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(Review Article)

HVAC system requirements for protection against epidemics similar to Covid-19

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Abstract

Tuberculosis and in some cases, flu, colds and other airborne diseases. Since research is one of the biggest concerns of causing influenza pandemics, most research surrounding aerosol contamination revolves around environmental influences on the influenza virus. Many literatures suggest that influenza is transmitted primarily through close contact, such as exposure to large respiratory droplets, direct mouth-to-mouth contact and short-term exposure to infectious aerosols.

Diffusion can be accelerated or controlled by heating, ventilation and air conditioning (HVAC) systems. Researches continue that advances state of knowledge in the specific techniques that control airborne infectious disease transmission through HVAC systems, including ventilation rates, airflow regimes, filtration, and ultraviolet germicidal irradiation (UVGI). In this paper three methods of transmission of Airborne Infectious Diseases are discussed, namely through direct contact, large droplet contact, inhalation of droplet core.

An extensive literature review of many papers was conducted infectious diseases spread in several different ways and the transmission of infectious viruses. This review targets direct and indirect contact as well as infectious viruses known to be transmitted from the air. And he focused on preventive ventilation systems for these targets. This paper will give idea to support further research on engineering controls to reduce infectious disease transmission.

Keywords: Epidemics; Covid 19; Ventilation; HVAC Systems

1. Introduction

Nowadays, interest in environmental cleaning issues is increasing where previously regarded as not that important in this context, and the pollution of the HVAC (Heating Ventilating and Air Conditioning-Heating Ventilation & Cooling) systems becomes an imperative problem for people living indoors. Public health statistics are monitored in many developed countries and solutions are sought for the problems that arise under the responsibility of the related professional disciplines. If the problems arising from the usage are not followed up and resolved in modern buildings built with great costs to make our life more comfortable, it will be inevitable for a series of ventilation problems, especially health problems, to be solved.

People spend most of their lives indoors, and their pollutant levels can be much higher than those encountered outdoors. Assuming that we are using air conditioning systems more and more day by day, due to the fact that we spend our lives more indoors; heat, humidity and noise that are the environment comfort conditions that we need cause the development of HVAC systems for a long time. Another parameter that occurs depending on the usage conditions and

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time in these systems and which must be strictly controlled is pollution and hygiene. When HVAC systems are not cleaned regularly and hygiene conditions are not considered, each can become a home of bacteria and microorganisms. The increasing use of these systems in recent years has caused some diseases to spread. Viruses occurring especially in epidemic cases are among the most important of these health problems.

The virus is a causative agent of replicating microscopic infection that can only infect living cells. Viruses can infect all forms of living things, from animals and plants to microorganisms, including bacteria and arcs [1].

Coronavirus, which is also a viral type, are viruses that are a second subfamily to Coronaviridae which also cause illnesses to birds and mammals [2]. This virus which is not usually that serious in humans, notwithstanding it causing significant amount of cold cases, some rare coronavirus varieties such as MERS, -CoV, SARS-Cov and COVID-19 (2019-nCoV) cause respiratory system infections that might have mortality risk [2].

Alongside the fact that epidemic diseases such as coronavirus can be spread to breathing of the droplets scattered as a result of coughing and sneezing, there is a possibility that these droplets can be transmitted by touching contaminated surfaces.

2. Outbreak diseases and spread

Roy and Milton [3] define the scheme of classification of aerosol diseases as mandatory, preferential or opportunistic, based on the agent's ability to infect and induce disease. According to this classification scheme, tuberculosis may be the only infectious airborne disease (only for an infection initiated by aerosols).

For Mycobacterium tuberculosis, the aerodynamic diameters of the airborne particles are approximately 1 to 5 μm. Studies by Dick et al. [4,5] suggest that the common cold can be transmitted through the airborne droplet nucleus. In the study of Dick et al. [5], they document the possibility of transmission beyond 1 m (3 ft) under controlled conditions in experimental chambers and strongly suggest airborne contamination as at least one component of rhinoviral infection. Seasonal influenza control has been based on major droplet measures for decades, even though there is evidence of much more important airborne contamination by small particles. For example, in an influenza prevention study in a Veterans Administration nursing home in 1959, the upper room detected an 80% reduction in influenza in staff and patients using ultraviolet antiseptic irradiation. (UVGI-(upper room, in-room and air flow) [6].

