Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™

COVID-19

# Ventilation in Buildings

Updated Mar. 23, 2021 Print

## Summary of Recent Changes

### Updates as of March 23,2021

- Simplified language in the overall list of tools to improve ventilation.
- Added three new Frequently Asked Questions (FAQs) on the usefulness of carbon dioxide monitors to inform ventilation decisions, the useful of temperature and relative humidity to control the spread of COVID-19, and the use of fans indoors.
- Expanded the FAQ on emerging technologies to include more products available on the market.
- Added additional information with simple calculations to the FAQ on portable HEPA air cleaners to help consumers choose appropriate units for their spaces.

CDC recommends a layered approach to reduce exposures to SARS-CoV-2, the virus that causes COVID-19. This approach includes using multiple mitigation strategies, including improvements to building ventilation, to reduce the spread of disease and lower the risk of exposure. In addition to ventilation improvements, the layered approach includes physical distancing, wearing face masks, hand hygiene, and vaccination.

SARS-CoV-2 viral particles spread between people more readily indoors than outdoors. Indoors, the concentration of viral particles is often higher than outdoors, where even a light wind can rapidly reduce concentrations. When indoors, ventilation mitigation strategies can help reduce viral particle concentration. The lower the concentration, the less likely viral particles can be inhaled into the lungs (potentially lowering the inhaled dose); contact eyes, nose, and mouth; or fall out of the air to accumulate on surfaces. Protective ventilation practices and interventions can reduce the airborne concentrations and reduce the overall viral dose to occupants.

Reoccupying a building during the COVID-19 pandemic should not, in most cases, require new building ventilation systems. However, ventilation system upgrades or improvements can increase the delivery of clean air and dilute potential contaminants. Consult experienced heating, ventilation, and air conditioning (HVAC) professionals when considering changes to HVAC systems and equipment. Buildings that provided healthy, code-compliant indoor air quality prior to the pandemic can be improved for pandemic occupancy using less costly interventions. Below is a list of ventilation interventions that can help reduce the concentration of virus particles in the air. They represent a list of "tools in the mitigation toolbox," each of which can contribute towards a reduction in risk. Implementing multiple tools at the same time is consistent with CDC's layered approach and will increase overall effectiveness of ventilation interventions. These ventilation interventions can reduce the risk of exposure to the virus and reduce the spread of disease, but they will not eliminate risk completely.

While the list of tools can be universally applied across indoor environments, applying them to different building types, occupancies, and activities under environmental and seasonal changes can be challenging. The specific combination of tools chosen for use at any point in time can change. It will be up to the building owner or operator (with expert consultation as needed) to identify which tools are appropriate for each building throughout the year. In addition to buildings, vehicles – including public transportation such as buses, subways, trains, school buses, carpools, and rideshares – are also areas where ventilation improvements can be applied to reduce the spread of the virus and lower the risk of exposure.

## Tools to Improve Ventilation

Some of the following interventions are based on the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Guidance for Building Operations During the COVID-19 Pandemic . Not all interventions will work in all scenarios. Use caution in highly polluted areas when increasing outdoor air ventilation.

Consider using some or all of the following tools to improve ventilation:

- Increase the introduction of outdoor air:
  - Open outdoor air dampers beyond minimum settings to reduce or eliminate HVAC air recirculation. In mild weather, this will not affect thermal comfort or humidity. However, this may be difficult to do in cold, hot, or humid weather, and may require consultation with an experienced HVAC professional.
  - Open windows and doors, when weather conditions allow, to increase outdoor air flow. Do not open windows and doors if doing so poses a safety or health risk (e.g., risk of falling, triggering asthma

symptoms) to occupants in the building. Even a slightly open window can introduce beneficial outdoor air.

