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ENHANCING INDOOR AIR QUALITY AND COVID-19 RISK REDUCTION

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Disclaimer

This document is based on best available knowledge and recommendations from national and global healthcare institutions and organizations. While we are confident in the research reviewed in this document, we strongly recommend reviewing and implementing the guidelines presented by ASHRAE, CDC, WHO, local government, and other reputable organizations.

Introduction

The COVID-19 pandemic that has affected every corner of the globe in 2020 and will have profound, long-lasting impacts on buildings design.

There is a very active research effort into how the coronavirus is transmitted and what can be done to reduce its transmission. One of the primary ways the virus is transmitted is through airborne respiratory droplets. The American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) has stated, “Transmission of SARS-CoV-2 through the air is sufficiently likely that airborne exposure to the virus should be controlled. Changes to building operations, including the operation of heating, ventilating, and air conditioning systems, can reduce airborne exposures. Ventilation and filtration provided by heating, ventilating, and air-conditioning systems can reduce the airborne concentration of SARS-CoV-2 in the breathing zone and thus the risk of transmission through the air”.

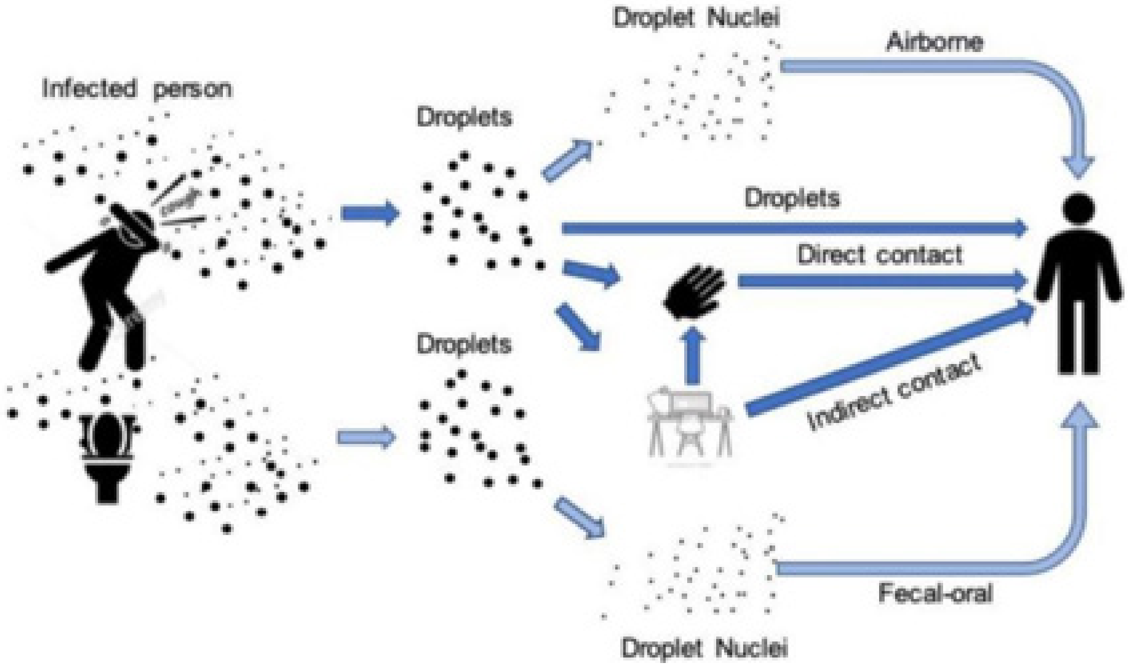
The purpose of this whitepaper is to outline recommendations and strategies for heating, ventilation, and air-conditioning systems (HVAC) that can help to reduce the risk of COVID-19 spread and infection in indoor environments. Research has proven that when properly maintained and operated, heating, ventilation, and air-conditioning systems (HVAC) can reduce the spread of viruses. These critical building systems not only provide thermal comfort but, according to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), may also improve resistance to infection.

