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Heating, Ventilation and Air Conditioning (HVAC) Systems in Buildings and COVID-19

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Key Findings

- Indoor settings pose an elevated risk of COVID-19 infection. Improper or insufficient ventilation has been frequently reported as a risk factor in outbreak investigations. As part of a multi-layered strategy following public health guidelines, enhancing outdoor air ventilation and/or enhancing filtration where possible, and a well-functioning HVAC system can complement other public health measures by removing and diluting virus from indoor air, thereby lowering exposure to COVID-19.

- Filtration and ventilation are important components in an indoor air quality improvement strategy to exhaust or capture gases, vapours and airborne particles including virus-containing dust and aerosols. Removal of these matter dilutes their concentration in indoor air and can reduce occupant exposures.

- Ventilation can be improved by more air changes using a combination of outdoor air and filtered recirculated air. Standards for air changes are set by various associations for different types of building environments. Outside of clinical settings, ventilation standards are traditionally based on comfort, rather than infection control.

- Natural ventilation strategies can greatly improve indoor air quality. The effectiveness depends on the weather and may not be feasible when outdoor climate is unsuitable. Establishing a cross-breeze through the opening of an opposite door or additional window will improve air flow.

- Indoor carbon dioxide (CO_2) levels may be used as an indicator of ventilation as part of a professional assessment and are typically evaluated based on time-averaged readings. High indoor CO_2 levels can potentially identify spaces with poor outdoor air supply but CO_2 is not a direct indicator of COVID-19 transmission risk. If CO_2 monitors are being considered for people with no background on their use, then advice on interpretation of levels and corresponding actions should be carefully considered.

- Air currents like those from a fan or AC unit from an infected individual to others nearby can be an important factor in transmission. Avoid directional air currents from person to person to reduce the spread of respiratory particles.

- There are case reports of unfiltered, recirculated air in a space linked to COVID-19 transmission in indoor settings with low or inadequate ventilation. To date, no reports have been identified of SARS-CoV-2 spreading through centralized heating, ventilation and air-conditioning (HVAC) systems.

- Routine inspections and maintenance as appropriate for the system are necessary.

Background

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is transmitted from an infectious person (source or case) to a susceptible person (receptor or contact) across a spectrum of respiratory particle sizes and distances. Infectious respiratory particles are inhaled by individuals or deposited on mucosal surfaces. Evidence supports factors that increase SARS-CoV-2 transmission risk including distance from the contact from the case, with prolonged and unprotected contact; as well as, inadequate ventilation, activities that increase expulsion of aerosols (e.g., shouting, exercising) and lack of masking for source control.[1]

Traditionally, the main purposes of a heating, ventilation and air-conditioning (HVAC) system are to help maintain good indoor air quality through adequate ventilation with filtration and to provide thermal comfort to building occupants.[2]

Ventilation and filtration can reduce SARS-CoV-2 transmission risk by removing and diluting virus-laden particles from indoor air. As is true of other layered measures, ventilation and filtration are not sufficient on their own to control the risk of transmission, and particularly from close contact exposures. Other key measures to reduce transmission risk include vaccination, limiting contacts, screening and self-isolation of people with symptoms, physical distancing, hand hygiene and well-fitting masks or respirators for source control and personal protection. Thus, while ventilation and filtration are important for overall indoor air quality as well as for COVID-19 risk reduction, these interventions must be used in conjunction with other public health measures to minimize transmission risk.

In this document, we provide a summary of ventilation and filtration concepts as they relate to the management of COVID-19 transmission.

Methods

A library search was done on MEDLINE, Inspec, Environment Complete, and Scopus databases as well as the NIH COVID-19 Portfolio for peer-reviewed and preprint publications on COVID-19 transmission related to HVAC, air, or indoor settings February 7, 2022. The full search terms are available upon request. Results were screened for key articles relevant to the topics covered in this document for the update.

Key terms defined in this document are based on the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) glossary of terms.[3]

Key issues related to ventilation and COVID-19

Filtration, ventilation and an HVAC system

Filtration and ventilation are important components in an indoor air quality improvement strategy to exhaust or capture gases, vapours and airborne particles or aerosols that contain the virus.[4] Removal dilutes their concentration in indoor air and can reduce occupant exposures. Key terms are described below.

