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Quantify impacted scope of human expired air under different head postures and varying exhalation rates

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ABSTRACT

Many researches indicate human respiration flow and background ventilation are two important aspects leading to possible respiratory disease spread. However, current studies on respiration flow and the resulted exhaled pollutant dispersion are limited, because different head postures, respiration mode, breath rate, room ventilation and so on, can exert profound impacts that are not understood very clearly. To evaluate the role of head postures on transmission of human exhaled pollutants, this study uses a computational fluid dynamics (CFD) program to study the exhalation flow of a sitting adult in a calm indoor office. Four different head postures are considered: sitting upright viewing front, sitting upright but head tilted viewing upward, sitting upright but head turned viewing the lateral, and sitting but pillowing head on a table. Based on the decay percentage of a gas concentration, the impacted scope of expired air is identified. The common posture by sitting upright viewing front is selected to investigate the change of impacted scope with increasing exhalation rates. The experimental test is also carried out using a breathing thermal manikin. This study finds out that the impacted scope of expired air under different head postures is different. The horizontal impacted distance is highly dependent on the specified threshold concentration. If a person sits around at a table and makes a deep exhalation, other people shall be apart from him/her with a larger distance to be free from the exhaled pollutant exposure, once his/her thermal plume is blocked by the table.

1. Introduction

With an increasing rate for human engaged in indoor activities, more concerns have been raised on indoor health, especially on how to control and prevent possible airborne disease transmission. The historical outbreaks of airborne contagious diseases like various types of influenza have severely strike the global economy and deprived hundreds of human lives. By July 8, 2009, over 94,000 influenza A (H1N1) cases and 429 influenza A-related deaths from 136 countries have been reported [1]. Not only the influenza could be deadly, there were 8098 people infected by the Severe Acute Respiratory Syndrome (SARS) and 774 of them died in 2003 [2]. The loss of the world economy due to SARS is close to 40 billion US dollars [3]. Some researches [4] reveal that the respiratory infectious disease seems to transmit through the airborne routes. An infected person may discharge the pathogens to the surrounding air by breathing, talking, coughing and sneezing, etc. Accompanied by strong expired air jets, pathogens can be transmitted away a certain distance. Apparently, it would be very helpful for controlling and preventing the disease transmission if the impacted scope of expired air from an infected person can be quantified accurately.

Toward the above aims, this paper investigates human expired air motion and the associated airborne pollutant transmission. The impacted scope of human expired air by the nose is determined quantitatively. The relationship of impacted region changing with increasing exhalation rates are to be revealed as well, by taking account of different head postures.

2. A brief overview of human expired air dispersion

A person inhales the ambient fresh air (typically in volume ratio oxygen possesses: 20.9%, carbon dioxide: 0.04%, water vapor: 0.75%, nitrogen: 78.4%.) with adequate oxygen and exhales the pulmonary air to sustain human metabolism. The exhaled air is featured by high concentration of carbon dioxide (4.2%) and water vapor (6.2%) [5]. The remnant pulmonary air components include oxygen (15.3%), nitrogen (74.3%), and droplets that are atomized on mucous membrane of respiratory tracts, etc. The droplets can carry

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