This indicates that air currents in high room areas with UVGI carry airborne infectious particles and make the ineffective. In the epidemic of 1986, H1N1 influenza virus was encountered among US Navy personnel, and this was attributed to military personnel flying on the same aircraft. Most infected sensitivities have been displaced more than 2 m from infected individuals [7].

A study published by Han et al. [8] which has significant import in the study of airborne transmission of viral disease. An outbreak of influenza A pandemic (H1N1) occurred in 2-8 June 2009 among members of a tour group in China who had travelled in the same tour bus for 7 h. During June 2-8, 2009, an outbreak of influenza A pandemic (H1N1) 2009 occurred among 31 members of a tour group in China. To identify the mode of transmission and risk factors, we conducted a retrospective cohort investigation. Apparently, the patient with the index case noticed flu-like symptoms before coming to China. Secondary cases developed in 30% of the tour group members who interviewed the index patient and a passenger sitting in two rows of the index case patient. Tour group members who did not talk to the index patient did not get sick. As a result, this H1N1 pandemic virus infection was due to an epidemic, an imported case patient being infected during coughing or vocalization. The virus spread by droplet transmission

while the index case patient was talking to other tourists. The findings of this research emphasize the importance of preventing droplet delivery during a pandemic.

Chu et al. [9] have documented that contamination of severe acute respiratory syndrome (a family of severe pneumonia caused by a member of the coronavirus virus family - the same family that can cause a cold) can occur airborne. In a dramatic outbreak of SARS, in the high- rise apartment of Amoy Gardens, airborne contamination from the droplet core seemed to represent the primary disease spread mode. This may possibly be due to a dried floor drain and airborne spread by the toilet exhaust fan and winds [10]. The observed pattern of disease spreading from one building to the other, and especially the upwind side of a building, could not be explained for any other satisfactory reason other than the road in the air.

In a study conducted in Chinese student dormitories, it supports to theory of airborne spread of the common cold. Ventilation rates were calculated from measured carbon-dioxide concentration in 238 dorm rooms in 13 buildings. A dose-response relationship was found between the open-air flow speed per person in the dormitory rooms and the proportion of those who had 6 or more cold infections annually [11].

In a literature review conducted by Wat [12], it is cited that the transmission and seasonality of six respiratory viruses, stating that rhinovirus, influenza, adenovirus and possibly coronavirus are transmitted by air.

What is important for every epidemic is the ways of spreading of the contaminated factor. Regarding COVID-19, the standard assumption is that the following two propagation pathways are dominant: large droplets (droplets / particles emitted during sneezing, coughing, or speaking) and surface contact (hand-hand, hand-surface, etc.). A third way of propagation that attracts more attention in the scientific community is the fecal (fecal originated) path.

2.1. Airborne Particles

Small particles can be transported in diseases such as tuberculosis, Q-fever and measles through ventilation systems [13]. Therefore, when outbreaks occur in the workplace, HVAC systems should be considered. Direct contact, infection with fomite and large droplet pathways means that the path in the air becomes relatively more important, as it is reduced by more effective prevention strategies. If influenza transmission occurs not only by direct contact or large droplets, such as the long-term public health tradition, but also by airway, as more recent data suggests, HVAC systems reduce the risk of disease transmission and potentially transmission by transmission.

There are practical limitations on what HVAC systems could do to prevent transmission of infections in large populations. In some cases, infections are transmitted in the absence of HVAC systems. Employers, operators and engineers are encouraged to cooperate with infection prevention specialists, who are familiar with the public of the infection in the workplace and the strategies for prevention and risk reduction.

Since small particles (droplets) remain in the air for some time, the design and working principles of HVAC systems can affect the transmission of the disease in several ways which are shown below:

- Providing Fresh Air to Sensitive People
- Containing Dirty Air and / or Discharging Outdoors
- Diluting the Air in a Place with Clean Air from Outside and / or Filtering the Air
- Cleaning the air in the room

In addition, the following strategies can benefit:

Dilution ventilation, laminar and other in-room flow regimes, differential room pressurization, personalized ventilation, source capture ventilation, filtration (central or unitary), and UVGI (upper room, in-room, and in the airstream).

