Literature study on ventilation and Air Conditioning (AC) systems associated with the SARS-CoV-2 pandemic

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ABSTRACT: Based on research on SARS-CoV-2, transmission is generally found to occur in a closed room. The medium through which the virus transmits is droplets. Droplet nuclei can be carried by air flow, causing airborne transmission. Ventilation and air conditioning also play a role in this type of transmission, so it is important to know how it happened and how to deal with it. The study was conducted through the collection of literature related to SARS-CoV-2 and ventilation and air conditioning. The literature data is analyzed and conclusions are drawn. The results obtained are weakness of the ventilation system, improper selection of air conditioners, and poor quality of the indoor environment as a facilitator of transmission. The solution to these problems is the need for careful planning related to building design, ventilation systems, and the right type of air conditioner. All these efforts have consequences in the form of high costs.

Keywords: SARS-CoV-2, airborne, ventilation, air conditioners

1 INTRODUCTION

SARS-CoV-2 (new coronavirus) has caused a global pandemic. This virus can cause deadly pneumonia. About 15% of sufferers require hospital treatment and one third require intensive care (ICU). This virus has a value of R_0 (basic reproductive number for infectious diseases) 3.28 or each patient can infect three other people (National Collaborating Centre for Environmental Health 2020). This R_0 value can increase sharply (5 to 14) in a closed room (building) (Dietz et al. 2020). The number of infected people in the world has reached 17,660,523 people, with the number of deaths up to 680,894 people, and this virus has entered 216 countries (World Health Organization 2020). Based on SARS-CoV-2 experiments, it can be deactivated at high temperatures, its infectivity decreases at high humidity, and can be removed (disinfection) using UV-C light (National Collaborating Centre for Environmental Health 2020).

1.1 Conditions that allow for SARS-CoV-2 to occur

The effectiveness of virus transmission is determined by the number of virus particles that enter the body through breathing and the length of exposure to the virus. The main transmission media of SARS-CoV-2 is through large droplets ($> 5 \mu m$ diameter) resulting from coughing or sneezing from an infected person when making direct contact. In addition, transmission can also occur through droplet nucle/aerosols (diameter $< 5 \mu m$) as a result of breathing, talking, screaming, or singing. This transmission through aerosols occurs when virus particles accumulate in a closed room with poor ventilation that is crowded with people and contact between people occurs for a long time (National Collaborating Centre for Environmental Health 2020).

1.2 Cases of transmission of SARS-CoV-2 in confined spaces

Cases of transmission of SARS-CoV-2 occurred in countries all over the world, including China and Singapore. These transmissions took place in public facilities such as schools, sports buildings, bars, shopping, and conferences, with the number of cases reaching between 50 and 100. There was a direct correlation between the transmission rate and how many and how close people are in a closed room (Leclerc et al. 2020). Another case study of transmission was in Guangzhou, China, which occurred in a restaurant. The restaurant is in the form of a 5-story building, does not have window openings, and fully uses air conditioning (AC) which applies an air recirculation system as a source of air conditioning. The incident involved three families (families A, B, and C) who sat at different tables (next to each other and the position of the family table A was in the middle) and the infected person came from family A. The position of the AC outlet and inlet was above the family table C and air flow flows from family table C to family table A then family table B and back to family table C. The distance of the infected person from family A to family table B and family C > 1 m, but strong AC air flow causes droplet nuclei/aerosols (< 5 μ m) spread to the table of family B and family C. Droplet nuclei can remain in the air for some time and can move far > 1m (Lu et al. 2020).

1.3 The role of ventilation and air conditioning systems in transmission of SARS-CoV-2

In modern times, humans spend most of their time in activities inside buildings, but many buildings are poorly ventilated, have unhygienic conditions, and are overcrowded. The cost factor is more of a priority than the user's health because creating a good environmental condition in the building/room requires high costs. The results showed that the rooms where we live and work are where SARS-CoV-2 is spread. Poor ventilation and AC systems facilitated the distribution (Qian et al. 2020). Therefore, it is important for us to know how the ventilation and air conditioning system facilitates the distribution of SARS-CoV-2 in the room and how we can reduce the risk of such spread through the proper application, operation, and maintenance of ventilation and AC systems.