Mechanical filtration involves the use of different types of fibrous media designed to remove particles from the airstream. A portion of the particles in air entering a filter attach to the fibrous media are removed from the air as it passes through the filter. The particle removal efficiency of the filter, the rate of air flow through the filter, location of the filter, and size of the particles filtered by the filtration system contribute to the reduction of indoor particle concentrations.[5]

Ventilation is the supply/distribution or removal of air from a space by mechanical or natural means.[6] Ventilation can be for the purposes of controlling air contaminant levels, humidity, or temperature within the space. It can be achieved through natural means, such as through openings (e.g., windows, doors) and by passive infiltration (e.g. drafts from unsealed cracks around windows and walls).[3] Mechanical ventilation is the active process of supplying air to or removing air from an indoor space by powered equipment such as motor-driven fans and blowers.[3] Examples include heating, ventilation and air-conditioning (HVAC) systems, and local (e.g., bathroom, cooking) exhaust fans. This document focuses on ventilation in the context of building spaces in the community, but not local exhaust ventilation used in certain occupational and industrial settings to control air contaminants at or near their source.[7]

An HVAC system is the equipment, distribution systems, and terminals that provide, either collectively or individually, the processes of heating, ventilating, or air conditioning to a building or portion of a building.[3] Note, most HVAC systems also incorporate the use of both filtered recirculated air and outdoor supply air, as do guidelines and standards on these systems.

Indoor settings and risk of COVID-19

Indoor settings pose an elevated risk of SARS-CoV-2 infection. Improper or insufficient ventilation has been frequently reported as a risk factor in outbreak investigations.

Outbreaks and clusters of COVID-19 are common in indoor spaces, both in homes, transport settings as well as congregate settings such as faith-based, elder care, meal and office settings.[8–11] Various studies and reviews cite inadequately ventilated spaces and high occupant density as possible contributors for transmission via inhalation of infectious aerosols.[8,12–15] Few clusters are reported in exclusively outdoor settings where ventilation is not an issue.[9] Experimental and modeling studies show respiratory aerosols during breathing and speech and droplet dispersion in air, and suggest the plausibility of transmission through inhaled virus in air.[16–19] There are also environmental sampling studies that demonstrate viral genetic material (ribonucleic acid, or RNA) in air and surfaces where COVID-19 patients have been,[20–23] including HVAC systems.[24] These studies suggest inhaled virus as a likely route of transmission in some outbreaks, mainly in the same room or space.[12]

Outbreak investigations in a restaurant[25,26] and an indoor squash court [27] have found inadequate or improper ventilation. Extended exposure time either to the infected individual, or to the air space where an infected individual had been present were suspected to have played a role. Other reports of outbreaks in fitness dance classes,[27] a call centre,[28] choir practices,[32] and recreational hockey,[29] as well as non-peer-reviewed reports of outbreaks in settings of intense exercise[30,31] are examples where inadequate ventilation may have contributed to transmission, but specifics on ventilation were not available from these reports and transmission through close contact and fomites were also plausible.

Overall, the evidence indicates that inadequate ventilation, activities that generate high levels of respiratory aerosols, limited physical distancing or crowding and longer duration of exposure increase the risk of aerosol transmission.[32] Ventilation reduces this risk by removing or diluting virus-laden particles in indoor air over time, but will not eliminate the risk of SARS-CoV-2 transmission during close contact exposures.

Natural ventilation strategies

Natural ventilation strategies can improve indoor air quality. The effectiveness depends on outdoor conditions and may not be feasible in some situations. Establishing a cross-breeze through the opening of an opposite door or additional window will improve air flow.

Natural ventilation refers to air passage through openings (e.g., windows, doors) and by passive infiltration. [5] Opening windows is a simple solution to immediately improve air quality.[33] However the degree of air exchange between indoor and outdoor air from natural ventilation can vary significantly, with the benefits of natural ventilation depending on outdoor conditions (such as wind and temperature differences as well as the position of the windows.[34] Comfort can also be affected if outdoor temperatures are hot, cold, or humid.

Establishing cross-ventilation by two or more openings on opposite or adjacent walls has been shown to improve air flow rates. A study conducted in a school during the summer shows the benefits of cross-ventilation over a single side of windows, with variable air flow rates depending on the side of the building.[34] In this setting, when cross-ventilation was not achieved, either by opening only windows or only the door, indoor particles appeared to be recirculated in the room and thus did not provide better air quality than the existing ventilation system.