There are two methods of exposure to airborne particles:

Close contact spread with large droplets (> 10 microns) released from the infected person and falling on surfaces not more than about 1-2 m.> Droplets consist of coughing and sneezing (sneezing typically creates more particles). Many of these large droplets fall on nearby surfaces and objects such as tables and tables. It can be transmitted to humans by touching these contaminated surfaces or objects; and then they can touch their eyes, nose, or mouth. If people stand within 1-2 meters of an infected person, they may be exposed directly to the virus by breathing the sneezing or coughing or exhaling droplets.

Close contact spread with small particles (<5 microns) that can be suspended in the air for hours and carried over long distances. These are also produced by coughing and sneezing and talking. Small particles (droplet core or residue) consist of evaporating (usually within milliseconds) and drying droplets. The size of a coronavirus particle is 80-160 nanometers (1 nanometer = 0.001 micron) and it remains active for up to 3 hours in indoor air conditions and 2-3 days on room surfaces in common indoor conditions (if there is no special cleaning). Such small virus particles are suspended in the air and can be transported in rooms over long distances with air currents or exhaust air ducts of ventilation systems. Propagation by airborne in the past caused SARS-CoV-1 contamination; there is currently no reported evidence specifically for transmission of Corona disease (COVID-19) in this way. There are also no reported data or studies that ignore the possibility of an airborne particle mechanism. An indication of this: Coronavirus SARS-CoV-2 could not be found in swabs from exhaust vents in rooms used by infected patients. This mechanism shows that it may not be enough to stay 1-2 m away from infected people and it is beneficial to increase the ventilation due to the removal of more particles [14].

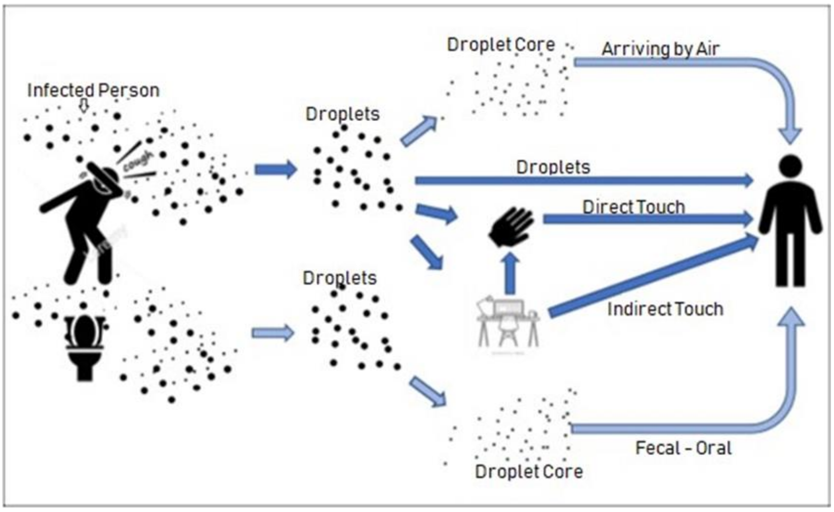

Figure 1 Mechanism of the World Health Organization exposure to COVID-19 SARS-CoV-2 droplets (dark blue colour) [14]

Exposure by air occurs through droplets that can be released from approximately 1m and which fall on to surfaces that are formed by infected and small fragments that have been released in one go which remain in the air for hours and travel long distance. Transmission aerobiology of droplets and small particles produced by a patient with an acute infection is shown in Figure 2.

