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The Role of HVAC Filters In Reducing Airborne Disease Transmission: A Review

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ABSTRACT

Since 2019, the Coronavirus infection has substantially impacted the worldwide ecosystem. This disease has apparently become airborne and has spread globally. Most daily activities have been curtailed to prevent the spread of the disease. Several measures have been devised by the World Health Organization to control the transmission of disease among humans. However, interior spaces are also crucial because individuals spend most of their time inside. To improve the interior living environment, it is necessary to develop a way to prevent the spread of airborne diseases. To obtain the desired level of efficiency and the requisite level of health for people to stay indoors, it is essential to install an efficient ventilation system. To avoid the transmission of airborne infections in confined areas, the purpose of this work is to examine the impact of the filtering mechanism in a controlled environment provided by Heating, Ventilation, and Air Conditioning (HVAC) systems. According to the study, ventilation, along with MERV13 or above recirculating filters, for instance, must be used (High-Efficiency Particulate Air) This criterion can be met with HEPA or a combination of outside air, filtration, and air-cleaning technology. To reduce the transmission of airborne diseases, the outcome of the study will result in a more effective installation of the mechanism of HVAC systems in interior environments.

1. Introduction

As a result of the global expansion of the Covid-19 virus, airborne illness transmission has become a significant issue. Globally, infection rates are extraordinarily high and affect many people, harming the economy, travel, and way of life [1]. This suggests that the virus can be transmitted through polluted air to a certain degree [2,3]. Since the introduction of Corona Virus, public health professionals and government entities have emphasized the importance of preserving social distancing to prevent future transmission of the virus [4]. Aside from personal hygiene and the use of face masks [5], little thought has been given to the possibility of airborne transmission. However, the implementation of the technique focuses mostly on the building's appearance. To apply it

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indoors, there will be constraints on occupancy, space area, and the placement of most activities, and it will be challenging to keep the method in place permanently.

To recognize the most effective filtration mechanism, the size of the virus and the permeability of the filter must be crystal obvious. The Coronavirus has a size that varies from 0.06 to 0.14 m [6], and the virus-containing aerosol is made up of virus particles in a respiratory fluid that is a complex mixture of different organic and inorganic constituents (water, salts, lipids, proteins, bacteria, and other viruses) suspended in the air. Their size is greater than that of the virus itself. Multiple sizes of Corona Virus-infected airborne particles, ranging from 0.25 m to 5 m [7–11], have been found, allowing for their facile transport over considerable distances.

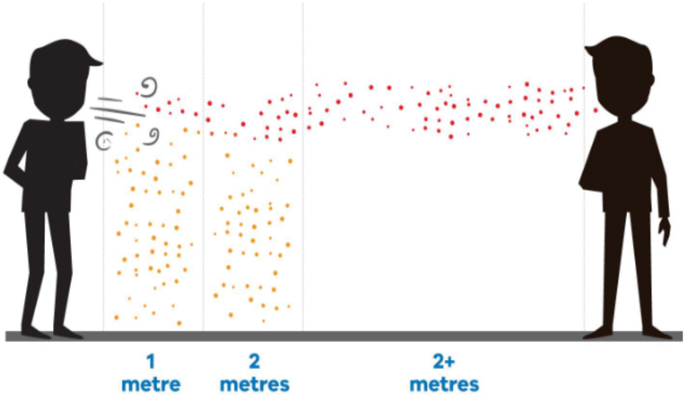


Fig. 1. Droplet Suspension [14]

Figure 1,[12] demonstrates that a person can contract the virus by inhaling droplets from an infected individual standing 1-2 meters away; Figure 2 demonstrates that a person can contract the virus by touching their mouth, nose, or eyes after touching contaminated surfaces or objects [13] and being within 1-2 meters of an infected patient. Numerous studies have shown that viruses can spread through indoor air, especially in busy, poorly ventilated areas [14].

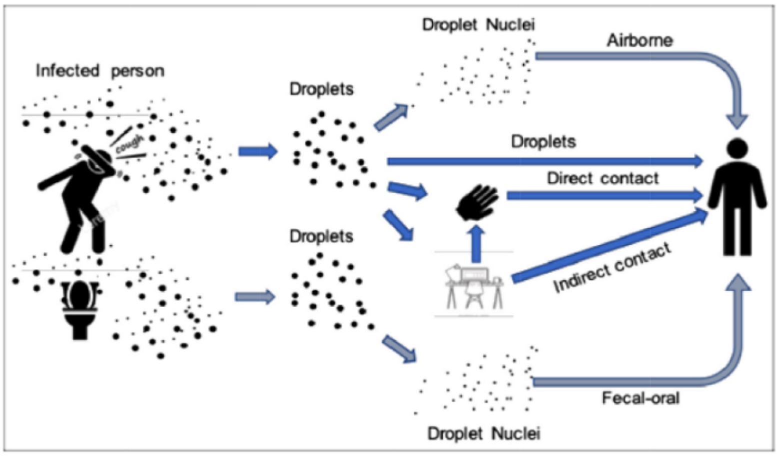


Fig. 2. Exposure mechanisms of Corona Virus and other flu viruses in buildings [13]