Relevance of air movement (e.g., air currents from room AC units and fans and pressure differences between rooms)

Air currents like those from a fan or AC unit from an infected individual to others nearby can be an important factor in transmission. Avoiding directional air currents around people's breathing zones will reduce respiratory droplets being spread from person to person. Rather than air flow at head level, options would be to direct the air upwards or to exhaust room air out of an open window while other open windows draw fresh air in. Pressure differences can be important for controlling the movement of air between different areas in a building.

Both ventilation and air movement within buildings have been associated with transmission of various infectious diseases, including tuberculosis, influenza, and severe acute respiratory syndrome (SARS).[26] Air currents created by fans or air conditioning systems affect the dispersion of respiratory droplets in the air.

In one COVID-19 outbreak, transmission between families at three tables in a densely occupied restaurant was reported. A wall air conditioner with no fresh air intake generating air currents that carried respiratory particles from an infected customer was suggested as a likely route of transmission.[25,26] Kwon et al also reported on transmission of COVID-19 in a restaurant likely from air currents produced by ceiling air conditioning units, with restaurant patrons greater than 2 metres apart becoming infected after short exposure times downwind of an infected individual.[15] Two other patrons located closer to the index case for a longer duration but not in the path of direct air flow from the index case, and three others at tables with the two secondary cases but facing away from the index case were not infected. It was noted that the restaurant was located on the first floor of a building without windows or a ventilation system so recirculation of air was likely.[15]

Avoiding strong air flow from one person to another may help prevent these situations. The United States Centers for Disease Control and Prevention (CDC) supports avoidance of contaminated air flow from one person to another and suggests that a window fan can be used to exhaust room air out while other open windows draw air in.[35]

When fans and air conditioners are used, the manufacturer's guidance should be followed for cleaning, disinfecting and maintaining them on a routine basis. These units are designed for temperature control and typically do not provide ventilation or filtration.

More detailed guidance on the positioning, use, and maintenance of fans and air conditioning units can be found in Public Health Ontario's report titled "The Use of Portable Fans and Portable Air Conditioning Units during COVID-19 in Long-term Care and Retirement Homes".[36] Portable air cleaners as a potential source of strong currents is also discussed in Public Health Ontario's FAQ on portable air cleaners.[37]

Pressure differences

Pressure differences affect air movement through an indoor environment and are typically considered during HVAC design. Supplying extra air to a room without removing it will lead to positively pressured rooms from which air will escape. Removing air via exhaust from a space without additional supply will lead to negatively pressured rooms, to which air will be drawn in. These pressure differentials are used intentionally in HVAC system design to influence air movement indoors. For example, Canadian Standards Association (CSA) standards for healthcare facilities specify whether a specific room should be under negative or positive pressure, depending on the intended use for the room and whether air escaping from the room could be considered safe.[38] A hospital laundry room intended for soiled linens needs to be under negative pressure, so that contaminated air does not leak out of the room. Clean linen laundry rooms are recommended to be under positive pressure, so that air from outside of the room does not contaminate clean linen.[38]

Analysis of outbreaks at two quarantine hotels suggested that pressure differences between hotel rooms and corridors may have allowed air flow from one unit to another through the corridor during simultaneous door opening of adjacent units.[39–41] When building uses change or evolve or new renovations occur, air movement patterns can be affected if these pressure differences are not considered. An HVAC professional should be able to describe pressure differences and how air would be expected to move through a space when the HVAC system is performing as designed. They could also describe how changing building use or activities may affect pressure and airflow in a given building.

Recirculation of indoor air

There are case reports of unfiltered, recirculated air as a cause of SARS-CoV-2 transmission in indoor settings with low or inadequate ventilation. To date, no reports have been identified of SARS-CoV-2 spreading through centralized HVAC systems In general, limiting unfiltered or poorly filtered recirculated air and bringing in fresh air would lower the concentration of viral particles present in indoor air.

Recirculation in the context of HVAC systems usually refers to indoor air returned to and filtered in the central system, then redistributed within the building. Some degree of recirculation in HVAC systems is often necessary to maintain humidity and temperature goals and control energy costs. Limiting recirculation of unfiltered or poorly filtered indoor air would exhaust more potentially infectious particles and bring in fresh air, reducing transmission risk. In recirculated air, removal of viral particles will depend on the efficiency of the filter used in an HVAC system.