Facts about COVID-19

COVID-19 is a disease caused by a new strain of coronavirus SARS-CoV-2. “CO” stands for corona, “VI” for virus, and “D” for disease. Formerly, this disease was referred to as “2019 novel coronavirus” or “2019-nCoV”. The COVID-19 virus is a new virus linked to the same family of viruses as Severe Acute Respiratory Syndrome (SARS) and some types of common cold.

The virus is transmitted through direct contact with respiratory droplets of an infected person (generated through coughing and sneezing). Individuals can also be infected from and touching surfaces contaminated with the virus and touching their face (e.g., eyes, nose, mouth). The COVID-19 virus may survive on surfaces for several hours.

COVID-19 also has the potential to be transmitted through another route: airborne transmission. Airborne transmission occurs when large droplets are released into the air (via coughing, sneezing, talking, shouting) and evaporate and desiccate into small particles, also known as droplet nuclei. These droplet nuclei can remain airborne for several hours and when infected, can spread COVID-19 to other individuals.



Why Indoor Air Quality (IAQ)?

The air in an occupied building will normally pass through an HVAC system multiple times per hour depending upon the building type and design. This means that the air we breathe as building occupants will be re-conditioned and re-circulated frequently by the HVAC system, and this includes all air particulates, both desirable and un-desirable. This recirculated air has been exposed to all conditions in the building, whether it be volatile organic compounds (VOCs) directly from a manufacturing process or direct output from building occupants in the form of carbon dioxide. Additionally, any airborne particulates carried by a person can be safely assumed to be part of the recirculated air. When evaluating indoor air quality and determining a plan of action with respect to HVAC systems, these compounds and particulates should be considered. **While specific airborne pathogens or other microorganisms may often be the most news-worthy concern, the negative impacts of other airborne contaminants in the airstream are significant and detrimental to both a building occupant's health as well as their cognitive function. Therefore, having an air quality strategy directly related to a building's HVAC system or design is extremely important so that the ability for a technology or strategy to control or remove these other airborne contaminants is not overlooked.**

HOW CAN AIR QUALITY BE IMPROVED BY THE HVAC SYSTEM?

Many different types of technology and design or control strategies are available to be implemented within an HVAC system. Additional hardware installation into or near the HVAC system such as higher air filtration, or modifications to the design or controls strategies such as higher ventilation, demand-controlled ventilation, and humidity control. Strategies may be applied to existing and new HVAC systems.

HOW CAN BUILDING'S HVAC SYSTEMS MITIGATE THE SPREAD OF AIRBORNE DISEASE?

A building's heating, ventilation, and air conditioning (HVAC) system has always been known as the mechanical system in the building that appropriately heats and/or cools the building and its occupants. However, the perceived role of the HVAC system is changing. The recent COVID-19 pandemic shed the light on potential building impacts to occupant health and safety, and therefore, on the increased focus on the role of the HVAC system and how it can assist in the indoor air quality (IAQ). Organizations such as ASHRAE and the CDC have come out with many new or updated guidelines or standards specific to HVAC systems and IAQ.

HVAC systems that are well-maintained and operated should not increase the risk of virus transmission. Air conditioning and ventilation are considered effective control strategies for preventing infection and ill health.

The CDC recommends increasing HVAC system ventilation and filtration to reduce the airborne concentration of SARS-CoV-2 if present in smaller droplets in the air as part of a comprehensive program to control the spread of COVID-19. The program also includes frequent hand washing, good respiratory etiquette, appropriate social distancing, face coverings, cleaning and disinfecting surfaces, and staying home if sick.

CDC guidance for HVAC system operations and maintenance is based on American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recommendations. ASHRAE has released guidance and position statements on best practices for HVAC usage within the built environment and recommended using HVAC to reduce the airborne transmission of COVID-19.

