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Distributions of respiratory contaminants from a patient with different postures and exhaling modes in a single-bed inpatient room

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ABSTRACT

This study investigated contaminant transport and evaluated the ventilation performance in a single-bed inpatient room. The study performed comparative experimental analysis on the distributions of respiratory contaminants breathed out and coughed out by a patient in a full-scale chamber, which simulated a single-bed inpatient room. The contaminant exhaled by the patient was simulated by an SF_6 tracer gas and 3-μm particles at steady-state conditions. The differences in the contaminant distribution between the coughing and breathing cases were insignificant for the mixing ventilation case, while for the displacement ventilation, the contaminant concentrations in the upper part of the room were higher for the coughing case. The contaminant concentrations in the inpatient room for the case with the patient sitting on the bed were lower than those for the patient supine on the bed for the displacement ventilation under the same supply airflow rate. The SF_6 tracer gas and 3-μm particles released at a notable initial velocity for simulating a cough could give similar contaminant distributions in the inpatient room. Therefore, the experimental data can be used to validate a CFD model, and the validated CFD model can be used to investigate transient coughing and breathing processes.

1. Introduction

Respiratory infectious diseases, such as Severe Acute Respiratory Syndrome (SARS), could be transferred from a patient to other people in the proximity by air [1]. Many infections may have been the result of poor ventilation and insufficient protection of healthcare workers [2]. The experience with SARS indicated a disease transmission in a short route between healthcare workers and patients. Therefore, it is important to understand air and contaminant transport in inpatient rooms and to improve the ventilation system design for the rooms.

Many studies have been conducted on airborne disease transmission and ventilation systems in hospitals. Li et al. [3] reviewed the literature in the last half century and concluded that there is an association between the infection caused by airborne disease transmission and the ventilation in buildings. However, there is insufficient data to specify and quantify the minimum ventilation requirements in hospitals. Tang et al. [4] pointed out many important factors involved in the aerosol transmission of infectious diseases, including aerosol generation from breathing, coughing, and talking. They indicated that it should be possible to reduce the risk of aerosol transmission by altering the ventilation parameters in healthcare environments. This has been verified by our previous study [5] which showed that ventilation systems play a very important role in the contaminant distribution in an inpatient room. Qian et al. [6] indicated that the downward laminar airflow pattern recommended by the CDC was impossible to achieve due to turbulent flow mixing and thermal buoyancy. To prevent or minimize the spread of airborne infection, the physical characteristics of the indoor environment and the design and operation of building ventilation systems are critical [7]. Patients in hospital wards often generate airborne contaminants by different expiration modes, such as coughing, breathing, talking, and sneezing. Many experimental studies on coughing have showed that the average velocity of coughing varied from 1 to 10 m/s [8], while the average velocity of breathing is low so it can be treated as a stationary source. Thus, the contaminant is released at very different velocities in coughing and breathing. Transport of the contaminant exhaled by coughing should be different from that by breathing. Zhu et al. [9] used a CFD method to investigate the flow field and infection risk influenced by realistic coughing and breathing of occupants in a stagnant indoor environment. Their results showed that indoor ventilation conditions can greatly affect the chances of airborne infections by

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