Some accounts of restaurant and transit outbreaks have reported an absence of central ventilation, and recirculation of air through heating or cooling units with no filtration.[11,26] These accounts describe situations of recirculation with little to no ventilation with outdoor air and minimal dilution, in contrast to how air would be recirculated (with dilution and usually filtration) in building HVAC systems.

HVAC measures to minimize the risk from infectious aerosols

A well-functioning HVAC system, as well as enhanced outdoor air ventilation and/or enhanced filtration can complement other public health measures by removing and diluting virus from indoor air, thereby lowering exposure to SARS-CoV-2.

Air quality improvement strategies can reduce the concentration of virus particles in the air. Thus, most guidance encourage ventilation with outdoor air (i.e., avoiding recirculation) as far as practically possible and ensuring clean filters.[8,13,14,42–44] Assessment and adjustments to an HVAC system are best managed by a professional, as there are usually building-specific considerations. COVID-19 mitigation depends on a combination of interventions which will vary with respect to how effective they are and how practical they are to implement. The key is to always practice as many protective measures, as consistently as possible.

Reduce occupancy

Exposure to virus can be reduced by minimizing occupancy in a space, particularly where it is not possible to increase outdoor air ventilation.[45] Avoiding closed spaces, close contact and being in the way of another person's direct air flow (e.g., via a fan's air flow) are other measures to reduce exposure.[8,12,14,46]

Increase outdoor air ventilation (minimize recirculation)

For central air handling units at a building level or serving multiple zones, limiting recirculation is ideal, e.g., operating on the highest reasonable outdoor air supply. ASHRAE provides guidance on COVID-19 which an HVAC professional can help apply to specific building scenarios.[47] Some HVAC systems may not allow changes to outdoor air fractions, and opening windows may be a good alternative to bring in outdoor air, although the air flow will be variable (e.g., if there are no breeze or temperature differences).[14,43,46] Ventilation via open windows may be improved by utilizing a fan facing out to exhaust air and other open windows that bring outside air in.[35]

Increase filter efficiency

Filtration removes virus and other aerosols and particles from indoor air. Filters require appropriate maintenance and may also be upgraded where the system allows to maximize effectiveness.[8,14,42,43,46] The effectiveness of a filter is rated by the Minimum Efficiency Reporting Value (MERV), ranging from 1 to 16, with 16 being the highest efficiency. The rating is based on the fraction of particles removed from air passing through it under standard test conditions.[47] ASHRAE's COVID-19 guidance suggests using MERV 13 or higher rated filters based on their ability to filter out virus-sized particles (<1 µm).[47] Higher efficiency filters may not be a viable option for some HVAC systems as they may cause greater resistance to air flow than allowable by design specifications. In these cases, upgrading MERV filters to as high a rating as will be tolerated by the system will still improve the clearance of smaller particles. For example, a move from a MERV 8 filter (20 % efficient at filtering 1-3 micron particles) to a MERV 11 filter (65 % efficient at filtering 1-3 micron particles) can substantially improve particle removal.[47] When central HVAC systems are unavailable or not capable of providing sufficient outdoor air ventilation or filtration of air and a space is poorly ventilated, and when further upgrades are not feasible, portable air cleaning units can be considered to help control particle concentrations in the air (see PHO's FAQ on portable air cleaners for more information).[37]

Humidity has uncertain implications

There is some evidence to support that low relative humidity (RH) may enhance survival of SARS-CoV-2 on fomites.[48] As the RH increases, expelled respiratory droplets also fall from the air faster onto surfaces, decreasing the number available for conversion to aerosols.[49] While various organizations[50–52] have suggested maintaining a RH level of 40–60% as a supportive measure, there is a lack of evidence on the effectiveness of targeting a particular RH to mitigate SARS-CoV-2 transmission. Additionally, maintaining high RH levels risks the build-up of condensation and mould development in the winter season, which may contribute to poor indoor air quality and health problems.[53]

Air changes and clean air delivery

In general, ventilation can be improved by more air changes using a combination of outdoor air and filtered recirculated air. Recommendations for air changes are set by various associations for different types of building environments and are traditionally based on comfort, rather than infection control.

Many metrics exist in ventilation to quantify how much clean air is delivered to a room. In most cases, delivery of clean air depends first on the amount of fresh outdoor air, but filtered recirculated air can also improve air quality. Fresh outdoor air alone is often used to calculate air changes per hour, while 'effective' air changes per hour calculations can also include filtered recirculated air.