Changes to building operations, including the operation of HVAC systems, can reduce airborne exposures. The following sections outline risk management strategies that could be applied to reduce the risk of airborne transmission. These recommendations follow CDC and ASHRAE guidelines for building operations intended to slow the transmission of viruses via HVAC systems. Recommended procedures from ASHRAE include:

1. Increasing ventilation and Maximizing the amount of fresh air (outside air)
2. Improving filtration
3. Controlling and maintaining relative humidity
4. Air Purifiers
5. Ultraviolet Germicidal Irradiation Lights
6. Other strategies

Increasing Ventilation and Maximizing the Amount of Fresh Air (Outside Air)

Ventilation refers to the distribution and removal of air from space by mechanical or natural means. ASHRAE standard 62.1, along with many building codes dictate minimum rates of outdoor air introduction into a building depending upon building type, building use and occupancy level.

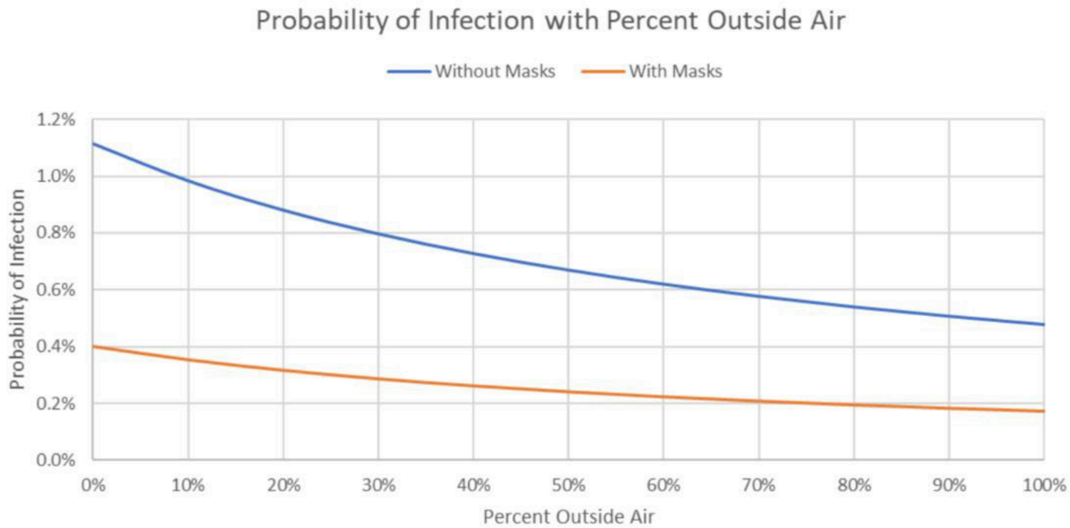
In recent years, adjusting HVAC systems to bring in less outdoor air lowered heating and cooling energy costs. However, during the pandemic, research has found that increasing ventilation rates improves air quality and reduces the risk of infection from long-range airborne diseases.

To minimize risk of transmission through the air, building HVAC system operations will be modified to provide the maximum amount of outdoor air that the HVAC equipment is rated while minimizing the percentage of recirculated air. Outdoor air and recirculated air ratios will be based on outdoor conditions and the capacity of the building's HVAC system.

The concern with increasing outside air flow beyond the equipment limits is that it can cause insufficient building heating/cooling, increasing operating and utility costs and damage to HVAC equipment and possibly the building itself. Higher ventilation rates can also lead to increases in the relative humidity of a building, with extreme RH resulting in thermal discomfort and negative health impacts. Changes to the ventilation of buildings must occur with these concerns of other impacts in mind.

Furthermore, increasing ventilation rates often requires a full HVAC system re-design. Not all systems can be retrofitted to significantly raise ventilation rates as this often requires larger equipment and/or significant changes to current ductwork.

Following graph shows the probability of infection for different outside air percentages, both with and without a masking policy. These numbers are for a typical office environment with a building size around 20,000 ft2. While an increased outside air rate is helpful, implementing a masking policy for every individual in the building will significantly reduce the probability of infection.



