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A Review on the effect of air distribution in Protected Occupied Zone Ventilation

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Abstract
Indoor air quality and comfort are directly related to ventilation and air distribution strategies. The purpose of this article is to examine the research done on airflow distribution systems and the efficiency of ventilation in a protected inhabited zone. This analysis demonstrates that different tasks of the ventilation system, such as removing heat, removing pollutants, supplying fresh air to the breathing zone, and protecting occupants from cross infection, need different measures of effectiveness or efficiency when evaluating ventilation systems. The study also provides a thorough foundation by discussing techniques for monitoring and analyzing ventilation and air distribution. Finally, we undertake a discussion on the utility and advantages of various ventilation systems, providing a roadmap for future research. The findings of the investigation provide a foundation for the potential future use of individualized ventilation.

Keyword: Air distribution, Thermal comfort, Air quality, Energy efficiency Ventilation, Ventilation effectiveness, Ventilation efficiency Performance

I. INTRODUCTION

The smallpox pandemic in Meschede, Germany (1970), measles (1985), tuberculosis (TB) (1990), SARS (2003), and H1N1 (2009) were all sudden worldwide outbreaks of respiratory infections that had devastating effects in many nations. However, during the energy crisis of the 1970s, the interior environment sector has been trying to strike a middle ground between air distribution and indoor air quality, thermal comfort, and energy efficiency. However, the sick building syndrome and other health problems associated with too airtight buildings lead to lost productivity. There has been a rise in recent years in both the number of complaints and the monetary cost associated with poor indoor air quality. [1]

Ventilation systems in homes are installed to dilute and flush out interior contaminants. The purpose of this research is to determine the efficacy of protected zone ventilation (PZV), also called "protected occupied zone ventilation" (POV), in reducing occupant exposure to common indoor pollutants. The effectiveness of PZV in reducing exposure to gaseous and particle contaminants found in enclosed spaces was evaluated. [2]

Hong Kong hospital wards have reportedly experienced outbreaks of severe acute respiratory distress syndrome (SARS), which has been linked to the coronavirus (SARS-CoV) and can cause epidemics. This suggests a link between the quality of the building's ventilation system and the frequency with which infections occur. In particular, intensive care unit (ICU) and elderly population nosocomial infection rates were shown to be significantly correlated with HVAC system functioning features such relative humidity and temperature.

Here are three techniques for ventilating a building: ventilation that is mechanical, natural, or hybrid (mixed-mode). [3]

Natural ventilation: Natural forces, such as thermal buoyancy force and winds arising from changes in the densities of interior and outside air, are used to drive outdoor air through specifically engineered openings in the building envelope. A few examples of apertures that serve a specific function include solar chimneys, wind towers, Windows, doors, and trickling ventilators. Natural ventilation is impacted by weather, architectural choices, and occupant habits.

Mechanical ventilation: Mechanical fans are used to power mechanical ventilation systems. Ventilation fans may be installed in ducts or on windows, walls, or other surfaces to bring fresh air into a room or remove stale air from an enclosed area. The kind of mechanical ventilation used is based on the local climate. It may be necessary, for instance, to lessen or avoid interstitial condensation in hot and humid climates, which occurs when warm, wet air from within a building penetrates a wall, roof, or floor and comes into touch with a cold surface.

Hybrid or mixed-mode ventilation: In order to achieve the necessary (design) flow rate, hybrid (mixed-mode) ventilation depends on external driving forces. When the flow rate of natural ventilation is insufficient, mechanical ventilation is used. Exhaust fans may be used to increase ventilation in rooms with patients who have airborne illnesses (after appropriate testing and design). But it's important to employ this straightforward hybrid (mixed-mode) ventilation method with caution. The fans should be installed in such a way that the air is exhausted directly to the exterior of the building via a wall or roof. Before being used, the exhaust fan size and number must be determined based on the desired ventilation rate.

A. Recent advances in HVAC system

Heating, cooling, air filtration, air distribution, air flow rate, and air exchange rates are just a few examples of how a well-functioning HVAC system adapts to environmental and individual demands. Modern systems can regulate IAQ by monitoring and modifying factors including temperature, carbon dioxide (CO2) concentration, humidity, and airflow rates. [4]

The goal of constructing a "green hospital" includes reducing energy use, and a "intelligent HVAC" system may do this by sensing how people are using a given room and adapting it accordingly.

In light of the fact that different spaces and people have different ventilation needs, there has been a shift towards 'personalized ventilation' (PV), in which the air terminal devices (ATD) supplying the air are placed near the breathing zone of the occupants, who can then control the temperature and humidity of the air they breathe in. [5]

The impact of airflow distribution systems on indoor air quality, the spread of aerosols/particles, and respiratory illness has been the subject of very few research. The purpose of this work is to examine the available research on airflow distribution systems in order to determine which approaches to air distribution for indoor ventilation are the most effective.