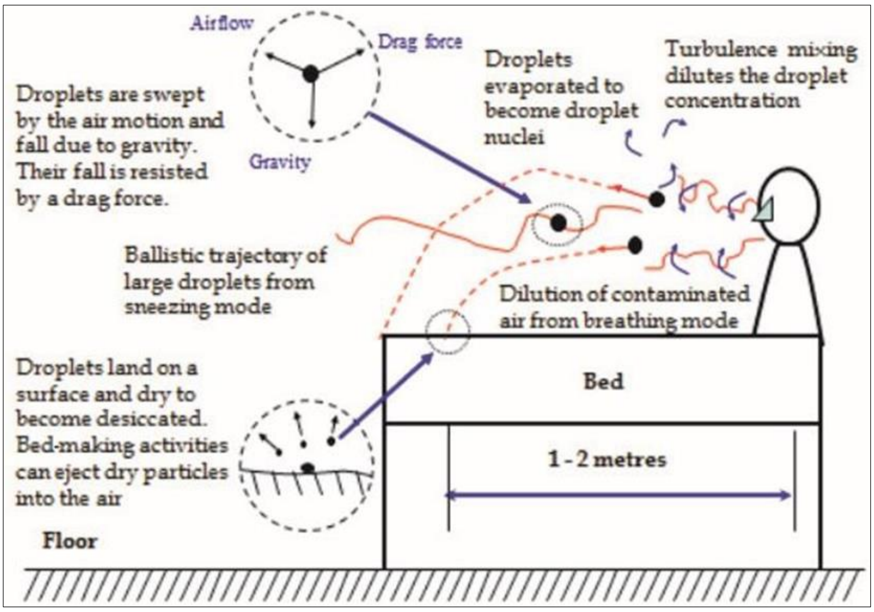

Figure 2 Droplet Suspension: An example of the aerobiology of droplets and small air particles produced by an infected patient [15]

Since large droplets are heavy and settle rapidly under the influence of gravity, overall dilution, pressure differences, and exhaust ventilation do not significantly affect droplet concentrations in terms of speed or direction unless they reduce the diameter by evaporation, thus creating an aerosol. Here, the term droplet cores are used to describe the drying of large droplets as small airborne particles [16].

Transmission modes are limited to aerosols that can travel longer distances along the route, including HVAC systems. It is not known that HVAC systems drag larger particles.

The size separation between the droplets and small particles is the mass median aerodynamic diameter (Mass Median Aerodynamic Diameter (MMAD) 2.5 to 10 μm [17]. Even particles with a diameter of 30 μm or larger can hang in the air [18].

Studies by Xie et al. [19] show that large droplets are between 50 and 100 μm in diameter during the original release. Tang et al. [20] proposed the large-scale droplet diameter chart for droplets with large droplet diameter (> 60 μm), small droplet diameter (<60 μm) and mass median aerodynamic diameter 10 μm.> The exact size limitation is less important than knowing that large droplets and small particles behave differently and the latter can stay in the air.

Small particles that can be released into the air can typically be produced by coughing, sneezing, shouting, and to a lesser extent by singing and speaking. Even breathing can produce such particles in sick and highly contagious individuals [21]. Particle size distributions of cough materials are thought to cover a wide diameter range from very small to large droplets, depending on differences in patients and diseases [22].

Fennelly et al. (2004) measured cough aerosol emanating directly from tuberculosis patients. Patients produced three to four colony-forming units containing up to 633 CFUs (CFU, a direct measure, live, growing and infectious organisms using culturing techniques). The size distributions measured in this study show that most living particles in cough-borne aerosols are immediately breathable, ranging from 0.65 to 3.3 μm. However, there is insufficient data to precisely define or predict the cough particle size distribution for many diseases and research is needed to be able to characterise them [24].

In the 1950s, the relationship between particle size, air suspension and transmission effects had just begun to become clear. Different paths have required different control strategies that have evolved in infectious disease practice over many years. Today, there are practice standards for infectious disease and hospital epidemiology. It was found that the rate of transmission of many diseases is higher if sensitive individuals approach at a distance of approximately 1 to 2 m. (Infectiouspneumonias, likepneumococcaldiseas to Hoge at al. [25] or plague (CDC2001) are thought to be transmitted in this way).

In this short range, the susceptible person will receive both inspirable large droplets and airborne particles from the infected person (see. It has a significantly greater exposure to droplets of varying size, such as Figure 1). To prevent such short-range exposure, maintaining a distance of 2 m between infected and susceptible, whether by droplet or by air, is considered protective and methods such as ventilation dilution are not effective.

2.1.1. Mathematical Model of Infection in the Air

Riley and Nardell [22] present a standard model of airway infection, referred to as equation 1 below, called the Wells-Riley equation.

$$C = S(1 - e^{-Iqpt/Q}) \qquad (1)$$

Number of new infections (C), Sensitivity number (S), Number of infections (I),

The number of airborne infection doses (q) added to the air per unit time by an infectious case, Pulmonary ventilation per volume sensitive per unit time (p), Exposure Time (t), Disinfected air where fresh or quantum is distributed (Q).