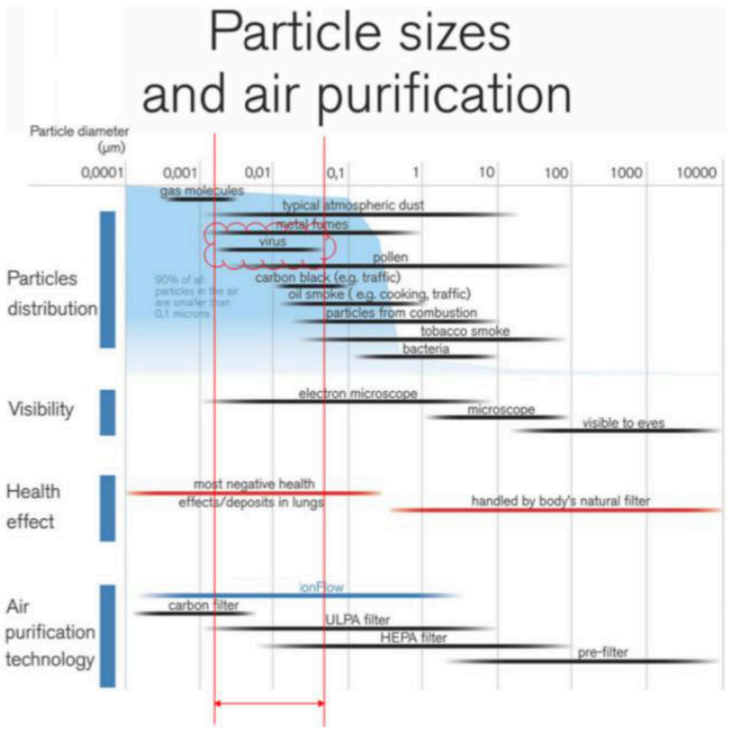
CONCERNS:

Air quality standards in the region need to be considered. If the building is in an area with significant outdoor air pollutants, then the introduction of higher amounts of outdoor air may be detrimental to the health of the building occupants.

Increasing ventilation rates often requires a full HVAC system re-design. Not all systems can be retrofitted to significantly raise ventilation rates as this often requires larger equipment and/or significant changes to current ductwork.