Air changes per hour

The air change rate for a space is the volume of air supplied to and removed from a space from any source or exit, per unit of time divided by the volume of the space.[3] Standards for air change rates are available from the for HVAC systems in specific zones or areas in healthcare facilities in CSA Z317.2:19.[38] For example, examination/treatment rooms in emergency departments need 9 air changes per hour. These air change rate standards for clinical settings account for the potential for airborne infection risks.[38] Air changes per hour is most useful in smaller rooms with ceiling heights generally less than 12 feet. In rooms with higher ceilings such as gymnasiums, aerosols and particles will have a larger space to dilute into. In these instances, a volumetric flow per area or per person is a more appropriate measure of adequate ventilation.[54]

For other indoor settings, ASHRAE Standard 62.1 provides minimum ventilation rates, specified as outdoor air rates. These rates are adjusted for individual facilities depending on use context and occupancy. Individual rooms can be compared to the standard either by determining the room occupancy (L/s*person) or using room area (L/s*m^2). Acceptable indoor air quality will vary according to the type of setting (e.g., correctional facilities, offices, educational settings, hotels, food and beverage settings), occupancy and area.[55] Acceptable indoor air quality is defined by ASHRAE as "air in which there are no known contaminants at harmful concentrations, as determined by cognizant authorities, and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction".[3] While outdoor air ventilation rates are not specifically meant to address transmission of airborne viruses, bacteria or other infectious agents, higher air change rates logically translates to lower risk through reduced concentrations and exposure.

ASHRAE provides additional guidance for HVAC systems for the COVID-19 pandemic which can be applied with the support of professionals who can assess specific buildings for measures most appropriate and feasible.[56] Professionals can also assess the outdoor air ventilation rates provided by a mechanical HVAC system for a building and the different spaces within.[57] The CSA guidance for workplaces during the pandemic reinforces that air exchange rates should be modified on a building-by-building basis with careful evaluation of the ventilation system because adjustments can lead to issues related to thermal comfort and humidity, and undesired effects on air circulation.[58]

Clean air delivery rate and effective air changes

Clean air delivery rate (CADR) is a term used to describe the amount of clean air delivered to a space as determined by the effectiveness of filtration and the amount of air moving through that filter. While most often used to describe the effectiveness of portable air cleaners, CADR is also conceptually useful in describing how air passing through a MERV or high-efficiency particulate air (HEPA) filter in a central system would be expected to have reduced viral particles. A clean air delivery rate can also be calculated for recirculated air from an HVAC system to account for viral aerosol and particle removal.[54]

Air change recommendations often assume the use of fresh outdoor air delivery in air change calculations. Given that filters can remove viral particles, 'effective air changes per hour' is a measure that accounts for both fresh outdoor air and filtered recirculated air.[54] If using an effective air change per hour calculation to make room-specific assessments, suggestions are usually to strive for a specific rate of effective air changes (for example 4-6 effective ACH) using any combination of the following: outdoor air ventilation; recirculated air that passes through a filter with as high a MERV filter as possible, accounting for the filter efficiency; or passage of air through portable air cleaners with HEPA filters.[54] This effective air change metric could be used in situations where multiple rooms are being assessed within a building, to compare how well ventilated one space is to another and to target ventilation improvements where necessary.

Indoor carbon dioxide (CO_2) measurement as an indicator of ventilation

Indoor CO_2 levels may be used as an indicator of ventilation as part of a professional assessment and are typically evaluated based on time-averaged readings. High indoor CO_2 levels can potentially identify spaces with poor outdoor air supply but CO_2 is not a direct indicator of SARS-CoV-2 transmission risk. If CO_2 monitors are being considered for people with no background on their use, advice on interpretation of levels and corresponding actions should be clear.

CO_2 is exhaled by people and can build up in indoor spaces compared to normal outdoor ground-level CO_2.[59] Ventilation can lower indoor CO_2 levels by introducing fresh outdoor air, leading to its use as a proxy for indoor air removal or dilution, with high levels of CO_2 potentially identifying poorly-ventilated spaces. There are a variety of ways CO_2 levels can be measured and analysed, but in general measurements are collected over a period of time to capture the effect of ventilation on CO_2 levels. Measurements are also carried out in the occupied area of a room with the sensors located away from windows, doors, and ventilation grilles.[51] Follow up measurements can be made if ventilation is increased in a space to verify the effectiveness of the changes. Accuracy of CO_2 sensors used, placement and setting (e.g., large volume spaces) and occupant activity should be considered when reviewing the data. As well, calibration procedures for CO_2 sensors should be followed according to the manufacturer's guidance.