The base here (Iqpt / Q) represents the degree of exposure to infection and ($C = S(1 - e^{-Iqpt/Q}$) is the possibility of a single susceptible person to become infected.

It is worth knowing that this model does not take into account the varying sensitivity among uninfected individuals. For this and other reasons, exposure does not necessarily lead to infection.

2.2. Transfers by Contact

For contact prevention, it is important to rub the hands inside and outside of the hand with soap or detergent for 20 seconds in accordance with simple hygiene rules and dry the hands with a paper towel without touching anywhere else. Airport etc. Ozone and UV applications are made with hand dryer type devices for hand disinfection in crowded areas.

The anti-viral and anti-microbial properties of ozone are well documented, but their mechanisms of effect are not well understood, and several macromolecular targets could be added [26-30]. Aqueous ozone solutions are used as disinfectants in many commercial situations, including wastewater treatment, laundries and food processing. However, ozone gas has a number of potential advantages over other decontaminating gases and liquid chemical applications [31].

Thus, ozone is a natural compound, easily produced in place from oxygen or air, and is divided into oxygen for a half-life of approximately 20 minutes (± 10 minutes depending on the environment). As a gas, it can penetrate much more efficiently than manually applied liquid sprays and aerosols in all areas in a room, including crevices, fixtures, fabrics, and furniture substrates [32-34]. The only major drawback is its wear and potential toxicity to humans when exposed for a long time to certain materials, such as natural rubber. Recognition of the risk of pathological outcome after exposure to ozone gas to humans and experimental animals has led to restrictions in its use in public places.

2.3. Temperature and Humidity

Many HVAC systems can control indoor humidity and temperature, which can in turn influence transmissibility of infectious agents. While many evidences currently suggests that controlling relative humidity (RH) may reduce the transmission of some airborne infectious organisms, including some influenza strains, it would not be right to generalise it.

Memarzadeh [35] review targets direct and indirect contact as well as infectious viruses known to be transmitted from the air. According to Memarzadeh [35], in the review of 120 articles on the effect of moisture and temperature on the transmission of infectious viruses, many researchers suggest that three mechanisms could potentially explain the effect of RH on transmission. A possible mechanism is slower evaporation of large droplets affected by high humidity. Otherwise, it is certain that a lower humidity will turn them quicker into droplet nuclei.

An example of the possible impact of a large number of mixer transmission factors can be found in an airplane reference by [36] who described a flu epidemic that occurred on the Alaska Airlines flight. During a stop, the ventilation on the plane was closed for 3 hours, during this time the passengers were restless and moved around the cabin. During the flight, one passenger, the so-called index case, was acutely ill with laboratory-approved influenza A, and 72% of other passengers imprisoned on the plane were infected with influenza.

Infection formation increased as the time spent on the plane increased. There was no clear evidence for a single mode of transmission, and at first glance it suggests that there is a route transmission via air. However, there are several confusing variables that indicate droplet and contact transmission from the index state. These included free movement of passengers in the aircraft cabin; this resulted in the possible touch of surfaces that contaminated their hands; the index was sitting next to the toilet, so almost all passengers went through the index case during the stay and the aircraft with HVAC was inoperable. Therefore, sick passengers may have been infected by any of the common forms of transmission. Neither temperature nor humidity were considered in this study.

Nicasve et al. [37] show by modelling that the emitted droplets will evaporate up to 50% of their initial diameter and in the case of the initial diameter being <20 μm, this will occur before the drops fall onto a surface. For larger diameters and higher humidity, it will not be fast enough to turn large droplets into droplet nuclei before they fall. Wang et al. [38] found that people inhaled fewer droplets at a higher RH.

3. Ventilation and HVAC Requirements

It is estimated that more than 40% of primary energy in OECD (and European) countries is consumed in buildings and that half of this is dissipated through ventilation and air infiltration [39]. However, besides the energy costs of ventilation, health effects are also important. Ventilation carries open air to a building or room and is responsible for distributing the air inside the building or room. The general purpose of ventilation in buildings is to provide healthy air for breathing, both by diluting the pollutants from the building and by removing the pollutants from it [40-41].