2 RESEARCH METHODS

The first phase of the study was carried out by gathering various literature on SARS-CoV-2, the spread of SARS-CoV-2, WHO standards, ventilation, and air conditioning systems, as well as the influence of the artificial environment in controlling outbreaks. The second step is to analyze the literature, then make conclusions related to the role of ventilation and AC in transmission and reduce the risk of SARS-CoV-2 transmission. In addition, based on the results of the analysis, conclusions are drawn regarding the application, operation, and maintenance of ventilation systems and ACs that were appropriate during the SARS-CoV-2 pandemic. Data collection was carried out through various literature in the form of guidelines issued by the World Health Organization (WHO) and journals published during the SARS-CoV-2 pandemic since late 2019.

3 RESULTS AND DISCUSSION

3.1 Relationship between ventilation and airborne disease transmission

Based on the results of the study, a link was found between ventilation and transmission of diseases through the air, including WHO (2009):

- Inadequate ventilation and low rates of ventilation through ventilation have an effect on increasing airborne disease transmission.
- The high air exchange through ventilation (ventilation rate) can increase the dilution capability so as to reduce the risk of transmission.

- Air flow from pathogen-contaminated areas (sources of disease) can expand or increase the spread of disease. Conditions that must be met in order to cause the spread of disease due to air flow are high concentrations of pathogens from contaminated areas and low air exchange rates.

3.2 *Relationship between ventilation and airborne disease transmission*

One of the air exchanges in the building can occur through ventilation. Ventilation can be divided into three types: natural, mechanical, and hybrid ventilation (mixed mode). Natural ventilation utilizes openings in buildings and climatic/environmental conditions, mechanical ventilation utilizes technology (e.g., fans and exhaust), while hybrid ventilation combines both (World Health Organization 2009). Natural ventilation has several weaknesses that can be a facilitator of airborne disease transmission, namely (World Health Organization 2009):

- Natural ventilation is very dependent on climatic conditions and the environment around where the building is located, consequently natural ventilation can be optimally applied in one location but is very difficult to apply in other locations.
- It is difficult to obtain a stable air condition inside the building through natural ventilation, for example due to changes in the difference in air pressure between outside and inside the building.
- Natural ventilation can experience various problems such as environmental conditions around buildings that are not conducive, equipment damage (when using technology on hybrid types), poor system planning, poor maintenance, and operation so that it cannot function properly.

3.3 *Contradiction in efforts to maximize room air exchange and its solution*

Utilization of ventilation to obtain high levels of air exchange and regulate the flow of air movement in buildings is very important in reducing the risk of airborne disease transmission. But it can also cause other problems concerning the comfort, health, and safety of humans who are in the building. The first problem, namely natural ventilation through openings in buildings, can cause noise and pollute air quality in the room through pollution from outside the building. The greater or more openings, the greater the risk of noise and pollution. The second problem, in hot and humid climates (such as tropical climates) openings can cause high humidity in the room, which triggers the growth of mold and mildew which endanger human health. The third problem, openings can cause the entry of insects, wild animals, and even increase security risks. The fourth problem, openings that apply the principle of cross-air circulation (continuous opening from one room to another) can cause difficulties in meeting safety standards in the event of a fire (room protection from fire spread) and fire smoke control standards (World Health Organization 2009). Efforts to overcome the problems above can be reached in several ways. First, in the initial stages of planning the site design, building (shape, orientation, and layout) and building envelope must be carefully considered to maximize air exchange in the space but also reduce the risks that may arise due to openings. Second, at the beginning of building design, positioning, magnitude, and type of openings are very important to maximize air exchange. Third, the selection of light barriers outside the building that is right affects the comfort of the temperature inside the room. Fourth, the selection of the right building material (both for exterior and interior) is also important to achieve a comfortable temperature in the room. Fifth, the use of hybrid ventilation can help solve the problem of safety risks and maintain the stability of the exchange rate and the direction of air flow in the building (World Health Organization 2009).