There are limitations to using CO_2 monitoring as an indicator of transmission risk, because it does not account for filtration or the activities taking place within an indoor space. For example, CO_2 levels are not affected by mitigation measures such as the use of masks or HVAC system filters or isolating someone who is highly infectious, while combustion devices and pets will increase CO_2.[59,60] Because of this, rather than being used as a direct measure of transmission risk, many guidelines suggest the use of CO_2 as a tool to prioritize improvements in ventilation or other mitigation strategies.[51] Guidelines for indoor CO_2 levels have been proposed by the U.K. Scientific Advisory Group for Emergencies Environmental Modelling Group (SAGE-EMG) and ASHRAE (for schools and universities) to inform ventilation adjustments.[51,56]

European and German guidelines have proposed a traffic light-based indicator of continuous CO_2 levels for use by room occupants.[43,51,60] Although these thresholds are meant to create awareness among room occupants of indoor air quality,[60] the limitations discussed above should be considered for continuous CO_2 monitoring. Other questions that arise include what actions would be linked to these levels, when the actions would be triggered, and the recourse if the desired effect is not achieved with the action. The National Collaborating Centre on Environmental Health review provides a useful summary on CO_2 monitoring.[60]

HVAC systems on partial or limited occupancy modes

Generally, most HVAC guidance documents recommend against a complete shutdown of the HVAC system, even during a building shutdown. During normal operations, guidance also suggests running the system for longer than usual and maintaining outdoor air ventilation rates when the building has fewer occupants than typical.

ASHRAE recommends operating the HVAC system in occupied mode when people are present in the building including periods of reduced occupancy.[61,62] ASHRAE also recommends continuing to run the HVAC system in occupied mode for additional time pre- and post-occupancy and provides more detailed guidance on determining the duration. ASHRAE and the Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA) recommend maintaining normal temperature and humidity set points (see previous section for humidity considerations).[43,62]

During routine operations, REHVA similarly recommends increasing outdoor air supply and exhaust ventilation and starting ventilation at least two hours before the building is occupied and continuing to run the ventilation for at least two hours after the building has been vacated.[43] REHVA recommends lowering the ventilation rate or switching off when people are absent outside of the two hour pre- and post-occupancy period.[43]

Inspection or maintenance

Routine inspections and maintenance as appropriate for all air management systems are necessary.

Recommended inspection and maintenance measures for air handling systems (including inspection and replacement of filters, if applicable) are essential to follow.[8,63]Adjustments to ventilation (e.g., increased outdoor air) may require more frequent inspections and filter changes.[8] System humidifiers should be inspected to ensure they are cleaned, maintained and operating properly.[63] As ventilation systems are complex and changes made have unintended effects, adjustments should be made in consultation with a HVAC specialist to verify intended parameters and appropriate maintenance procedures.

There is a joint standard from the American National Standards Institute (ANSI), ASHRAE and Air Conditioning Contractors of America (ACCA) for HVAC inspection and maintenance. ANSI/ASHRAE/ACCA standard 180-2018 (Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems) details procedures and establishes minimum HVAC inspection and maintenance requirements that preserve a system's ability to achieve acceptable thermal comfort, energy efficiency, and indoor air quality in commercial buildings.[64] This guidance can be considered by facility operators in order to optimize HVAC system operation on a routine basis, regardless of an infectious disease pandemic.

Some buildings may use Energy Recovery Ventilators (ERVs) which are HVAC systems that transfer energy (heat in winter, cold in summer) from indoor exhaust air to outdoor supply air to lower energy costs associated with heating or cooling outdoor air used for ventilation. ERVs should be inspected and properly maintained. Pressure differences and design limitations in some types of ERVs (those with exhaust and supply airstreams co-located in the same enclosure) have the potential for mixing which is known as exhaust air transfer. There are system checks, maintenance techniques and modifications that can assess and reduce exhaust air transfer if necessary. ASHRAE provides detailed guidance on operation of ERVs during epidemics.[65,66]

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Summary of Revisions

Revision Date	Description of Changes	Page Number
April 2023	For example, examination/treatment rooms in emergency departments need 9 air changes per hour.	8

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