Exposure to indoor pollutants can pose a serious health risk especially for sensitive populations such as the young, asthmatic, or elderly [42-43]. Liddament [39] reviews ventilation and its impact on indoor air quality. Aim of his study is to review these aspects with particular reference to recent research and developments. Good indoor climate can be achieved, not so much by introducing expensive concepts, but by developing a rational approach to identifying needs and applying the necessary tools to deal with each need.

Drinka et al. [44] reported that a long-term care facility has a relationship between influenza infection and ventilation system design in different buildings. The higher the percentage of outside air circulating in the buildings, the lower the percentage of infected patients.

Ventilation systems in all types of buildings need to be developed to include a suitable temperature and humidity. While arranging the ventilation system of any building, the organisation of the filters that clean the air from the particles should be done carefully as well as the correct determination of the size of the ventilation ducts and fans and the air flow rates in the ducts. In hospitals, ventilation systems (Heating, Ventilation and Conditioning; HVAC) are of special importance when it is aimed to protect the health of patients and hospital workers and to prevent hospital-borne infections.

There should not be any additional risk of infection due to the operation of a ventilation system. A ventilation system is based on 3 basic principles:

- Ventilation rate: the amount of outside air supplied to the space and the quality of the outdoor air,
- Air flow direction: general air flow direction in a building that should be from clean areas to dirty areas.
- Air distribution or air flow model: outside air must be efficiently supplied to each part of the space, and airborne pollutants produced in each part of the space must also be effectively removed.

Ventilation performance in buildings can be evaluated from the following four aspects, which correspond to the three main ventilation elements discussed above.

- Does the system provide adequate ventilation rate as required?
- Is the total airflow direction in a building from clean areas to dirty areas (e.g. Enclosure areas such as isolation rooms or laboratories)?
- How effective is the system in delivering ambient air to anywhere in the room?
- How effective is the system in removing air pollutants from all parts of the room? [45]. The following risks can be added to the risk of normal infection in cases of poor planning, improper installation or malfunction in ventilation systems:
- The entrance of microorganisms in the air through the supply air,
- Aspiration of bacteria from non-sterile areas,
- Induction of polluted air due to potential uncontrolled air circulation to the air supplied by the ventilation system,
- Transfer of microbes in the air uncontrollably through the air suction duct system from the areas where air is provided by the ventilation system,
- Systems that do not have ventilation systems that are not suitable for maintenance and systems that do not have sealed sensitive filter (F9) units that protect the air ducts at the exit of the plant become environments suitable for microorganism reproduction over time [46] and create danger.

Therefore, in the installation of ventilation systems in closed spaces, it is necessary to know the properties of infectious agents that are transmitted by indoor air, and to determine and design the required areas in advance. It must provide an optimum airflow that will protect the optimum temperature, humidity and the health of staff and visitors.

In infectious diseases, it is possible to solve human-to-human transmission by engineering methods through the transmission and transportation of droplets in enclosed spaces. In the same environment, if an effective air filtration system comes into play, the risk may be eliminated.

The second possible mechanism is that the relative humidity may move at the level of the host. Inhalation of dry air can cause the nasal mucosa to dry out, which makes the host more susceptible to respiratory virus infections. The third possible mechanism is the ability to move at the virus particle level to affect the virulence of the relative humidity. Yang and Marr [47] minimised the complexity of the relationship between aerosolised viruses and relative humidity, including hypotheses, which could explain the relationship between moisture and viability of viruses in aerosols, such as water activity, surface inactivation, and salt toxicity. They also proposed their own hypothesis that changes in pH (induced by evaporation) in the aerosol endanger infectivity. They concluded that the exact mechanisms underlying the relationship describing this situation were largely unconfirmed; there are still large gaps in the literature, and full understanding will require more in-depth studies with interdisciplinary cooperation. Memarzadeh [35] also concludes that there is insufficient evidence to say that protecting a closed environment at a certain temperature and a certain RH will reduce airborne susceptibility and hence transmission of influenza virus compared to a similar environment.

3.1. Causes of Pollution Formation and Particle Emission Analysis

According to the conditions of the environment in each facility and building, it can receive particles in various ways, and these particles can have harmful effects according to the purpose of the building. Located in natural air; pollen, bacteria, various dead and living microorganisms, particles caused by erosion or volcanic eruptions carried by the winds, exhaust emissions, burns from the office machines or industrial facilities, chemical reactions, particles arising from manufacturing, carpets, seats, curtains in the place are particles and microorganisms that spread from humans through the respiratory or hairy-bald skin and clothing. In order for this classification to be functional, pollutants are classified in 3 main categories.