People are concerned that the HVAC system in the building may become a source of airborne disease transmission and have voiced their worries. There is a lack of research and search obscurity regarding the global COVID-19 epidemic, which is detrimental to humans, particularly in HVAC systems [15]. However, both the Federation of European Heating, Ventilation, and Air Conditioning Association (REHVA) [16] and the American Society of Heating, Refrigerating, and Air Conditioning

Engineers (ASHRAE) [17] acknowledged that building ventilation plays a crucial role in reducing the risk of transmission [18,19].

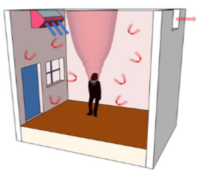
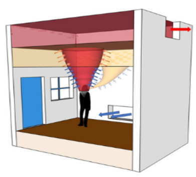
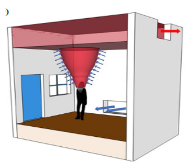
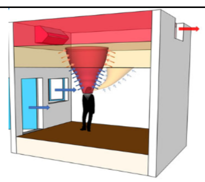
2. Methodology

The aim of this study is to examine the influence of the Filtration Mechanism in the Mechanical Ventilation System on Airborne Disease Transmission in an enclosed environment to determine the effects on the occupants and prevent the development of airborne disease transmission. The study is conducted using qualitative approaches, with parameter data obtained based on past research on the influence of indoor mechanical ventilation on the spread of airborne diseases. The collected data will be analyzed considering the literature review to determine the practicability of the filtering mechanism in the indoor mechanical ventilation system.

2.1 Indoor Transmission of Airborne Disease

The increase in illnesses linked to indoor gatherings led to the revelation that airborne transmission was occurring within households [20]. The infectious airborne disease can spread to other people in one of four ways such as direct contact with an infected person, indirect contact via means of fomites, the transmission of a droplet, or through aerosolized particles in the air [21]. The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pathogen, which causes COVID-19, is known to spread by respiratory droplets inhaled by an infected person [22]. Based on the table 1 below it depicts ventilation flows with the major flow components, including the body plume, inlet flows, stratification, and arrows showing entrainment and mixing [23].

Table 1
Application of HVAC system

Figure	Description
a) 	As a result of mixing ventilation, hot air rises to the ceiling and, except for the vicinity of the inlets and vents, the indoor climate remains rather constant.
b) 	Displacement ventilation when a mask is not worn. The secondary breathing plume stratifies beneath the hot upper layer, and the second layer's fluid is entrained into the body plume and evacuated from the interior environment.
c) 	Displacement ventilation when a mask is worn by the occupant. In this scenario, the breathing plume becomes entangled with the body plume near its origin and is expelled from the higher layer.
d) 	When we switch off the mechanical ventilation input and instead open the top-level doors and windows of space, ignoring the wind's effect, we effectively establish a displacement ventilation scenario (here shown when no mask is worn).

2.2 Application of HVAC System in the Enclosed Area

It is interesting to think about whether HVAC systems can slow the transmission of infectious diseases given that many HVAC systems move air, and some infectious diseases propagate through the air [24]. This assertion is an attempt to cast doubt on the functionality of the HVAC systems. According to a different specialist, the HVAC system is the most effective method for limiting the airborne spread of dangerous diseases. However, improper operation may contribute to the airborne transmission of disease [25]. Several studies [26,27] have established the impact of HVAC systems in regulating or exacerbating the virus's transmission. For instance, a group of researchers [28] has hypothesized about the potential of self-reinfection of the virus by aerosol transmission, helped by the airflow in hospital conditions. The HVAC system's airflow still has the potential to transmit aerosols [29]. In a crowded environment, inadequate ventilation may result in an increased infection rate. Consequently, the professional HVAC societies in various nations, including but not limited to ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers), REHVA (The Federation of European Heating, Ventilation and Air Conditioning Associations), SHASE (The Society of Heating, Air-Conditioning, and Sanitary Engineers of Japan), JSRAE (The Japan Society of Refrigeration and Air-Conditioning Engineers), PAHO (The Pan American Health Organization), and HSE [30].