- Use fans to increase the effectiveness of open windows:
  - To safely achieve this, fan placement is important and will vary based on room configuration. Avoid placing fans in a way that could potentially cause contaminated air to flow directly from one person to another (see FAQ below on indoor use of fans). One helpful strategy is to use a window fan, placed safely and securely in a window, to exhaust room air to the outdoors. This will help draw outdoor air into the room via other open windows and doors without generating strong room air currents. Similar results can be established in larger facilities using other fan systems, such as gable fans and roof ventilators.
- Ensure ventilation systems operate properly and provide acceptable indoor air quality for the current occupancy level for each space.
- Rebalance or adjust HVAC systems to increase total airflow to occupied spaces when possible.
- Turn off any demand-controlled ventilation (DCV) controls that reduce air supply based on occupancy or temperature during occupied hours. In homes and buildings where the HVAC fan operation can be controlled at the thermostat, set the fan to the "on" position instead of "auto," which will operate the fan continuously, even when heating or air-conditioning is not required.
- Improve central air filtration:
  - Increase air filtration to as high as possible without significantly reducing design airflow. Increased filtration efficiency is especially helpful when enhanced outdoor air delivery options are limited.
  - Make sure air filters are properly sized and within their recommended service life.
  - Inspect filter housing and racks to ensure appropriate filter fit and minimize air that flows around, instead of through, the filter.
- Ensure restroom exhaust fans are functional and operating at full capacity when the building is occupied.
- Inspect and maintain exhaust ventilation systems in areas such as kitchens, cooking areas, etc. Operate these systems any time these spaces are occupied. Consider operating them even when the specific space is not occupied, to increase overall ventilation within the occupied building.
- Consider portable high-efficiency particulate air (HEPA) fan/filtration systems to enhance air cleaning (especially in higher risk areas such as a nurse's office or areas frequently inhabited by people with a higher likelihood of having COVID-19 and/or an increased risk of getting COVID-19). See the FAQ below on HEPA filters and portable HEPA air cleaners. (Note: Portable air cleaners that use filters less efficient that HEPA filters also exist and can contribute to room air cleaning. However, they should be clearly labeled as non-HEPA units.)
- Generate clean-to-less-clean air movement by evaluating and repositioning as necessary, the supply louvers, exhaust air grilles, and/or damper settings. See the FAQ below on Directional Airflow. This recommendation is easier to accomplish when the supply and exhaust points are located in a ceiling grid system.
- Consider using ultraviolet germicidal irradiation (UVGI) as a supplemental treatment to inactivate SARS-CoV-2, especially if options for increasing room ventilation and filtration are limited. Upper-room UVGI systems can be used to provide air cleaning within occupied spaces, and in-duct UVGI systems can help enhance air cleaning inside central ventilation systems.
- In non-residential settings, consider running the HVAC system at maximum outside airflow for 2 hours before and after the building is occupied.

The ventilation interventions listed above come with a range of initial costs and operating costs, which, along with risk assessment factors – such as community incidence rates, facemask compliance expectations and room occupant density – may affect the selection of tools. The following are examples of cost estimates for ventilation interventions:

- No cost: opening windows; inspecting and maintaining dedicated exhaust ventilation; disabling DCV controls; repositioning outdoor air dampers
- Less than $100: using fans to increase effectiveness of open windows; repositioning supply/exhaust diffusers to create directional airflow
- $500 (approximately): adding portable HEPA fan/filter systems
- $1500 to $2500 (approximately): adding upper room UVGI

# Ventilation FAQs

## Can COVID-19 be transmitted through HVAC (ventilation) systems?

The risk of spreading SARS-CoV-2, the virus that causes COVID-19, through ventilation systems is not clear at this time. Viral RNA has reportedly been found on return air grilles, in return air ducts, and on heating, ventilation, and air conditioning (HVAC) filters, but detecting viral RNA alone does not imply that the virus was capable of transmitting disease. One research group reported that the use of a new air-sampling method allowed them to find viable viral particles within a COVID-19 patient's hospital room with good ventilation, filtration and ultraviolet (UV) disinfection (at distances as far as 16 feet from the patient). However, the concentration of viable virus detected was believed to be too low to cause disease transmission. There may be some implications for HVAC systems associated with these findings, but it is too early to conclude that with certainty. While airflows within a particular space may help spread disease among people in that space, there is no definitive evidence to date that viable virus has been transmitted through an HVAC system to result in disease transmission to people in other spaces served by the same system.

Healthcare facilities have ventilation requirements in place to help prevent and control infectious diseases that are associated with healthcare environments. For more information, see the CDC Guidelines for Environmental Infection Control in Health-Care Facilities.

Non-healthcare (e.g., businesses and schools) building owners and managers should, at a minimum, maintain building ventilation systems according to state and local building codes and applicable guidelines. Ensuring appropriate outdoor air and ventilation rates is a practical step to ensure good indoor air quality.

## How long will it take to dilute the concentration of infectious particles in a room once they are generated?

While large droplets (100 micrometers [μm] and larger) will settle to surrounding surfaces within seconds, smaller particles can stay suspended in the air for much longer. It can take several minutes for particles 10 μm in size to settle, while particles 5 μm and smaller may not settle for hours or even days. Dilution ventilation and particle

filtration are commonly used to remove these smaller particles from the air. Larger particles can also be removed using these strategies, but since they fall out of the air quickly, they might not have a chance to get captured by filtration systems.

The time required to remove airborne particles from a space can be estimated using Table B.1 in the CDC's Guidelines for Environmental Infection Control in Health-Care Facilities (2003). The estimates assume the source of infectious particles is no longer present in the space. The estimates are based upon the rate that particle-free air is delivered to the room and the desired removal efficiency (99% or 99.9%). The particle-free air, measured in air changes per hour (ACH), can be uncontaminated supply air or the clean exhaust from a High Efficiency Particulate Air (HEPA) fan/filtration system [See HEPA filtration discussion below].

Although there are some highly contagious airborne diseases (like measles) where CDC provides specific guidance for 99.9% clearance wait times, the general recommendation in CDC's Guidelines for Environmental Infection Control in Health-Care Facilities is to wait to allow for a 99% reduction of any generated airborne particles before re-entering the room.

