Effect of air exchange rate on the removal of aerosol in a test chamber

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Introduction

Various air distribution methods are used in rooms in order to ensure good indoor air quality (IAQ) and removal of particles from the zones occupied by people. It is known that air movement contributes to transmission and spread of infectious disease and the proficient ventilation systems may provide a solution to sufficient IAQ.

It is important to develop an understanding of aerosol dispersion in the room under various air exchange rates and air distribution methods. In this study, we have analysed behaviour of aerosol under various ventilation rates and regimes.

Methods

A room-imitating test chamber (floor area 13 m^2, volume 32.5 m^3) equipped with two air supply and two air disposal units in the ceiling was used during the experiment. Two distribution methods – one-way and four-way mixing – of pre-filtered and conditioned air were employed at four air change rates (1, 2, 3, and 4 h^{-1}).

A solution of 10% sodium chloride (NaCl) was periodically dispersed by a nebulizer (model MRE CN24 3–Jet Collison Nebulizer, BGI Inc., Waltham, MA, USA) and dried by mixing it with air (v/v ratio of 1:5). Aerosol particle charge was reduced to equilibrium by a corona charger before supplying it to the chamber. The aerosol was fed at a height of 1.1 m in the air supply side for 1 s at a flowrate of 36 lpm. Peak $PNC_{2.5}$ reached 3500 - 5100 cm^{-3}.

Real-time particle size distribution (PSD) measurements were performed using an Optical Particle Counter (OPC) (model HANDHELD 3016 IAQ, Lighthouse worldwide solutions, Fremont, CA, USA). Aerosol concentration was measured at 1.8 m above the ground representing human breathing zone. The OPC was positioned below the air disposal device in order to reflect the dynamics of aerosol to be removed from the chamber.

Results

The aerosol concentration was fluctuating rapidly in the chamber, showing substantial turbulence in the air movement, although air velocity was maintained below 0.1 m/s. Fig. 1a) presents normalized particle concentrations in case of one-way mixing air supply, at four levels of air exchange rates. It is evident that with increasing air exchange rate, the particles were transported to the exhaust more rapidly (peak concentration occurring ~30 s later in case of 1 h^{-1} vs. 4 h^{-1}). Moreover, in cases of 1 and 2 h^{-1}, the aerosol concentration remained at elevated levels after 5 minutes, showing ineffective removal of particles.

In case of four-way mixing, aerosol dispersion pattern was distinctively different. Air exchange ratio did not seem to have a prevailing effect on $PNC_{2.5}$ close to the exhaust. Moreover, high air exchange rates seemed to disperse particles in the entire volume of the chamber, slowing the overall removal rate. At the same time, four way mixing may be effective tool to immediately reduce particle concentration at the point of generation.

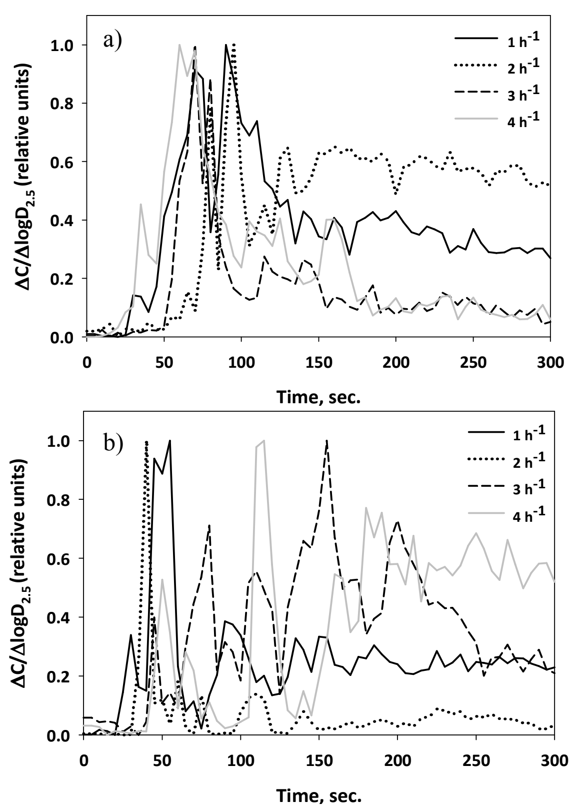

Figure 1. Variation of PNC2.5 (5 sec average) over time under various air exchange rates at a) one way mixing air supply and b) four-way mixing air supply.

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