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CFD simulation of airborne pathogen transport due to human activities

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ABSTRACT

Computational Fluid Dynamics (CFD) is an increasingly popular tool for studying the impact of design interventions on the transport of infectious microorganisms. While much of the focus is on respiratory infections, there is substantial evidence that certain pathogens, such as those which colonise the skin, can be released into, and transported through the air through routine activities. In these situations the bacteria is released over a volume of space, with different intensities and locations varying in time rather than being released at a single point.

This paper considers the application of CFD modelling to the evaluation of risk from this type of bioaerosol generation. An experimental validation study provides a direct comparison between CFD simulations and bioaerosol distribution, showing that passive scalar and particle tracking approaches are both appropriate for small particle bioaerosols. The study introduces a zonal source, which aims to represent the time averaged release of bacteria from an activity within a zone around the entire location the release takes place. This approach is shown to perform well when validated numerically though comparison with the time averaged dispersion patterns from a transient source. However, the ability of a point source to represent such dispersion is dependent on airflow regime. The applicability of the model is demonstrated using a simulation of an isolation room representing the release of bacteria from bedmaking.

1. Introduction

Transmission of infection by airborne routes is widely recognised as a key factor in the spread of many diseases including Tuberculosis, Severe Acute Respiratory Syndrome (SARS) and Influenza, and control strategies involving ventilation design and face masks for patients and staff are widely advocated [1]. However, despite a growing body of evidence that aerial transmission may be important, there is little research on strategies to control airborne transport and environmental contamination arising from pathogens that colonise the skin, such as Methicillin Resistant *Staphylococcus aureus* (MRSA). Although MRSA is primarily transferred via contact spread it may also colonise the nasal passages as a result of airborne contamination [2], spreading to the skin and potentially resulting in further transfer to wounds or ingestion [3]. Since MRSA has the ability to survive for several months on hospital surfaces [4,5] any airborne particles depositing on surfaces have the potential to create long term reservoirs of infectious material that can be transferred by touch to new patients. Boswell and Fox [6] showed surface contamination reduced when portable air cleaning devices were deployed, clearly indicating that airborne transport plays a role in the dispersion of MRSA in the environment. The release of particles contaminated with MRSA into the air may occur from the skin which is shed during routine activities such as walking [7,8], bedmaking [9–11] and undressing and washing [7,12,13]. In such cases dispersion does not occur from a single point in space, as a respiratory release. Instead the dispersal of bacteria will vary in spatial location and intensity depending on the activity. Understanding this release, and the likely environmental contamination that results, is key to developing appropriate interventions for reducing the aerial transmission of such pathogens.

In this paper we consider the development, validation and application of appropriate Computational Fluid Dynamics (CFD) models for evaluating the airborne dispersion of pathogens in hospital environments due to activity. The study has three main objectives to assess the transport model assumptions, source definition and applicability of CFD models in a typical ward environment:

1. *Experimental validation of modelling techniques for bioaerosol transport*: bioaerosol experiments are conducted in a climatically controlled chamber in order to validate the transport

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