Table 2
Application of HVAC system

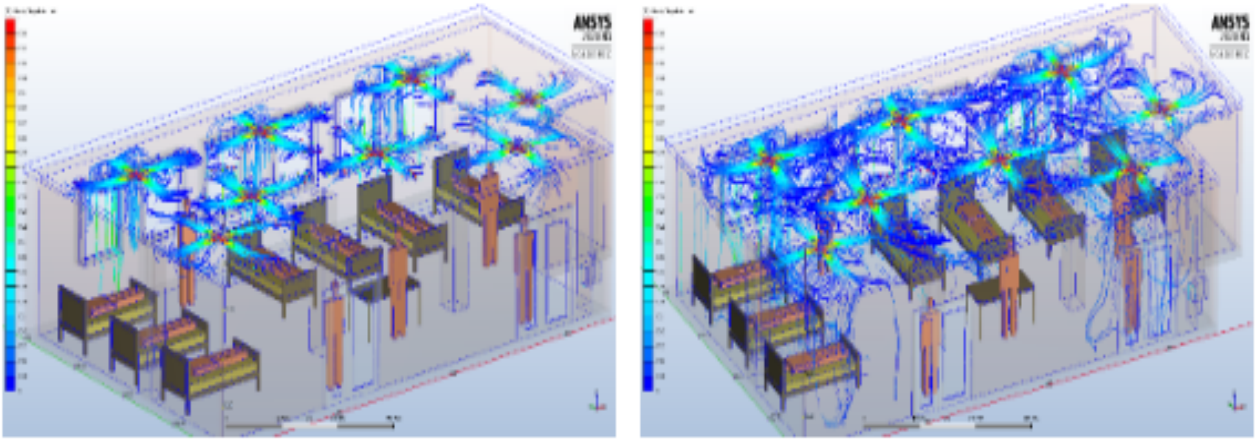
Author	Description	Findings
Pan Y *et.al* (2021) [32]	Due to inadequate awareness about this sort of virus, people once feared using air conditioning systems in buildings even though there were no similar instructions or recommendations for the existing operation and management standards for HVAC systems in buildings.	Decreases the risk of COVID-19 spreading during a pandemic and ensures the potential and capability of HVAC systems. The idea of integrating regular with emergency time in buildings in the future is strengthened by reconsidering adaptive HVAC systems in buildings that are suitable not only for the COVID-19 virus but for other pandemic scenarios
Elsaid *et.al* (2020) [15]	There are conflicting views on whether the deadly COVID-19 outbreak is spread by air, which acts as a heat exchange medium between HVAC systems and air-conditioned spaces.	75% of the samples were positive before utilizing the PAC with the HEPA filter, and COVID-19 was found in the air. Yet, it was anticipated that the PAC with the HEPA filter would be 80% efficient in stopping the spread of COVID-19 after use; as a result, it is advised for use in spaces with insufficient ventilation.
Faulkner *et.al* (2022) [33]	To increase interior safety during the pandemic, recommendations were made for building operations. Included were suggestions for the functioning of the heating, ventilation, and air conditioning (HVAC) system, such as ensuring adequate airflow and employing filters with a minimum efficiency reporting value (MERV) of 13 or above.	It has been demonstrated that recommended solutions are effective in enhancing indoor air quality, but their effects on HVAC system function, such as energy usage, are not quantified and require additional investigation.

Following is a summary of the prior research that supports the use of HVAC to prevent the transmission of airborne infections indoors. The fundamental purpose of building ventilation is to provide fresh air for breathing and remove excess heat and impurities [13]. According to Dietz, the following HVAC system solutions are crucial for limiting the spread of disease in constructed environments [31]:

1. Air filtration using HEPA or ULPA technology (either centrally or through a portable air purifier in each room).
2. Regulating humidity to stop the spread of contaminants and the formation of mold (recommended range of 40 to 60 percent relative humidity).
3. Preference for displacement ventilation as opposed to mixed ventilation (where possible to implement)

AHUs with full fresh air supply and interior fan coil units acting as space cooling terminal units make up the central HVAC system.

The simulation study utilized a total of 6000 particles with identical diameters that were evenly distributed across seven inlet grids. The particles are disseminated in all four directions at the ceiling using the HVAC system, indicating a uniform dispersion across the room based on Figure 3. Although the HVAC system may appear to provide a faster and more uniform distribution of infecting particles, this is offset by the option of using HEPA filters, which are a supplementary method for decontaminating Coronavirus aerosols in healthcare settings [34–36].