3.1.1. Pollutants

Air, as is known, consists of "other" gases, including 78% nitrogen, 21% oxygen and 1% gases such as carbon dioxide and various chemical compounds [48]. Indoor pollutants can be evaluated in one of three categories.

Category 1

Pollutants produced in the environment: These types of pollutants generally have a detectable source in the environment. This category includes carbon dioxide coming out of humans, biological odors and synthetic flavors, cigarette smoke, volatile organic compounds originating from adhesives and other substances, solvents and cleaning agents, chemicals for process or storage and cooking odors.

Category 2

Environmental pollutants introduced into the environment: When considering these types of pollutants, the type of pollutant first, and then the ways of entering the environment should be investigated. Carbon dioxide, sulfur dioxide, industrial chemicals and solvents are in this group. The most common way these pollutants reach the environment is; 1) building openings that serve a specific purpose, such as windows and doors, 2) building openings that do not serve aspecific purpose, such as leaks at the window edges, and 3) outdoor air used by the ventilation system.

Category 3

Organic pollutants that reproduce in the environment: This type of pollutants are the most common, the most dangerous and unfortunately the least comprehended group. It occurs in areas with high humidity and favourable temperatures. General forms of these pollutants can be regarded as germs and mould. Since pollutants in these three categories need to be handled differently in an HVAC system, they will be referred to as category 1,2 and 3 pollutants in this article [48].

Efficiency of Removal of Pollutants from the Environment
Efficiency of Removal of Pollutants from the Environment is defined by the formula below: $E_c = (C_{to} - C_s) / (C_{ort} - C_s)$

Ce: Concentration of pollution in return air, Cs: Pollution concentration in blowing air, Cort: Average pollution concentration in a room.

$$E_c = (C_e - C_s) / (C_{oz} - C_s)$$

Coz: Average pollution concentration in the habitat [49].

Ventilation Air

When properly designed and operated, the concept of "mixing volume" prior to the air conditioning device, as the point of delivery of the air taken from the outside to dilute Category 1 pollutants, may be a "perfectly" valid concept for simple systems from 50 years ago. However, given the complexity of today's systems, this concept is not technically sufficient [48].

Ozone and Particle Status in Our Environment

Ozone is not found in a free form in nature. It consists of the breakdown of the oxygen molecule with the effect of ultraviolet cosmic rays, whose wavelength is very short in the upper layers of the atmosphere. It is found 200-400 mg per 100 m3 in fresh air. It is very weak in the city air with reducing powders. Ozone is also a powerful bactericidal that makes the air favourable for health. The fresh air smell we feel after lightning strikes in stormy weather actually expresses the increasing ozone density [48].

3.2. Cleaning Requirements for General HVAC Systems

The paths to be followed at this stage are also determined by standard methods in western countries. First of all, internal and external sources that may cause pollution for the whole building should be identified, and the problematic parts should be modified as much as possible. Pollution Retention: Dirt removed during cleaning must be properly collected and measures must be taken to prevent it from spreading to other parts of the HVAC system during cleaning. For this, the part to be cleaned should be isolated from the system.

Particle collection: If the particle collecting equipment (vacuum) exhaust outlets have to remain inside the building, 99.97% sensitivity of HEPA filters should be used for 0.3 micron (and larger) particles. If particle collecting equipment (vacuum) exhaust outlets can be thrown out of the building, appropriate mechanical filtration will be sufficient to retain dust from the HVAC system [48].

3.3. Disinfection

When the ventilation ducts are not cleaned for a long time, unwanted microorganisms can form inside the duct. The spread of spores, bacteria, and viruses cannot be completely prevented by following current health (hygiene) standards. It provides an ideal environment for the growth of microorganisms such as mould, fungus, bacteria and virus in HVAC systems such as cooling coils. This causes infections in comfort ventilation. Spread of microorganisms in ventilation systems causes mould or low product quality [49].

Figure 3 Internal View of Dirty-Clean Ventilation Channel [50].

Disinfection, is the process of removing an object or environment from microorganisms at a level preventing it from being a source of infection. It is evaluated in three categories as high, medium and low-level disinfection according to the level of affecting bacteria spores and mycobacteria.