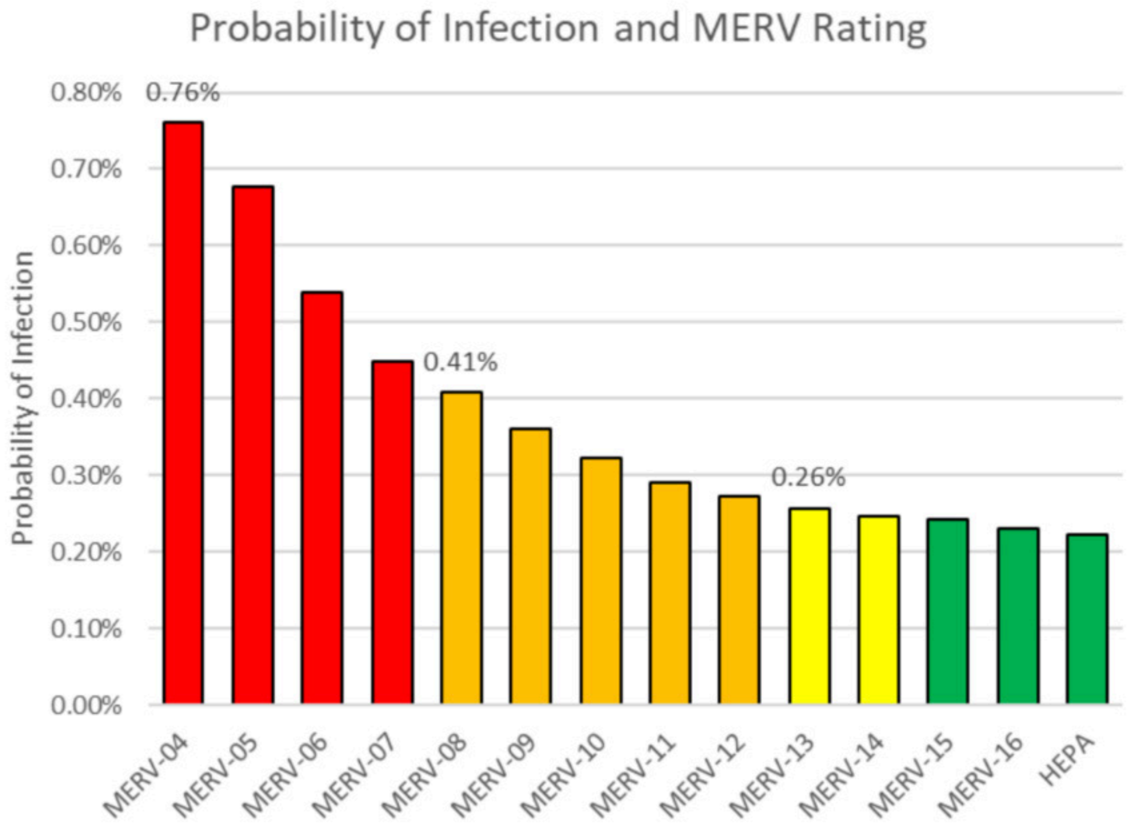
Improving Filtration

Filtration refers to the use of air filters to remove particulate matter (PM) from the outdoor and recirculated air in a building before circulating it through the HVAC system. Filters are rated on their ability to capture and retain particles of different sizes. A majority of air filters are rated using the minimum efficiency reporting value (MERV), where the higher the rating, the larger the percentage of PM captured by the air filter on each pass. A MERV 1 filter has the lowest removal efficiency while a MERV 16 filter has the highest removal efficiency. HEPA filters are those with a MERV rating above 16, and they will be rated to remove at least 99.97% of airborne particulates down to the size of 0.01 microns. Research has shown that a higher rated MERV filters (i.e., MERV 13-16) were found to achieve the greatest risk reduction of influenza, tuberculosis and rhinovirus infection. Guidelines set out by ASHRAE recommend that buildings upgrade their air filters to a minimum rating of MERV 13. MERV 13 filters can remove microbes and particles that range from 0.3 to 10.0 Qm, while COVID-19 has been observed in aerosolized particles at sizes that range from 0.25 to 0.5 Qm. While the virus itself ranges in size from .08 to 1.2 micron. Thus, the highest rated MERV filters may be able to reduce the risk of infection from COVID-19, though there is no guarantee that the filter will capture all particles.



Filters shall regularly be inspected to make sure they are installed and fit correctly, with no gaps or air bypass. Filters shall be maintained and changed based on manufacturer's recommendations.

The graph below shows the probability of infection for different MERV filters for the same building size as before.



CONCERNS:

Air quality standards in the region need to be considered. If the building is in an area with significant outdoor air pollutants, then the introduction of higher amounts of outdoor air may be detrimental to the health of the building occupants.

Increasing ventilation rates often requires a full HVAC system re-design. Not all systems can be retrofitted to significantly raise ventilation rates as this often requires larger equipment and/or significant changes to current ductwork.

ALTERNATIVE FILTER STRATEGIES:

Another effective solution is to use antimicrobial treated filters to neutralize COVID-19. Given that COVID-19 has a membrane wall, the treated filter works to trap the virus and break down the virus's membrane while also inhibiting the growth of other harmful micro-organisms such as bacteria, fungi, mold spores, and other airborne contaminants.

Controlling and Maintaining Relative Humidity

Relative humidity “is the amount of moisture air can hold compared to the maximum amount ofmoisture the air can hold at a specific temperature.

Controlling humidity is the act of either adding or removing moisture from the air. In a typical HVAC system, moisture can be added to the air by using a humidifier, which can be located either inside the HVAC equipment or in the supply duct work. Both methods are common and are often used in dry climates.

Studies have shown that percent relative humidity (RH) can modulate the risk of infections.

More recent research has shown that humidity may not directly affect the virus itself, but it does help humans fight-off the virus.

RH below 40% can increase risk by allowing infectious aerosols to shrink rapidly and become droplet nuclei possibly remaining suspended in air and traveling great distances. RH above 60% is also another risk factor, as it can increase the risk for surface contamination. humidity above 40% inactivates almost 80% of viruses. Controlling the relative humidity reduces the transmission of certain airborne infectious organisms. ASHRAE Building Readiness Guide, and other authorities recommend that maintaining relative humidity between 40% and 60% RH helps to reduce the survival rate of airborne diseases and COVID-19 infection rates.