In the absence of guidance specifying a longer wait period for SARS-CoV-2, the wait time associated with 99% clearance is appropriate for healthcare and other spaces. Regardless of whether the 99% or 99.9% column on Table B.1 is used, the value in the table is usually an under-estimation of the actual dilution clearance time as noted in the table's footnotes which include the following statement: "The times given assume perfect mixing of the air within the space (i.e., mixing factor = 1). However, perfect mixing usually does not occur. Removal times will be longer in rooms or areas with imperfect mixing or air stagnation." Appropriate use of Table B.1 to establish clearance times from any space requires multiplying the time in the table by a mixing factor (k) that ranges between 1 and 10. This factor represents how well the ventilation system mixes and dilutes the concentration of airborne particles within the room.

As a rule of thumb, rooms with higher airflow rates (6 ACH and higher) and good placement of supply and exhaust grilles (hospital airborne infection isolation rooms) are considered to have "good" mixing and thus a mixing factor of k = 3 is often used for these spaces. In that case, the time identified from Table B.1 should be multiplied by 3 to determine the actual clearance time prior to re-entry. Nonventilated or poorly ventilated spaces have typical values of k ranging from 8 to 10. Increased ACH generally lead to reductions in k, although k can also be reduced by the use of a fan in the space, which does not have an impact on ACH. Ultimately, wait times can be reduced by increasing ACH, reducing k, or a combination of both.

**Example 1**. Given: A room measuring 12 feet x 10 feet with a ceiling height of 10 feet is served with a 100% outdoor air ventilation system that delivers 65 cubic feet per minute (cfm) of supply air ($Q_s$ = 65 cfm) and exhausts 80 cfm of air from the room ($Q_e$ = 80 cfm). The room has average air mixing, so assign k = 5.

Question: How much time is required to reduce the airborne concentration by 99 percent?

Solution: Since $Q_e$ is larger than $Q_s$ by 15 cfm, the heating, ventilation, and air conditioning (HVAC) system is pulling 15 cfm of air into the room from adjacent areas (i.e., the room is under negative pressure). For this example, the 15 cfm of transfer air is assumed to be free of infectious airborne particles. The clean volumetric air flow rate (Q) is the larger value between $Q_s$ and $Q_e$, so Q = 80 cfm. Calculate the air changes per hour:

ACH = [Q x 60] / (room volume) = (80 cfm x 60) / (12' x 10' x 10') = 4800/1200 = 4.0 ACH

Using Table B.1 the perfect mixing wait time based on 4 ACH and a 99% reduction of airborne particles is 69 minutes.

Using the mixing factor of 5, the estimated wait time for 99% reduction of airborne contaminants in the room is 5 x 69 = 345 minutes or 5 hours and 45 minutes.

**Note:** Determining the true value of the mixing factor is difficult and requires special equipment to measure air flows and conduct tracer gas decay testing. Thus, conservative estimates of k are often used (as described above). Also, the addition of an air cleaning device (e.g., a portable HEPA filtration unit) within the same room will reduce the wait time. The flow rate from the air cleaning device can be added to Q determined above, which will increase the overall ACH in the room. The air movement created by the air cleaning device can also decrease the value of k. Together, the increased ACH and decreased k can help substantially reduce wait times. See Example 2 for more information, including an example of the calculations.

## Can ventilation filters effectively capture SARS-CoV-2 viral particles?

Filters for use in heating, ventilation, and air conditioning (HVAC) systems are generally tested under procedures outlined in ANSI/ASHRAE Standard 52.2-2017-Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size. This standard was developed by ASHRAE, a global society focused on building systems, indoor air quality, and sustainability in the built environment, and is available for free online viewing during the ongoing pandemic. Based on the filtration efficiency determined by the testing procedures, filters are assigned a Minimum Efficiency Reporting Value (MERV). The MERV provides a measure of the "filter efficiency" over the range of particle sizes prescribed in the test procedure. MERV values range from 1 to 16 and higher MERV values correspond to more efficient filters.

Research shows that the particle size of SARS-CoV-2 is around 0.1 micrometer (µm). However, the virus generally does not travel through the air by itself. These viral particles are human-generated, so the virus is trapped in respiratory droplets and droplet nuclei (dried respiratory droplets) that are larger than an individual virus. Most of the respiratory droplets and particles exhaled during talking, singing, breathing, and coughing are less than 5 µm in size. CDC recommends using the highest efficiency ventilation filters possible, without having detrimental effects on overall HVAC system performance. ASHRAE has similar guidance; however, they recommend a minimum filtration efficiency target of MERV 13, provided there are not substantial negative impacts on the HVAC system performance and occupant comfort. A MERV 13 filter is at least 50% efficient at capturing particles in the 0.3 µm to 1.0 µm size range and 85% efficient at capturing particles in the 1 µm to 3 µm size range. Collectively these particles are capable of remaining airborne for hours and are most associated with deep lung penetration. A MERV 14 filter is at least 75% and 90% efficient, respectively, at capturing those same particles. Efficiencies for MERV 15 and MERV 16 filters are even higher. Thus, the recommended filters are significantly more efficient at capturing particles of concern than a typical MERV 8 filter, which is only around 20% efficient in the 1 µm to 3 µm size range and is not rated for capture efficiency of the smaller 0.3 µm to 1.0 µm particles.

