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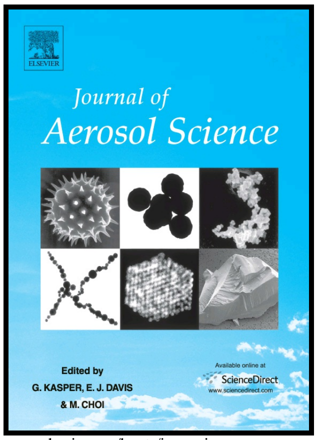

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The impact of ambient humidity on the evaporation and dispersion of exhaled breathing droplets: a numerical investigation

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Abstract

The impact of ambient relative humidity (RH) and airflow patterns on the evaporation and dispersion of infectious droplets exhaled from an infector was studied by the computational fluid dynamics (CFD) method. The DPM (discrete phase model) was employed to calculate the two phase flow, i.e. droplets and air. The model is validated by experimental and simulation results in literature. Pure water droplets with different diameters (every 10 μm between 10 μm and 100 μm) are exhaled from an infector in different ventilation systems, i.e. mixing and displacement with different RHs (0, 30%, 60% and 90%). The diameter variation, spatial distribution and spreading distance of droplets are simulated and compared. Results showed that evaporation of droplets under mixing ventilation is quicker than it under displacement ventilation due to accelerated heat and mass transfer between droplets and air by turbulence. However, the dried out time for small droplets (10 μm) are extremely short, whatever the ventilation system is. Slow air velocity in displacement system or high RH environment may lower the evaporation speed of middle size droplets (50 μm) and accelerate the dropping of large size droplets (200 μm). For 100 μm droplets, they evaporate fast with low RHs while deposit fast with high RHs. Most droplets concentrate within ± 0.5 m of the person's mouth before they become droplet nuclei or fall onto the ground. This model may offer some suggestions in identifying favorable humidity-control ways to prevent the short-range infection transmission.

Keywords

droplets; evaporation; dispersion; ventilation system; relative humidity (RH)

1. Introduction

Many as 4 million persons died annually due to respiratory infections, which accounted for 7% of the total deaths worldwide (WHO, 2004). Respiratory infectious diseases were considered to be transmitted via three routes, namely contact, airborne and fomite (Castle & Ajemian, 1987). Respiratory droplets or droplet nuclei exhaled from infectors serve as carriers of pathogens. The infection risk along the transmission paths can be assessed as a function of exposure dose, exposure duration, pulmonary ventilation rate, etc (Qian et al., 2009) and corresponding prevention measures can be taken. Much higher risk is observed with close proximity to the source patient and it decreases rapidly with the distance from the infection source (Kowalski & Bahnfleth, 1998; Lidwell & Williams, 1961; Tze-Wai et al., 2004), indicating the great importance of short-range modes. The short-range modes proposed by Liu et al. include both the conventional large droplet route and the newly-defined short-range airborne transmission at a threshold distance of 1.5 m (Liu et al., 2016), which could be more dangerous than the long-range airborne transmission. Among various transmission routes of respiratory infectious diseases, the short-range droplet transmission is an important way to deliver infectious pathogens (Qian et al., 2007). Droplets are exhaled by different respiratory activities, such as breathing, talking, coughing