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Study of Particle Dispersion on One Bed Hospital using Computational Fluid Dynamics

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Abstract

Increasing concerns about the spread of airborne disease in hospital such as severe acute respiratory syndrome (SARS), chickenpox, measles, tuberculosis and novel swine-origin influenza A (H1N1) have attracted public attention. A present study was carried out to look for the source of contamination (patient itself) and examine the route of contaminant transfer in the hospital. This article provides recommendation for future work to improve the yield and save the energy consumption simultaneously. The risk of airborne infection can be minimized in hospital wards by using a high air change rate. The Local mean age of air will decrease with an increasing flow rate because the source must be considered to be constant. The location of the outlet openings plays an important role for the transfer of the contaminant particle in the hospital.

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1. Introduction

The average person inhales around 16,000 quarts of air per day. Each quart of air contains some 70,000 visible and invisible particles, which equates to a total intake of over a billion particles per day. The necessity of air cleaning solutions is especially critical in healthcare environments, where higher concentrations of harmful or infectious microorganisms are being emitted into the air. The presence of contaminant particles may cause discomfort to the eyes, irritation of the respiratory system, and may even spread disease.

CFD is the analysis of system involving fluid flow, heat transfer & associate phenomena such as chemical reactions by means of computer based equation. It is very powerful & spans a wide range of industrial & non industrial application area. It has to be proven to be an efficient approach for analyzing indoor airflow, heat transfer and contaminant dispersion process. The prediction of airflow in an ICU, the flow equation must account for turbulence and buoyancy. Conservation equations for mass, momentum & energy can be established for each cell. Two major concerns in ventilation scheme design, operation and malfunction analysis have been identified: (i) indoor air quality (IAQ) and thermal comfort, (ii) energy consumption and efficiency.

2. Literature review

Xiaojun et al. [1] have presented that there is no direct relationship to quantify the transient influence of different boundary conditions including contaminant in supply air, contaminant source and initial condition on indoor contaminant distribution. The proposed expression can explicitly and quantitatively reflect the impact of supply air, contaminant source and initial condition on the contaminant distribution indoors. An experimental measurement is employed to validate the reliability of the analytical expression. It is shown that the results from the expression agree well with experimental measurement. Kim et al. [2] have presented a study, carried out to look for the source of contamination and examined the route of contaminant transfer in the mini-environment applied in liquid crystal display (LCD) process clean room of Korea. It was revealed that the critical contamination source was the stocker and the contaminants were transferred by the airflow pattern. The velocity distribution was improved and the particle concentration was reduced in the target mini-environment. King et al. [3] have used aerobiology test room arranged in three different layouts- an empty room, a single-bed and a two-bed hospital room. Comparison with CFD simulations using Lagrangian particle tracking demonstrates that a realistic prediction of spatial deposition is feasible, and that a Reynolds Stress (RSM) turbulence model yields significantly better results than the \(k-\varepsilon\) RNG turbulence model used in most indoor air simulations. Results for all layouts demonstrate that small particle bio aerosols are deposited throughout a room with no clear correlation between relative surface concentration and distance from the source.

Villafruela et al. [4] have analyzed the dispersion of the exhaled contaminants by humans in indoor environments; with special attention to the exhalation jet and its interaction with the indoor airflow pattern in both mixing and displacement ventilation conditions. The objectives of this study are to increase knowledge regarding the exhaled contaminant distribution under different environmental conditions and to validate whether a steady boundary condition of the exhalation flow may simulate human breathing in an effective and accurate way. The results show a very good agreement of the numerical results obtained for test and the experimental data. The fact confirms the use of numerical simulation as a powerful tool to predict the contaminant distribution exhaled by a human. Hang et al. [5] have investigated how the walking motion of health care worker (HCW) influences gaseous dispersion in a six bed isolation room with nine downward supplies and six ceiling-level or floor-level exhausts. The flow near and behind HCW is easily affected by the motion of HCW. The flow disturbance induced by HCW walking with swinging arms and legs is a mixing process. HCW motion indeed affects airborne transmission, but its effect is less important than ventilation design. No matter with or without HCW motion, the ceiling-level exhausts perform much better in controlling airborne transmission than the floor-level exhausts with the same air change rate (12.9 ACH). Smaller air change rate of 6 ACH experiences higher concentration and more gaseous spread than 12.9 ACH. The realistic human walking which is the simplified motion of a rectangular block produces stronger flow disturbance. Finally surface heating of HCW produces a stronger thermal body plume and enhances turbulence near HCW, thus slightly strengthens airborne transmission.
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