Mechanical cleaning works carried out in HVAC systems may not reach the desired result in some cases. If it is certain that there are repetitive microbial contaminations in tests performed after mechanical cleaning, then disinfection methods should be used.

One of these methods is disinfection with UVC beam. These rays coming from the sun, which is the only natural ultraviolet ray source in the universe, are filtered by the atmosphere in different proportions. While almost all UVA rays and some of UVB rays can reach the earth, UVC rays, also known as germicidal rays, cannot exceed the atmosphere. Otherwise, no microorganism could exist on earth, and life would disappear.

However, special purpose UVC bulbs have been developed in order to use the germicidal effect of UVC rays wherever and in the desired rate. The UVC rays emitted from these bulbs destroy the DNA structure of the microorganism that comes across them in seconds, destroying their ability to reproduce and form colonies. All microorganisms, including viruses and bacteria that have become resistant to antibiotics today, are vulnerable to UVC rays.

A certain UVC beam dosage is required for each type of microorganism for successful disinfection. Therefore, it is very important to determine the target microorganism first for UV disinfection. Bulb and disinfection device should be determined and designed accordingly [51].

With UV disinfection systems using UVC lamps to be placed in the air ducts, by using the areas in the air duct in the most accurate way; it is possible to clean the infected (bacteria, virus) air moving in the channel.

Comparatively, with low investment expenditures, by using sterile Air UVC disinfection systems, the risk of infection can be prevented and cross-contamination can be reduced. Sterile Air recirculation systems are used to disinfect rooms with low convection or in areas where direct emissions are not applicable. Sterile Air circulation systems have capacities of 180 m^3 / h - 450 m^3 / h and can easily be installed and used [52].

Figure 4 UVC - Disinfection Ventilation Systems [52]

Weaknesses of ambient disinfection with UV rays: In order for UV rays to be effective, the humidity rate must be below 50-60%. Since the effectiveness decreases in the presence of organic matter, UV should not be applied without removing organic substances from the environment. Since UV is harmful to human skin and eyes, protection measures should be taken in order not to be exposed to UV above the specified limits. These rays should either be used in non-human environments or human exposure should be prevented by placing them in closed systems in areas of use [53].

4. Conclusion

Viruses, bacteria etc. that have existed since the formation of the world. microorganisms will continue to be in contact with all living things in the world. The measures to be taken in the contact of these microorganisms by air are of great importance. In this sense, it is of great importance that the ventilation systems are sterile. Areas that are not controlled in terms of ventilation technique cannot be called sterile or clean areas. The way and quantity of the air that filtered through sensitive filter, which is the number of air changes, determines the efficiency of the bacterial dilution process in the ambient air as well as the indoor air quality. For this reason, proper designing of air quantities and air delivery patterns, measuring the air quantity in the performance tests with the correct methods, proving and documentation of compliance with the project and standards should be provided.

A good ventilation system responds to the needs at maximum efficiency. It is possible to ensure that a good ventilation system provided by determining user requests, qualifying the project and design, checking whether the equipment used in the installation carries the project and design values, checking whether the equipment assemblies are done correctly, checking whether the equipment's compliance with the specifications and standards are evaluated, checking whether the system functions in accordance with the project and installation during operation, by checking whether it can provide sufficient capacity, by checking whether automation can provide the tasks defined to it even in the worst case scenarios, and by ensuring that all working functions are provided.

Measures can be taken to protect from microorganisms with modern applications in ventilation systems. In addition to the filtration system for potential infected area or infected area disinfection, working environment safety can be provided with Ozone Generator / UV (Ultraviolet) equipment to be integrated into the HVAC system.

This paper reflects the following results briefly by summarizing:

- Alongside the fact that epidemic diseases such as coronavirus can be spread to breathing of the droplets scattered as a result of coughing and sneezing, there is a possibility that these droplets can be transmitted by touching contaminated surfaces.
- Many infectious diseases are transmitted through inhalation of airborne infectious particles termed droplet nuclei,
- Airborne infectious particles can be disseminated through buildings including ventilation systems,
- Airborne infectious disease transmission can be reduced using dilution ventilation, specific in-room flow regimes, room pressure differentials, personalized and source capture ventilation, filtration, and UVGI.

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