CONCERNS:

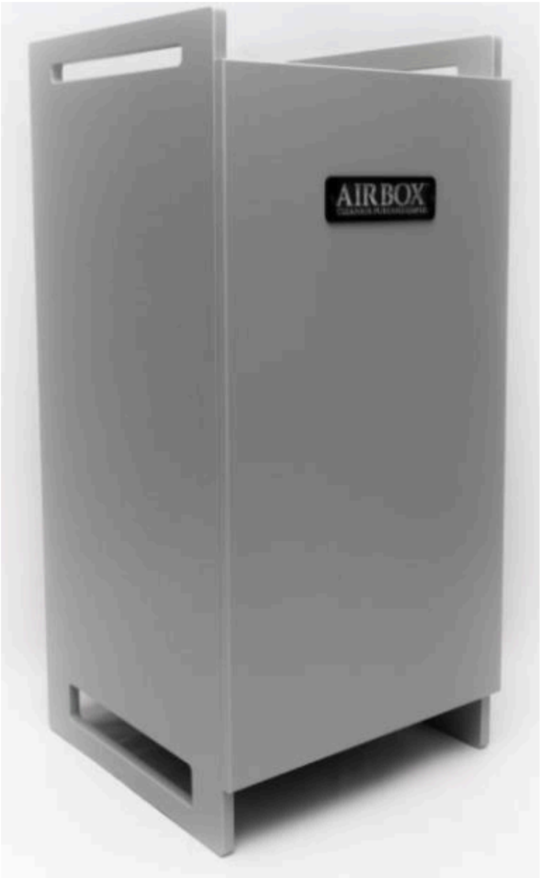
Controlling the humidity in the space will require additional items in the HVAC system which will add system cost and most likely require additional space. Adding a humidifier in an AHU or in the supply ductwork will also require a water or steam connection to the equipment and may require ongoing water treatment, depending upon the water quality and/or manufacturer’s requirements. Most HVAC manufacturers will provide factory options for humidifiers to be installed in their AHUs and retrofitting supply ductwork with a humidifier is typically non-invasive.

Air Purification

Another option to increase air changes within a space while treating the airflow is the use of multiple air purifiers. These provide the ability to increase air changes and increasing indoor air filtration when the existing HVAC systems are unable to achieve that, Directing the airflow so that it does not blow directly from one person to another reduces the potential spread of droplets that may contain infectious viruses. In addition, these portable units may include several of the technologies previously noted, such as HEPA filtration, antimicrobial treated filters and antimicrobial enclosures. HEPA filters are effective for controlling the spread of viruses. Portable units are easier to deploy and may be moved as need to accommodate changes within the workplace. If MERV 13 filters cannot be installed in a building, ASHRAE recommends providing portable HEPA filtration units to filter and recirculate air within each space. Portable HEPA filtration units are also beneficial for naturally ventilated buildings.

Portable air cleaners with high-efficiency particulate air (HEPA) filters are useful to reduce exposures to airborne droplets and aerosols emitted from infectious individuals in buildings. It is important to use only the type with HEPA filtration as portable and in-duct air cleaning devices and Ionizing units that produce ozone can be harmful to health.

Portable air purifiers should be places strategically to ensure the air in the space is circulated effectively and the “dead zones” where air becomes stagnant are minimized. Portable units must be sized appropriately for each room they are used in, and at times multiple units will be required per room. Airflow patterns and where people are located in the room should be considered when sizing and selecting air purifiers. The units must remain operational while the space is occupied and continue running after the occupants have left.



Ultraviolet Germicidal Irradiation Lights

Ultraviolet Germicidal Irradiation (UVGI) in HVAC involves installing ultraviolet lights (often referred to as "bulbs") in the HVAC system. The bulbs emit an intense, short wavelength light intended to kill or damage the cells inside microorganisms.