Increasing filtration efficiency can increase the pressure drop across the filters. This can lead to increased fan energy, reduced airflow rates, and/or issues controlling indoor temperature and relative humidity levels. Scientific developments in filter design and manufacturing have reduced the amount of the increased pressure drop and its resulting impact on HVAC operations, but not all filters have adopted the newer technology. Prior to a filtration upgrade, the specific filters under consideration should be investigated for their pressure drop ratings at the flow rate(s) of intended use and the potential impacts of that pressure drop evaluated against the capabilities of the existing HVAC system.

High-efficiency particulate air (HEPA) filters are even more efficient at filtering human-generated infectious particles than MERV 16 filters. However, outside of a few unique applications, HEPA filters are rarely used in central HVAC systems. [See the question on Portable HEPA Filtration to learn more about them and their application in protective air cleaning].

## What is meant by “directional airflow?” How and where should it be used?

Directional airflow is a protective ventilation concept where air movement flows in a clean-to-less-clean direction. This ventilation concept is applied to areas where the “clean” environment requires a higher level of protection and/or where the “less-clean” environment has a higher risk of containing airborne contaminants (activities or occupancy by individuals with a higher risk of being infectious). Examples of “clean” spaces might include healthcare facility triage stations or rooms/corridors adjacent to higher risk activities. Examples of “less-clean” spaces might include spaces that contain known/suspect infectious persons or spaces where a known activity has increased likelihood of generating infectious airborne particles.

The creation of directional airflow can be accomplished within a particular space or between two adjacent spaces. This can be done passively, through intentional placement of supply and exhaust heating, ventilation, and air conditioning (HVAC) grilles, or by the intentional creation of pressure differentials between adjacent spaces through specification of offset exhaust and supply air flow rates. Creation of the directional airflow can also be done actively, through the use of fans exhausting through open windows, strategic placement of ductwork attached to portable HEPA filtration units, or dedicated exhaust systems (installed or portable) that generate a desired airflow by exhausting air out of windows, doorways, or through temporary ducts. In specific settings, specialized local control ventilation interventions that establish the desired airflow directions can also be used (see the NIOSH Ventilated Headboard).

Directional airflows must be evaluated carefully. Testing of the directional airflow effectiveness can be accomplished using visual tracer techniques that use “smoke tubes” or handheld “fog generators.” Other tools, such electronic monitors or visual aids to monitor pressure differences can be used when directional airflow is established between two adjacent spaces. To reduce the potential for directing airflow from infectious towards non-infectious space occupants, it is important that the “clean” and “less-clean” space determinations be established using infection control risk assessment considerations.

## What is a HEPA filter and why use a portable HEPA air cleaner?

Research shows that the particle size of SARS-CoV-2 is around 0.1 micrometer (µm). However, the virus generally does not travel through the air by itself. These viral particles are human-generated, so the virus is trapped in respiratory droplets and droplet nuclei (dried respiratory droplets) that are larger. Most of the respiratory droplets and particles exhaled during talking, singing, breathing, and coughing are less than 5 µm in size. By definition, a High Efficiency Particulate Air (HEPA) filter is at least 99.97% efficient at capturing particles 0.3 µm in size. This 0.3 µm particle approximates the most penetrating particle size (MPPS) through the filter. HEPA filters are even more efficient at capturing particles larger **and** smaller than the MPPS. Thus, HEPA filters are no less than 99.97% efficient at capturing human-generated viral particles associated with SARS-CoV-2.

Portable HEPA filtration units that combine a HEPA filter with a powered fan system are a preferred option for auxiliary air cleaning, especially in higher risk settings such as health clinics, vaccination and medical testing locations, workout rooms, or public waiting areas. Other settings that could benefit from portable HEPA filtration can be identified using typical risk assessment parameters, such as community incidence rates, facemask

compliance expectations, and room occupant density. While these systems do not bring in outdoor dilution air, they are effective at cleaning air within spaces to reduce the concentration of airborne particulates, including SARS-CoV-2 viral particles. Thus, they give effective air exchanges without the need for conditioning outdoor air.

In choosing a portable HEPA unit, select a system that is appropriately sized for the area in which it will be installed. This determination is made based on the air flow through the unit, which is typically reported in cubic feet per minute (cfm). Many portable HEPA filtration units are assigned a Clean Air Delivery Rate (CADR) (See EPA's Guide To Air Cleaners In The Home ), which is noted on a label in the operators manual, on the shipping box, and/or on the filtration unit itself. The CADR is an established standard defined by the Association of Home Appliance Manufacturers (AHAM). Participating portable air cleaner manufacturers have their products certified by an independent laboratory, so the end user can be assured it performs according to the manufacturer's claims. The CADR is generally reported in cfm for products sold in the United States. The paragraphs below describe how to select an appropriate air cleaner based on the size of the room in which it will be used. The procedure below should be followed whenever possible. If an air cleaner with the appropriate CADR number or higher is not available, select a unit with a lower CADR rating. The unit will still provide incrementally more air cleaning than having no air cleaner at all.