II. LITERATURE REVIEW

(Essa et al., 2022) [6] Since it uses less energy than traditional air conditioning systems, displacement ventilation (DV) is a great option for classrooms that need to keep students and teachers comfortable while still keeping the building cool. Ventilation systems, however, need to be evaluated in light of the present epidemic in terms of limiting the transmission of infection. Therefore, the purpose of this research is to evaluate the efficacy of displacement ventilation in reducing the spread of illness in classrooms by examining the impact of source location on the distribution of pollutant concentrations. As an example in point, we choose a moderately sized digital video (DV) lecture hall at Osaka University in Japan. This study used CFD software to model ten scenarios with a single pollutant source. The cases were studied using indices such the local air quality index and the scale of ventilation efficiency to determine the temperature distribution, the vertical distribution of contaminants, and the quality of the air that the subjects breathed. The findings showed significant difference across instances with regards to the distribution pattern of contaminants, the number of afflicted occupants, the average inhaled-air quality, and the diffusion radius. As a result, the ventilation system's design's advantages and disadvantages were highlighted, along with the variables impacting the variance, which were then analyzed to draw conclusions about the influence of each component.

(Mahdi et al., 2020) [7] The primary purpose of this research is to investigate the impact of incorporating personal ventilation systems into displacement ventilation systems, with the objective of better understanding how to achieve thermal comfort for people. The experiments were carried out in a full-scale (3 m 1.75 m 3 m) thermally insulated room. The CFD models are verified with the help of the experimental work's findings. Personal ventilation was found to increase both air quality and thermal comfort,

and it was determined that a flow rate of 10 l/s resulted in optimal device performance in terms of air distribution performance index and effectiveness of temperature (t), which were approximately 71% and 1.8, respectively.

(Saran et al., 2020) [8] Keeping good "indoor air quality" is a crucial non-pharmacological strategy in preventing hospital-acquired infections, and this review aims to describe the global variation in standards and guidelines for maintaining "heating, ventilation, and air- conditioning" (HVAC) systems in intensive care units. “An online search and review of standards and guidelines published by various societies including American Institute of Architects (AIA), American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), Centers for Disease Control and Prevention (CDC), Department of Health Estates and Facilities Division, Health Technical Memorandum 2025 (HTM) and Healthcare Infection Control Practices Advisory Committee (HICPAC) along with various national expert committee consensus statements, regional and hospital-based protocols available in a public domain were retrieved.” We discussed the fundamental structural features of HVAC system and also the differences in the implemented standards of HVAC system in the ICU around the globe, and we also evaluated a selection of materials and textbooks detailing HVAC structural aspects. In conclusion, current infection control practice recommendations should include universal criteria for HVAC systems, with a mention on the kind of ICU.

(Ameen et al., 2019) [9] Experimental evaluation and comparison with mixing and displacement ventilation were used to draw conclusions about the efficacy of a newly developed corner impinging jet air distribution system with an equilateral triangle cross section. Tracer gas decay, air velocity, turbulence intensity, temperature, and the placement of nine uniformly spaced standard vertical points were all measured for each system. High air change efficacy, a stratified flow pattern, and a uniform temperature field are all characteristics of displacement ventilation systems, which the new approach mimics. High-quality and encouraging findings were found for both the local air change efficacy and the air exchange effectiveness of the corner impinging jet, both of which are strong indicators of ventilation efficiency.

(Aganovic & Cao, 2019) [10] Controlling the spread of respiratory disease-causing airborne pathogens requires adequate ventilation in regular hospital wards. Protected occupied zone ventilation (POV) is studied here for its possible efficacy in lowering the spread of disease in hospital isolation wards. An infected patient lying in bed and a healthcare provider in a seated position were simulated using two life-size breathing thermal manikins. The receiver's privacy is not compromised by the patient's location behind them. The POV system may help hospitals minimize the spread of disease by decreasing the amount of air that circulates within isolation wards. In an isolation ward, when contact between the infected and safe areas is limited or nonexistent, a POV system may function to its fullest extent.

(Bayoumi, 2018) [11] In warm, humid climates, the potential for radiant cooling is restricted because of the higher danger of condensation due to wide openings in the building envelope, despite the fact that radiant cooling is far more effective than typical all-air room cooling systems. To prevent condensation from forming within a building with completely sealed windows and "mechanical ventilation", external air in such a climate must be extensively dehumidified. This research looks at what happens when you combine "hybrid ventilation "(window and mechanical) with radiant cooling on days when the weather is pleasant outdoors. An optimization strategy is devised and implemented to improve energy efficiency and allow for the safest possible window opening during the peak seasons (summer and fall). Different scenarios and settings are explored using IDA-ICE software to perform dynamic thermal analyses of a typical studio classroom model. Several situations and methods of ventilation and air conditioning regulation are combined and analyzed. Different scenarios have different possibilities and constraints. Verification of the optimization procedure and assessment of its impact on IAQ and user comfort are accomplished via the development of ANSYS-CFX and another research. The findings demonstrate that the proposed method may substantially cut energy usage and provide condensation-free window openings.

III. CONCLUSION

Personal ventilation systems measure how well an individual is shielded from a pollutant's source by defining the exposure efficacy. When it comes to factors like thermal comfort, indoor air quality, and energy efficiency, the air distribution system is a crucial player. Furthermore, the efficiency of various ventilation systems will depend on the duties they are expected to do, and these systems may be evaluated using various indices.

The potential for energy savings when switching between ventilation technologies should be assessed in light

of the space's whole circumstances, including productivity, indoor air quality, and thermal comfort. Combining multiple ventilation methods, such as MV and DV or PV and DV, may be more effective than utilizing each approach alone.

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