce the likelihood of encountering and inhaling virus-containing particles, have received substantial attention. However, there is less public awareness about existing indoor air recommendations that can directly reduce the number of virus-containing particles in indoor air and thereby reduce the risk of inhaling these particles from shared air.

Methods to reduce the concentration of SARS-CoV-2 particles in indoor air include ventilation, filtration, and disinfection. Much remains to be learned about benefits of specific interventions and combinations under different circumstances. However, observational studies and modeling suggest substantial effectiveness for these strategies used alone, combined, and with other approaches. For example, in a 2020 study that included 169 Georgia elementary schools, COVID-19 incidence was 39% lower in 87 schools that improved ventilation compared with 37 schools that did not (35% lower in 39 schools that improved ventilation through dilution alone [incidence rates, 2.94 vs 4.19 per 500 students enrolled] and 48% lower in 31 schools that improved ventilation through dilution combined with filtration [incidence rates, 2.22 vs 4.19 per 500 students enrolled]).[1] A simulation

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model found that filtration with 2 high-efficiency particulate air (HEPA) cleaners alone or combined with mask wearing could potentially reduce exposure to infectious particles by an estimated 65% or 90%, respectively.[2]

To date, there has been limited and uneven implementation of interventions to prevent SARS-CoV-2 transmission by reducing its concentration in the air. A report in *Morbidity and Mortality Weekly Report* highlights the considerable heterogeneity and inequity that schools report in the deployment of these measures.[3] In this report based on a nationally representative sample of 420 schools in 2022, low-cost interventions (opening windows and doors) were widely used, but higher-cost and resource-intensive strategies such as upgrading heating, ventilation, and air conditioning (HVAC) systems were used much less frequently. Schools in rural areas or at mid-level poverty (with 26% to 75% of students eligible for free or reduced-priced meals) were least likely to implement several measures.[3] It is likely that comparable disproportionalities exist in other indoor settings, from homes to businesses to large public spaces such as airports.

Reducing contaminants in shared air by improving air handling systems in buildings is an attractive, broadly effective structural measure that does not require repeated individual actions. An individual can wear a mask, open windows and doors, turn on fans and vents, and use portable air cleaners. Like fluoridation of drinking water to prevent tooth decay and road and vehicle design improvements to increase road safety,[4] structural interventions that reduce the concentration of SARS-CoV-2 particles in the air can protect more people with less individual effort. Such strategies are increasingly valuable as society learns to coexist with COVID-19 and people return to sharing indoor spaces.

A growing list of options exists for structural interventions to prevent COVID-19 through dilution, filtration, and disinfection of shared indoor air. Air handling system upgrades, improvements, or setting changes can reduce viral particle concentrations by bringing in outdoor air to dilute potential contaminants. Using air filters with higher minimum efficiency reporting value (MERV) ratings in HVAC systems can more effectively filter respiratory particles from recirculated air. Portable and commercially available HEPA air cleaners can do the same for a single room without modifying the building's existing air handling system. These devices can be especially useful in areas used by people at greater risk of having or acquiring COVID-19. Air disinfection methods such as upper room and in-duct UV germicidal irradiation are options for health care facilities and other settings (eg, school nurses' offices, homeless shelter sleeping areas) where people with COVID-19 are likely to be present or where there is crowding and the health status of individuals is unknown.

Through the American Rescue Plan, Congress has appropriated nearly a half trillion dollars ($350 billion to state, local, and tribal governments and $122 billion to schools), roughly half of which remains available to support indoor air quality improvements in small businesses, industrial settings, commercial buildings, low-income housing, transportation hubs, and schools. To ensure that maximum benefit is realized from these resources and to protect the public from ineffective or potentially harmful technologies, the Environmental Protection Agency (EPA) recently issued guidance for building owners and operators as part of the agency's Clean Air in Buildings challenge.[5] Centers for Disease Control and Prevention (CDC) guidance likewise highlights proven interventions to improve ventilation and filtration in buildings.[6] The CDC also provides interactive tools for home and schools to estimate the effects on indoor air quality of simple changes such as opening windows, upgrading HVAC filters, or using a HEPA air cleaner.[7]

Balancing effectiveness, equity, and feasibility means that the optimal set of interventions will vary by setting and situation. Many enhancements to ventilation and filtration can be made at no or low (<$100) cost, including opening windows, inspecting and maintaining HVAC systems, and using fans to increase the effectiveness of open windows. Portable HEPA air cleaners can be added for a few hundred dollars each.[6] Environmental or safety considerations (eg, temperature extremes, fall risk, crime) might make low-cost interventions such as opening windows less feasible in some circumstances. In underresourced settings, there may be fewer resources to mitigate such concerns (eg, converting windows on high floors that cannot be opened to windows that can be opened with window guards). Although do-it-yourself options are not recommended as permanent solutions, they can be less costly and, when properly constructed, may be more practical in resource-constrained settings than commercial options.[8]

Most costly are large structural improvements, such as new or updated HVAC systems in public buildings; however, these structural changes most equitably improve indoor air quality for many people simultaneously and can also generate energy savings costs. The CDC, EPA, ASHRAE, and other organizations have voluntary recommendations and guidance for HVAC systems.[5,6] Schools that take advantage of available funding to follow these recommendations can improve health and safety for all students and employees. Businesses that update HVAC systems not only benefit from energy efficiency and future cost savings but also make the environment safer for all workers and customers, especially essential workers who may need to interact with large numbers of people in the public.

Several methods are readily available to assess if improvements are working. Carbon dioxide monitors can provide insight on how well an occupied space is ventilated.[6] Airflow measurement devices and tracer gas tests can directly examine ventilation rates. Aerosol sensors can determine the effectiveness of filtration systems.

Improving air quality has the potential to reduce not only infections with SARS-CoV-2 but also infections with other respiratory viruses and bacteria, reactive airway disease (eg, asthma) triggered by antigens,[9] pulmonary and cardiovascular injury from inhalation of harmful respiratory particulates (eg, wildfires, smog), and toxicity from inhalation of volatile organic compounds. A once-in-decades opportunity now exists to make sustained improvements to public and private indoor air quality, reduce COVID-19 risk, and improve school, workplace, and consumer health and safety.

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