In a given room, the larger the CADR, the faster it will clean the room air. Three CADR numbers are given on the AHAM label, one each for smoke, dust, and pollen. The smoke particles are the smallest, so that CADR number applies best to viral particles related to COVID-19. The label also shows the largest room size (in square feet, $ft^2$) that the unit is appropriate for, assuming a standard ceiling height of up to 8 feet. If the ceiling height is taller, multiply the room size ($ft^2$) by the ratio of the actual ceiling height (ft) divided by 8. For example, a 300 $ft^2$ room with an 11-foot ceiling will require a portable air cleaner labeled for a room size of at least 415 $ft^2$ (300 × [11/8] = 415).

The CADR program is designed to rate the performance of smaller room air cleaners typical for use in homes and offices. For larger air cleaners, and for smaller air cleaners whose manufacturers choose not to participate in the AHAM CADR program, select a HEPA unit based on the suggested room size ($ft^2$) or the reported air flow rate (cfm) provided by the manufacturer. Consumers might take into consideration that these values often reflect ideal conditions which overestimate actual performance.

For air cleaners that provide a suggested room size, the adjustment for rooms taller than 8 feet is the same as presented above. For units that only provide an air flow rate, follow the "2/3 rule " to approximate a suggested room size. To apply this rule for a room up to 8 feet tall, choose an air cleaner with an air flow rate value (cfm) that is at least 2/3 of the floor area ($ft^2$). For example, a standard 300 $ft^2$ room requires an air cleaner that provides at least 200 cfm of air flow (300 × [2/3] = 200). If the ceiling height is taller, do the same calculation and then multiply the result by the ratio of the actual ceiling height (ft) divided by 8. For example, the 300 $ft^2$ room described above, but with an 11-foot ceiling, requires an air cleaner that can provide at least 275 cfm of air flow (200 × [11/8] = 275).

While smaller HEPA fan systems tend to be stand-alone units, many larger units allow flexible ductwork to be attached to the air inlet and/or outlet (note that larger ducted units don't fall under the "room air cleaner" description and may not have a CADR rating). Using ductwork and placing the HEPA system strategically in the space can help provide desired clean-to-less-clean airflow patterns where needed. Ducted HEPA systems can also be used to establish direct source capture interventions for patient treatment and /or testing scenarios (See CDC/NIOSH discussion on Ventilated Headboard). Depending on the size of the HEPA fan/filter units and how the facility in which they are being used is configured, multiple small portable HEPA units deployed to high risk areas may be more useful than one large HEPA unit serving a combined space.

**Example 2.** Given: The room described in Example 1 is now augmented with a portable HEPA air cleaning device with a smoke CADR of 120 cfm ($Q_{hepa}$ = 120 cfm). The added air movement within the room improves overall mixing, so assign k = 3.

Question: How much time is saved to achieve the same 99% reduction in airborne contaminants by adding the portable HEPA device to the room?

Solution: The addition of the HEPA filter device provides additional clean air to the room. Here, the clean volumetric air flow rate (Q) is: $Q = Q_e + Q_{hepa}$ = 80 cfm + 120 cfm = 200 cfm.

ACH = [Q x 60] / (room volume) = (200 cfm x 60) / (12' x 10' x 10') = 12,000/1,200 = 10 ACH.

Using Table B.1, the perfect mixing wait time based on 10 ACH and a 99% reduction of airborne particles is 28 minutes.

Using the mixing factor of 3, the estimated wait time for 99% reduction of airborne contaminants in the room is 3 x 28 = 84 minutes. Thus, the increased ACH and lower k value associated with the portable HEPA filtration unit reduced the wait time from the original 5 hours and 45 minutes to only 1 hour and 24 minutes, saving a total of 4 hours and 21 minutes before the room could be safely reoccupied.

Adding the portable HEPA unit increased the effective ventilation rate and improved room air mixing. This resulted in over a 75% reduction in time for the room to be cleared of potentially-infectious airborne particles.

## Does ultraviolet germicidal irradiation (UVGI) kill SARS-CoV-2?

Yes. Ultraviolet germicidal irradiation (UVGI), otherwise known as germicidal ultraviolet (GUV), is a disinfection tool used in many different settings, such as residential, commercial, educational, and healthcare settings. The technology uses ultraviolet (UV) energy to inactivate (kill) microorganisms, including viruses, when designed and installed correctly.

There is still a lot to learn about SARS-CoV-2 and the extent of airborne viral particles and spread. However, UVGI can inactivate viruses in the air and on surfaces.* The design and sizing of effective UVGI disinfection systems requires specific knowledge and experience.

Seek consultation with a reputable UVGI manufacturer or an experienced UVGI system designer prior to installing UVGI systems. These professionals can assist by doing necessary calculations, making fixture selections, properly installing the system, and testing for proper operation specific to the setting.

*Note: CDC's recommendation for primary surface disinfection in occupied environments is to follow the CDC/EPA guidance for surface disinfection.

## What types of ultraviolet germicidal irradiation (UVGI) devices are available for cleaning and disinfection in the workplace?