3.4 *Air Conditioning (AC) and its relationship with airborne disease transmission*

Based on research, the AC system can be a facilitator of airborne disease transmission but can also reduce the risk of transmission through (European Centre for Disease Prevention and Control 2020):

- An AC system that uses the right filter can filter droplets and even droplets of the nuclei from SARS-CoV-2.

- ACs can reduce the risk of spreading disease by increasing air exchange (introducing fresh air from outside the building).
- The AC system can be a SARS-CoV-2 transmission medium in buildings if it only uses the air recirculation method.
- Air flow from the air conditioner can expand/increase the range of the droplet (especially the droplet nuclei) from the infected person to its surroundings in the room.

3.5 *Strategies for selection and operation of Air Conditioning (AC) during the SARS-CoV-2 pandemic period*

The selection of the right system, operation and AC equipment is very important in reducing the risk of SARS-CoV-2 transmission. Based on the following research, several ways that can be taken to reduce these risks, namely the use of proper filtration for air conditioners. SARS-CoV-2 has a size spectrum of 0.25–0.5 μm and thus requires high efficiency filtration to prevent the transmission of SARS-CoV-2 pathogens. Health facilities (for example hospitals) to prevent airborne disease transmission using MERV-13 or higher and combined with HEPA filters to filter out very small pathogens in the air. Setting an air-conditioning system that can maintain room humidity (RH) between 40% and 60% can limit the spread and survival of SARS-CoV-2. Utilizing an air handling unit (AHU) in an AC system to increase room air exchange (taking clean air from outside the building) can help melt contaminants (virus particles) from the air. Based on the results of studies of irradiation for 10 minutes using UV-C light can deactivate (99.999%) SARS-CoV and MERS-CoV, so that the irradiation method using UV germicidal (UVGI) can be applied to the AC system. This irradiation is carried out on a mechanical ventilation duct (ducting) to avoid direct contact with humans (Dietz et al. 2020). The use of a timer or CO₂ detector intended to save energy in an AC system must be avoided because it will reduce the level of air exchange in the room. In addition, the regulation of the air flow direction from the AC outlet must be sought not to lead directly to humans/users of the room, especially those who have long activities in the room and tend to be in a fixed position (not moving much) to prevent the transmission of pathogens directly and continuously through the air flow (European Centre for Disease Prevention and Control 2020). Efforts to reduce the risk of deployment through the selection of systems, operations, and AC equipment also have several consequences, such as increased energy use to increase air exchange through AHU which has an impact on inflated operational costs, increased air exchange (entering air from outside into the room) also impacts filtration requiring maintenance more often, not all AC systems can increase humidity in the room so to realize it requires certain AC equipment and special care in the room to prevent the appearance of mold and mildew due to increased humidity (Dietz et al. 2020).

4 CONCLUSION

Based on the discussion from various literature above, it can be concluded that the ventilation and AC system has a very large influence both on transmission and decreasing the risk of SARS-CoV-2 transmission. Weaknesses in the ventilation and AC systems if not addressed can be a driver of rapid increase in transmission of SARS-CoV-2. This can happen because most of modern human life is spent in buildings and it is certain that it will always come into contact with ventilation and AC which are part of the indoor environment conditioning system. This is exacerbated by the many conditions of modern buildings that do not have good ventilation.

However, efforts to reduce the risk of SARS-CoV-2 transmission through systems, operation, and maintenance of ventilation and air conditioning also have significant consequences in the form of planning costs, supply of equipment, operation, and maintenance, and require intensive maintenance on a regular basis. In addition, professional staff are needed to operate the systems and equipment and to socialize them well to the building users. Not all building owners and operators/managers have the financial ability to meet these standards, so careful analysis and

planning are needed to selectively choose the system to be implemented in accordance with the capabilities and field conditions.

Table 1. The factors that need to be considered related to the ventilation and air conditioning systems to reduce the risk of transmission. (Source: personal)

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