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SPATIO-TEMPORAL ANALYSIS OF AEROSOL TRANSPORT IN A HUMAN-SCALE ROOM : AN EXPERIMENTAL AND COMPUTATIONAL STUDY

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ABSTRACT

The study of aerosol transport in indoor environments is critical for occupational health and safety. In Quebec, 91% of recorded lung disease cases between 2012 and 2016, were linked to aerosol exposure. The aerodynamic behavior of aerosols is complex, as they are influenced by various mechanisms, including advection, gravitational settling, turbulent diffusion, and thermophoresis. Furthermore, experimental studies presented in the literature do not allow us to determine aerosols concentration in real time and at multiple sampling positions. This study aims to achieve two objectives: (1) to characterize the spatio-temporal evolution of aerosol concentration as a function of aerodynamic diameter and ventilation rate, and (2) to compare measured concentrations with predictions obtained from computational fluid dynamics (CFD) simulations. Measurements were conducted in a human-scale room of 53.4 m^3 using Di-Ethyl-Hexyl-Sebacate aerosols generated by a MAG 3000 Aerosol Generator. Experiments were performed for two particle diameters (0.5 µm and 1 µm) under three distinct ventilation rates. A network of optical particle counters was deployed to monitor aerosol concentrations in real time at 17 specific locations. The number of air changes per hour (ACH) was determined using the particle concentration decay curve. The ACH will be compared with airflow measurements (TSI Balometer ABT711) and the ACH predicted by CFD simulations. Airflow and aerosol dispersion will be modeled using the Fire Dynamics Simulator (FDS) software, which employs the large eddy simulation approach. FDS incorporates a Eulerian model that accounts for gravitational settling, turbulent deposition, and thermophoresis. At low ACH, the experimental results reveal significant spatial variations in aerosol concentrations, highlighting non-uniform ventilation conditions within the room. For this condition, the ACH ranged from 3.0 to 3.54 depending on the measurement position. At the highest ACH, the particle removal rate was similarly influenced by the measurement position, resulting in local ACH values between 7.25 and 7.98. Smaller particles (0.5 µm) demonstrated greater persistence in the air compared to larger particles (1 µm), which settled more rapidly. These findings underscore the critical role of ACH in controlling and eliminating aerosols. However, the experimental data also demonstrate that ACH alone is insufficient to predict exposure. Non-homogeneous ventilation conditions create concentration gradients and exposure levels that vary depending on the occupant's position. Comparisons with numerical results will enhance our understanding of under-ventilated zones and how these zones are affected by the ACH.