### Upper-room UVGI

Upper-room (or upper-air) UVGI uses specially designed UVGI fixtures mounted on walls or ceilings to create a disinfection zone of ultraviolet (UV) energy that is focused up and away from people. These fixtures disinfect air as it circulates from mechanical ventilation, ceiling fans, or natural air movement. The advantage of upper-room UVGI is that it disinfects the air closer to and above people who are in the room. Since the 1980s, UVGI systems have been widely used for control of tuberculosis (TB). The CDC guidance Environmental Control for Tuberculosis: Basic Upper-Room Ultraviolet Germicidal Irradiation Guidelines for Healthcare Settings provides information on appropriate UVGI system design, related safe operation, and maintenance. Based on data from other human coronaviruses, a UVGI system designed to protect against the spread of TB should be effective at inactivating SARS-CoV-2 and therefore prevent spread. UVGI systems usually require a few UV fixtures to be effective. For example, a rectangular-shaped waiting room with 10–30 occupants will require 2–3 upper-air UVGI fixtures. As part of system installation, care must be taken to control the amount of UV energy directed or reflected into the lower occupied space below levels recognized as safe. Reputable UVGI manufacturers or experienced UVGI system designers will take the necessary measurements and make any required adjustments to prevent harmful UV exposures to people in the space.

**Potential Application:** Can be used in any indoor environment; most useful in spaces highly occupied with people who are or may be sick.

### In-Duct UVGI

In-duct UVGI systems are installed within a heating, ventilation, and air-conditioning (HVAC) system. These systems are designed to serve one of two purposes:

**1) Coil treatment UVGI** keeps HVAC coils, drain pans, and wetted surfaces free of microbial growth. These devices produce relatively low levels of UV energy. This energy is continually delivered 24 hours a day, which is why they are effective. Coil treatment UVGI devices are not designed for disinfecting the air and should not be installed for the purpose of air disinfection.

**Potential Application:** Can be used to reduce HVAC maintenance and improve operational efficiency within large, commercial HVAC systems or residential HVAC systems; not recommended for inactivating airborne pathogens.

**2) Air disinfection UVGI** systems can be effective at applying intense UV energy to inactivate airborne pathogens as they flow within the HVAC duct. HVAC air disinfection UVGI systems generally require more powerful UV lamps or a greater number of lamps, or both, to provide the necessary UVGI required to inactivate pathogens in a short period of time. Air disinfection systems are often placed downstream of the HVAC coils. This location keeps the coil, drain pan, and wetted surfaces free of microbial growth and also disinfects the moving air.

**Potential Application:** Can be used inside any HVAC system to disinfect infectious airborne pathogens.

### Far-UV (or Far-UVC)

Far-UV is one of many emerging technologies that have become popular during the COVID-19 pandemic. While standard UVGI fixtures emit UV energy at a wavelength around 254 nanometers (nm), far-UV devices use different lamps to emit UV energy at a wavelength around 222 nm. Aside from the wavelength, a major difference between the two technologies is that standard UVGI systems are specifically designed to avoid exposing people to the UV energy, while many far-UV devices are marketed as safe for exposing people and their direct environment to UV energy. A review of peer-reviewed literature indicates that far-UV wavelengths can effectively inactivate

microorganisms, including human coronaviruses, when appropriate UV doses are applied. Questions remain about the mechanisms of killing microorganisms and overall safety. Far-UV might prove to be effective at disinfecting air and surfaces, without some of the safety precautions required for standard UVGI. Far-UV devices are best viewed as new and emerging technology. Consumers considering an emerging technology such as Far-UV should read the FAQ on emerging technologies below.

**Potential Application**: Yet to be determined.

## Many new air disinfection devices are marketed for their ability to inactivate SARS-CoV-2. How can I tell if they work as advertised?

CDC does not provide recommendations for, or against, any manufacturer or product. There are numerous technologies being heavily marketed to provide air cleaning during the ongoing COVID-19 pandemic. Common among these are ionization, dry hydrogen peroxide, and chemical fogging disinfection. Some products on the market include combinations of these technologies. These products generate ions, reactive oxidative species (ROS, which are marketed using many names), or chemicals into the air as part of the air cleaning process. People in spaces treated by these products are also exposed to these ions, ROS, or chemicals.

While variations of these technologies have been around for decades, relative to other air cleaning or disinfection methods, they have a less-documented track record when it comes to cleaning/disinfecting large and fast volumes of moving air within heating, ventilation, and air conditioning (HVAC) systems or even inside individual rooms. This does not necessarily imply the technologies do not work as advertised. However, in the absence of an established body of peer-reviewed evidence showing proven efficacy and safety under as-used conditions, the technologies are still considered by many to be “emerging.”

As with all emerging technologies, consumers are encouraged to exercise caution and to do their homework. Registration alone, with national or local authorities, does not always imply product efficacy or safety. Consumers should research the technology, attempting to match any specific claims against the intended use of the product. Consumers should request testing data that quantitively demonstrates a clear protective benefit and occupant safety under conditions consistent with the intended use. When considering air cleaning technologies that potentially or intentionally expose building occupants, the safety data should be applicable to all occupants, including those with health conditions that could be aggravated by the air treatment. In transient spaces, where average exposures to the public may be temporary, it is important to also consider occupational exposures for workers that must spend prolonged periods in the space.

