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Research Article

Decay characteristics of expiratory aerosol in various diffuser-induced airflow patterns using large-eddy simulation

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Abstract

This paper presents the decay characteristics of expiratory aerosol using large-eddy simulations coupled with Lagrangian particle tracking for evaluating the prevention of pathogen infection in a typical indoor environment. Ten cases of enclosed-rooms with five different diffuser-induced airflow patterns were investigated. For particles about 10 μm in diameter, which closely approximates the mean diameter of expiratory aerosol, the decay characteristics of each case with no obstacles proved that the most efficient case was the floor-supplied displacement type, followed by the ceiling-mounted line diffuser, floor-mounted diffuser, and ceiling-mounted square diffuser. The least effective case was the ceiling-mounted four-way cassette-type air diffuser under the same air changes per hour. However, in the situation of obstacles representing human bodies, the floor-supplied displacement type showed worse decay characteristics because of preventing the "piston flow-like" one-direction flow. On the other hand, the diffuser cases of the ceiling-mounted square type and the ceiling-mounted four-way cassette-type showed improved decay speed by exhaust and deposition. In particular, the ceiling-mounted square diffuser showed the most effective removal performance. These results imply that the flow configurations that induce small circulation caused by the inlet-outlet layout tend to improve the decay characteristics in terms of "the robust flow design" in a situation of complex flow field.

Keywords

large-eddy simulation,
expiratory aerosol,
indoor pathogen infection,
air diffuser layout,
airflow pattern,
human body

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1 Introduction

We spend over 90 percent of our time in confined micro-environments, i.e. transport, workplace, and residence (Klepesis et al. 2001). The apparent importance of controlling airborne transmission of infectious agents in indoor environments is well recognized. Today, controlling and reducing person-to-person airborne transmission of highly contagious diseases is a growing concern. The severe acute respiratory syndrome (SARS) outbreak in 2003 and the so-called swine flu (H1N1) pandemic in 2009 stimulated a series of engineering investigations into the transmission mechanisms for airborne infectious diseases within buildings. The recent increased interest in studying engineering control methods for airborne diseases is also associated with rapid social and environmental changes, such as urbanization, high density living, international air travel, and climate change, which have increased the risk of the emergence, re-emergence, and spread of different infectious diseases, especially airborne diseases (Weiss and McMichael 2004). In general, aerosol dynamics differ from gaseous pollutants due to the effects of gravity, inertia and deposition on solid surfaces. Proper understanding of aerosol transport is required to improve exposure assessment tools and models, and adopt better ventilation strategies that can substantially reduce indoor particle concentration and improve indoor air quality. When coughing, sneezing, talking or breathing, people inherently generate particles of different sizes and air jets with different initial characteristics. In their latest findings, Chao et al. (2009) summarized the scarce data on the particle size distribution of expiratory aerosols. The airflow pattern is the most significant parameter influencing droplet transport in indoor environments (e.g. Chao and Wan 2006). The choice of ventilation scheme controls the

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