Application of UVC lamps at strategic locations within the duct system will kill microorganisms in the airstream. However, placement is important since the coronavirus must be exposed for a period of time, which requires multiple UVC lamps within the airstream. The air velocity inside the ductwork may require long sections of UVC light arrays to provide the proper exposure time needed to de-activate the virus.

Portable UVC lighting systems are effective in deactivating the virus. Lamp placement, intensity, distance from the virus and duration of light exposure must be considered to use these systems properly. Portable UVC systems can be placed in the space for the required amount of time to deactivate the virus, then moved to other locations throughout the space.

CONCERNS:

While UVGI has been shown to be effective at reducing the transmission risk and sterilizing or inactivating airborne particulates, UVGI does not remove them. UGVI is considered a supplemental air cleaning measure and is not recommended as a substitute for other risk minimization strategies. Thus, like other IAQ technologies, mechanical filtration to trap and remove the now sterilized and/or inactivated particles is required.

Other Strategies

HVAC systems that introduce outside air may be operated for longer periods to increase the time that the spaces are occupied for multiple shifts and to flush them with fresh air. The implementation of flush-out cycles will capture and dilute the air within the workplace prior to workers returning the following day. During unoccupied periods, the amount of outside air may be increased beyond minimum outside air setpoints. Depending upon existing controls in place, it may be possible to enact automatic controls and setting of outside air volume, based upon monitoring interior conditions during these unoccupied period flushing cycles, by simple reprogramming of the control sequences.

For higher risk spaces, adjust system control to operate HVAC equipment 24/7. This strategy will allow extended operation of ventilation systems to flush the building of any viable aerosols that may be still suspended in the air after occupants leave.

The use of CO2 as a proxy for respiratory aerosols (RA's) provides a cost-efficient method of monitoring the safe levels of RA's in a room or building. Given that people release CO2 into the space around them as they breath, monitoring the level of CO2 provides a way to visualize the amount of fresh air entering a space and provide a level of risk for the potential to transfer viruses between individuals. It is recommended that an alarm be be set to trigger when the level of CO2 reaches 1000 PPM, so that the rising levels can be investigated, and that the building or room be evacuated if the level of CO2 reaches 2000 PPM.

CONCERNS:

Increasing the duration of operating HVAC systems and equipment will increase energy usage significantly.

Conclusions

Strategies proposed by the CDC, ASHRAE and other organizations encourage the usage of HVAC to prevent the airborne transmission of COVID-19 and are based on the preceding research. Implementing these recommendations into the built environment will require discussions and agreements among building owners, managers, floor planners, and construction workers. Each building type requires a unique implementation of proposed recommendations, due to a variety of location-specific factors including city- and state-policy, climate, temperature, wind speed, energy efficiency policies and more. When optimizing the HVAC system to a specific building type, all inputs and local incentives must be considered.

- Increasing ventilation rates and improving airflow patterns for buildings are a viable aspect of HVAC to use in reducing the spread of airborne diseases. Exceedingly high ventilation rates, based on building- and location-specific factors, may lead to other negative health impacts.
- Higher efficiency filters are a viable aspect of HVAC to use in reducing the spread of airborne diseases. Higher efficiency filters are better suited to removing the smallest particles, but are not guaranteed to capture all particles. They may also lead to higher operational costs in the short-term.
- Controlling relative humidity in the space is a good IAQ and HVAC strategy. However, controlling relative humidity will require HVAC systems be retrofitted, which would include a clean water source, a unit coupled with energy to heat to inject moisture, and a distribution method, either by injection into a duct system or the use of area humidifiers that inject moisture directly to the occupied spaces.
- Although UGVI is an effective tool for reducing the transmission risk, UGVI can be challenging to implement due to infrastructure limitations and timing related to supply chain issues and design requirements.
- Employment of portable and design integrated Air Purifiers can be an effective means of increasing Equivalent Ventilation rates, increasing filtration efficiency, and improving airflow patterns. The flexibility of this approach facilitates implementation in a wide range of HVAC designs and retrofits.

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