Preferably, the documented performance data under as-used conditions should be available from multiple sources, some of which should be independent, third-party sources. Unsubstantiated claims of performance or limited case studies with only one device in one room and no reference controls should be questioned. At a minimum, when considering the acquisition and use of products with technology that may generate ozone, verify that the equipment meets UL 867 standard certification (Standard for Electrostatic Air Cleaners) for production of acceptable levels of ozone, or preferably UL 2998 standard certification (Environmental Claim Validation Procedure (ECVP) for Zero Ozone Emissions from Air Cleaners) which is intended to validate that no ozone is produced.

## Can carbon dioxide ($CO_2$) monitors be used to indicate when there is good ventilation?

Carbon dioxide ($CO_2$) monitoring can provide information on ventilation in a given space, which can be used to enhance protection against COVID-19 transmission. Strategies incorporating $CO_2$ monitors can range in cost and complexity. However, greater cost and complexity does not always mean greater protection.

Traditionally, $CO_2$ monitoring systems are expensive, require extensive knowledge to accurately install and set up, and require sophisticated control programs to effectively interact with the building heating, ventilation and air-conditioning (HVAC) systems in real time. They were not designed to protect building occupants from disease transmission. Developers of whole-building $CO_2$ monitoring equipment/software for HVAC system operations have been around for decades, with the technology most often applied in the pursuit of energy savings. As the current pandemic response has progressed, this technology has been marketed as a potential tool for providing an indication of building ventilation efficacy, leading to questions about whether monitoring indoor $CO_2$ concentrations can be used as a tool to help make ventilation decisions.

In some well-designed, well-characterized, well-maintained HVAC environments, the use of fixed $CO_2$ monitors can be informative. When used, these monitors are often incorporated into demand-controlled ventilation (DCV) systems that are designed with a primary intent of maximizing energy efficiency through reductions in outdoor air delivery. However, guidance throughout the pandemic has been to exceed minimum ventilation whenever possible, in addition to masking, physical distancing, enhanced filtration, and other intervention-focused considerations. From the beginning of this pandemic's response, both CDC and ASHRAE have advised to deactivate DCV systems and operate the ventilation systems at maximum airflows, within the safety limitations of the equipment.

Fixed-position $CO_2$ monitors measure $CO_2$ concentration as an indicator of the number of people in the space. As the $CO_2$ concentration increases, the HVAC DCV system increases the amount of outdoor air ventilation in the space to dilute $CO_2$ (and vice versa). The number of $CO_2$ sensors, the placement of those sensors, and their calibration and maintenance are collectively a large and complex issue that must not be overlooked. For example, the $CO_2$ concentration measured by a fixed, wall-mounted monitor may not always represent the actual concentrations in the occupied space. If air currents from the room HVAC, or even make-up air from windows, flows directly over this monitor location, the corresponding concentration measurements will be artificially low. If the room has good air mixing, the measured concentration should approximate the true concentration, but rooms are rarely well mixed, particularly in older buildings with aging ventilation systems (or none at all). Also, if an elevated $CO_2$ concentration results in an air flow increase to one room, that air may be "stolen" from other rooms on the same HVAC system. This may result in elevated $CO_2$ concentrations in those other spaces which the HVAC system is unable to control.

Limited information exists regarding a direct link associating $CO_2$ concentrations to a risk of COVID-19 transmission. Changes in $CO_2$ concentrations can indicate a change in room occupancy and be used to adjust the amount of outdoor air delivered. However, $CO_2$ concentrations cannot predict who has SARS-CoV-2 infection and might be spreading the virus, the amount of airborne viral particles produced by infected people, or whether the HVAC system is effective at diluting and removing viral concentrations near their point of generation. As a simple example, a small room with three occupants will have the same level of $CO_2$ (and hence the same outdoor air ventilation rate controlled by the DCV system) whether no one has SARS-CoV-2 infection or whether one or more people are infected with the virus. Ventilation based on $CO_2$ measurements cannot recognize the increased risk of transmission in the second scenario.

A more modest, cost-efficient, and accurate use of $CO_2$ monitoring is the use of portable instruments combined with HVAC systems that do not have modulating setpoints based on $CO_2$ concentrations. The $CO_2$ meter can be purchased for under $300 and its measurements can be collected/logged near the breathing zones of occupied areas of each room. Under this approach, the HVAC outdoor air dampers could be set to introduce more outdoor air than code requires (as recommended by CDC and ASHRAE) and the resulting $CO_2$ concentrations in rooms at the real-world occupancy levels documented using a calibrated, handheld portable $CO_2$ meter. This documentation will be the $CO_2$ concentration benchmarks for each room under the HVAC operating conditions and occupancy levels.

