Effects of ventilation on airborne transmission: particle measurements and performance evaluation

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SUMMARY

This research aims to evaluate ventilation performance on airborne transmission in buildings, by analyzing the effect of different ventilation configurations and flow rates on contaminant removal effectiveness.

KEYWORDS

Ventilation, airborne transmission, air distribution, particle measurement, ventilation effectiveness

1 INTRODUCTION AND METHOD

Airborne transmission is widely recognized as the dominant transmission route between people for many respiratory viruses. It refers to the inhalation of infectious aerosols or “droplet nuclei” (droplet that evaporate in the air). These aerosols or “droplet nucleis” are often defined to be smaller than 5 µm and can travel distances of more than 1-2 meters from the infected individual (Wang et al., 2021). Ventilation strategies, air distribution methods, and air flow rates may have significant impacts on airborne transmission (Wej et al., 2016; Qsman et al., 2022). By evaluating ventilation configurations knowledge on how to control flow path of air in buildings to provide a desired combination of occupant thermal comfort and good hygienic conditions can be obtained (Cho et al., 2019). This research aims to evaluate different ventilation configurations for control of airborne transmission in a room by laboratory measurements.

Measurements were performed at RISE Research Institutes of Sweden laboratory inside a test room with dimensions of 4.2 × 5.0 × 2.5 m (L × W × H). The test room was equipped with a ceiling swirl supply diffuser, a TV set (120 W), ceiling light (60 W) and a dummy (70 W). Different flow rates (8, 15, 30 and 40 l/s), two ventilation exhaust positions (high and low), and contaminant source location in relation to ventilation exhaust were tested; see Figure 1(a). The contaminant source was simulated by potassium chloride (KCL) aerosols generated by AGK 2000. Particle number concentrations at four positions, one close to the ventilation exhaust and three other locations (A, B and C) along the centreline of the room at the height (H) of 1.2 m, were measured by four particle counters, Optical Particle Sizer (OPS) 3330, simultaneously. All measurements were made during steady state conditions for one hour. Correlation tests were also made to assess the relative bias among the particle counters. Results were analysed by:

$$\varepsilon_p = (C_e - C_s)/(C_p - C_s) \qquad (1)$$

Where ε_p is the particle removal effectiveness at point p, C_e, C_s and C_p is the particle concentration at the air exhaust, supply and a point inside the room. As the supply air was almost particle free $C_s = 0$.

2 RESULTS AND DISCUSSION

Comparisons of the particle removal effectiveness between different flow rates, for the two ventilation exhaust positions (high and low), at middle of the room (point B) with H = 1.2 m, is shown in Figure 1(b) and 1(c) respectively. As seen, the contaminant removal effectiveness is decreased as the flow rate is increasing from 8 to 40 l/s. With the low flow rates 8 and 15 l/s, the room air is mixed in the lower region, while in the upper region the contaminated air is accumulated, and the concentration level is high due to stratification and stagnation. A high exhaust is therefore more effective than a low exhaust to remove particles. The ventilation effectiveness is reduced from about 1.15 to 0.9 for the high exhaust (Figure 1b), while it is reduced from 1.0 to 0.8 for the low exhaust (Figure 1c). With the high flow rates 30 and 40 l/s, room air is fully mixed. The effectiveness is about 1 with 30 l/s, which is slightly reduced when increasing to 40 l/s and when moving the exhaust from a high position to a low position. This is due to short circuit which means that the jet from the supply diffuser is so strong that part of the fresh air reaches the exhaust directly without mixing with the room air. Although high flow rates result in a lower ventilation effectiveness, the absolute number of particles in the room would be less compared to low flow rates due to better dilution. This suggests that a balance between the contaminant dilution and removal should be considered when increasing flow rates to enable sufficient and effective ventilation.

As seen in Figure 1(d), moving the contaminant source close to the exhaust improves the particle removal efficiency for the high exhaust. For the low exhaust, the source location is not important as the room air is mixed in the region up to 1.2 m. Re-arranging room layout considering potential source locations could be a measure to reduce airborne transmission.

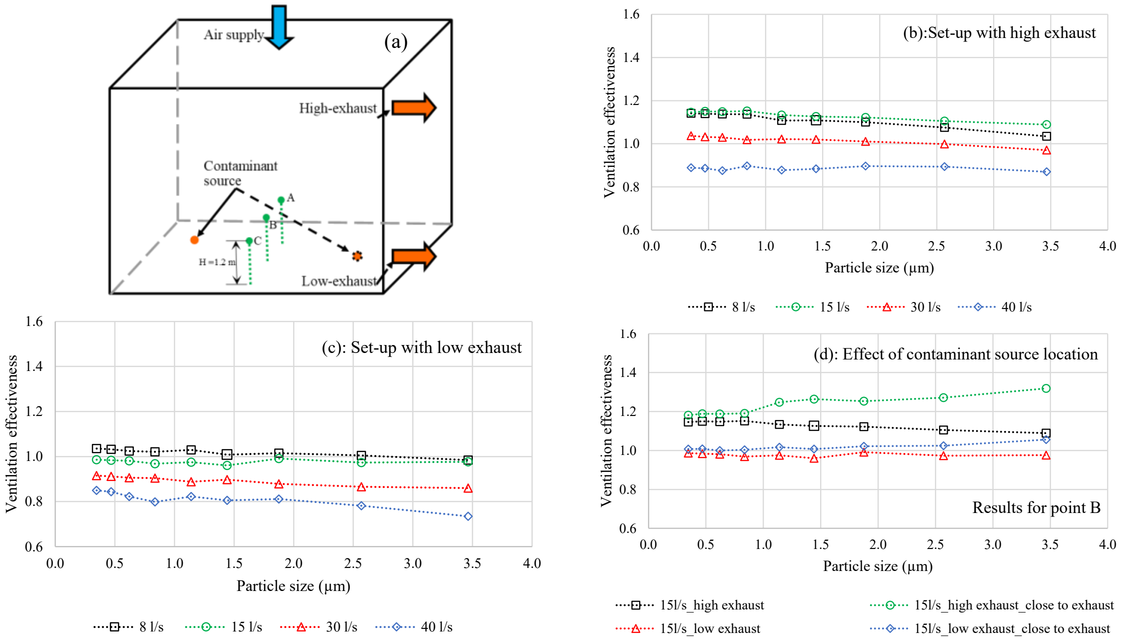

Figure 1: Measurement set-ups (a) and results (b-d)

3 REFERENCES

Wang, C. C., Prather, K. A., Sznitman, J., Jimenez, J. L., Lakdawala, S. S., Tufekci, Z., & Marr, L. C. (2021). Airborne transmission of respiratory viruses. Science, 373(6558), eabd9149.

Wei, J., & Li, Y. (2016). Airborne spread of infectious agents in the indoor environment. American journal of infection control, 44(9), S102-S108.

Osman, O., Madi, M., Ntantis, E. L., & Kabalan, K. Y. (2022). Displacement ventilation to avoid COVID-19 transmission through offices. Computational Particle Mechanics, 1-14.

Cho, J., Woo, K., & Kim, B. S. (2019). Removal of airborne contamination in airborne infectious isolation rooms. ASHRAE Journal, 61(2), 8-21.