(a) **(b)**

Fig. 3. Air inflow dispersion for heating, ventilation, and air conditioning systems at (a) and (b)

3. Discussion

The type of filtration mechanism used affects the effectiveness of the HVAC mechanism system. The type of selective filter will determine the airborne disease's penetration into specific locations. The Centers for Disease Control and Prevention (CDC) advise engineering measures that utilize the ventilation system of buildings to be improved to stop the spread of infectious diseases. The installation of portable high-efficiency particulate air (HEPA) fan/filtration systems to improve air cleaning (especially in high-risk areas, like nurse's offices or classrooms) and the confirmation that the building ventilation system is large enough for the space in question is few examples of these improvements [37]. Table 3 shows the minimum filter efficiency.

HEPA, which stands for High-Efficiency Particulate Air, is even more effective than MERV 16. A MERV 16 filter captures greater than 95% of particles throughout the whole test range (0.3-10.0 microns), whereas a HEPA filter captures 99.97% of particles with a size of 0.3 microns [38]. To qualify as HEPA-grade, filters must remove at least 99.97 percent of all particles between 0.15 and 0.2 mm in diameter, which are the particles for which HEPA filters are least efficient. Consequently, HEPA filters have a minimum efficiency of 99.97% for removing all particles, with much higher efficiencies for particles 0.15mm in diameter and larger [39].

Table 3
Minimum filter efficiency

Methodology		ISO16890 Minimum Filtration efficiency % of PM	
EN779.2012	ASHRAE 52.2	0.3 – 1.0 µm $ISOePM_1$	0.3 – 2.5 µm $ISOePM_{2.5}$
G1	MERV 1-2	Nil	Nil
G2	MERV 3-4	Nil	Nil
G3	MERV 5	Nil	Nil
G4	MERV 6-7	Nil	Nil
M5	MERV 8A-9A	>20%	>30%
M6	MERV 10A-12A	>40%	>50%
F7	MERV 13A	>50%	>60%
F8	MERV 14A	>60%	>75%
F9	MERV 15A-16A	>80%	>90%

It has been recognized that engineering solutions, such as providing enough ventilation or air filtration, are efficient means of improving Indoor Air Quality. Indoor air filtration can be provided by a central HVAC system, portable room air cleaners, or an integrated system. [40] For effective aerosol removal, the primary filter in the air handling unit must be a minimum F8 multi-pocket or Vbank filter, preferably an F9 filter [14]. The data in Table 2 refers to a variety of particle-range-specific filters and their respective efficiency rates. High MERV (Minimum Efficiency Reporting Value) filters often have a greater pressure drop than low MERV filters. [41]

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) [42] (effective September 2021) mandates the use of at least the minimum exterior air volumes for ventilation, in addition to MERV13 or higher recirculation filters or a combination of outdoor air, filtration, and air-cleaning technology (minimum ventilation plus MERV13). Particulate filters and disinfection devices in recirculated air streams can mitigate the danger, but they must be designed to manage the risk of airborne sickness and require routine maintenance [43]. Increased infection rates or outbreaks of airborne diseases are linked to inadequate ventilation or low ventilation rates. An infection may spread further away from the source due to the airflow from a contaminated source. As the physical distance from the source rises, the rate of infection (attack) decreases. The source location's airborne pathogen concentration must be sufficiently high for airflow-induced infection to occur (either due to high source strength or a low ventilation rate) [44]. However, the findings of Parhan and Brent's study, which used a modified particle-size-resolved version of the Wells-Riley model in Equation to estimate the risk reductions probably achievable by typical HVAC filters for a case study of influenza transmission in a fictitious office building, show that HVAC filtration can probably play a part in preventing the transmission of airborne infectious diseases[45] at a lower cost than providing an equivalent amount of outdoor air ventilation, as was typically studied in prior research [46-49]. To support the study from Parhan and Brent's, G. Correia et.al (2020) stated, HVAC has a crucial function in reducing the risk of transmission. [50]

4. Conclusion

In conclusion, the ventilation system plays a crucial role in preventing the spread of airborne diseases. To reach the needed level of efficiency, the filters with a high MERV (Minimum Efficiency Reporting Value) or HEPA are reported to create more efficiency in reducing the transmission of airborne disease. In addition, to be more precise, the HVAC mechanism system is referred to as indoor ventilation. Some skepticism exists, based on the literature review, that the HVAC system may be the agent responsible for the transmission of airborne diseases within the building. Based on the literature review, the installation of an indoor HVAC system affects the transmission of airborne diseases. For instance, HEPA, or High-Efficiency Particulate Air, is more effective than MERV 16. A MERV 16 filter captures greater than 95% of particles throughout the whole test range (0.3-10.0 microns), whereas a HEPA filter captures 99.97% of particles with a size of 0.3 microns. In order to overcome the controversial issues regarding the HVAC this paper proves for the installation of an efficient filter mechanism can help to overcome the transmission of airborne disease.

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