One potential target benchmark for good ventilation is $CO_2$ readings below 800 parts per million (ppm). If the benchmark readings are above this level, reevaluate the ability to increase outdoor air delivery. If unable to get below 800 ppm, increased reliance on enhanced air filtration (including portable HEPA air cleaners) will be necessary. Once the benchmark concentrations are established, take periodic measurements and compare them to the benchmarks. As long as the ventilation airflow is unchanged (outdoor air or total air) and the occupancy capacity is not increased, future portable $CO_2$ concentrations that are 110% of the benchmarks indicate a potential problem that should be investigated. Under the pandemic response, a pragmatic application of portable $CO_2$ measurement tools is a cost-effective approach to monitoring building ventilation.

## Should indoor temperature and humidity be used to help reduce the risk of COVID-19 transmission?

For COVID-19, the first steps in reducing the indoor concentrations of the virus are wearing face masks, physical distancing, and reducing occupancy levels. Improved ventilation is an additional prevention strategy. For ventilation systems, increasing outdoor air above the code minimum requirements, increasing total ventilation, and increasing filtration efficiencies are more effective at controlling infectious disease transmission than controlling indoor temperature and humidity. However, the use of temperature and/or humidity to reduce the risk of disease transmission should be considered on a case-by-case basis, taking into account the building enclosure, heating, ventilation, and air-conditioning (HVAC) system capabilities, level of control and/or building automation, local COVID-19 transmission rates, any unique clinical features of the occupants, and local climate.

Both temperature and humidity can influence the transmission of infectious diseases, including COVID-19, but that influence has practical limitations. Research on the impact of temperature has shown that SARS-CoV-2, the virus that causes COVID-19, is sensitive to elevated temperatures, with over 99.99% inactivation in only a few minutes at 70°C (158°F). However, this temperature is far outside the limits of human comfort and could damage some building materials. While temperatures lower than 70°C (158°F) are also effective, the required exposure time for inactivation increases as the temperature decreases. So, elevated temperatures offer the potential for decontamination of SARS-CoV-2 virus in the air or on surfaces, but the use of increased temperature solely for decontamination is not generally recommended and is not realistic for occupied spaces. Another important consideration is that when the temperature in a space is elevated, the corresponding relative humidity level decreases.

Current evidence is not persuasive that humidity significantly reduces transmission of SARS-CoV-2 beyond the level resulting from good ventilation and filtration. Some research studies have shown that the survival of viruses, including human coronaviruses, may be reduced when the relative humidity is in the 40–60% range. However, the reductions are modest and there are outliers to these findings. Consequently, neither ASHRAE nor CDC

recommends introducing humidification for the sole purpose of limiting transmission of COVID-19. While not affecting transmission, there are peer-reviewed studies that suggest preventing excessive dryness in the air could help maintain the effectiveness of the human body's immune system.

Some HVAC systems can actively control both temperature and humidity. However, the majority of HVAC systems do not have dedicated humidification capabilities. Some dehumidification happens during warmer months as a byproduct of cooling humid warm air below its dew point and causing water to condense out of the air. Less common is the ability to limit low humidity by introducing water vapor into the dry supply air.

Most existing residential and commercial buildings located in cold climates are not constructed to resist the corrosion and excessive moisture accumulation that can result from long-term, whole-building humidification. If additional winter humidification is used to maintain comfort and prevent excessive dryness of nasal and ocular membranes, first analyze the building enclosure to verify that condensation and moisture accumulation will not become a problem. ASHRAE Standard 160 (Criteria for Moisture-Control Design Analysis in Buildings) provides guidance for hygrothermal analysis of building enclosures. For commercial buildings that are properly constructed to allow for long-term humidification, and which have humidification capabilities already installed, there is no reason not to humidify the air to comfortable levels during the winter months.

In residential settings, portable in-room humidifiers may be used for sensory comfort and to reduce excessively low relative humidity levels. In these instances, use a humidifier with a built-in humidistat and control the relative humidity level near 40%. Higher humidity levels are not necessarily better and may lead to localized mold growth, mildew, and other long-lasting indoor air quality issues. Maintenance and cleaning of portable humidification systems is very important. Change the water in the humidifier daily and maintain and clean the humidifier in accordance with manufacturer recommendations.

## Can fans be used to decrease the risk of COVID-19 transmission indoors?

Yes. While fans alone cannot make up for a lack of outdoor air, fans can be used to increase the effectiveness of open windows, as described in the CDC list of ventilation improvement considerations. Fans can also be used indoors to improve room air mixing. Improved room air mixing helps distribute supplied clean air and dilute viral particle concentrations throughout the room, which reduces the likelihood of stagnant air pockets where viral concentrations can accumulate. As with all fan use during the COVID-19 pandemic, take care to minimize the potential to create air patterns that flow directly across one person onto another:

- Avoid the use of the high-speed settings
- Use ceiling fans at low velocity and potentially in the reverse-flow direction (so that air is pulled up toward the ceiling)
- Direct the fan discharge towards an unoccupied corner and wall spaces or up above the occupied zone.

Fans can also enable clean-to-less-clean directional airflow. Such applications should be evaluated closely to avoid unintended consequences and only adopted when supported by a safety risk assessment.

Last Updated Mar. 23, 2021
Content source: National Center for Immunization and Respiratory Diseases (NCIRD), Division of Viral Diseases