Modelling Infectious Aerosols

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Introduction

- Bio-aerosols such as the droplets people expel via coughing and sneezing have been long understood as an important mode of transmission of infectious diseases.
- Transmission via infectious droplets can be split into two categories: droplet transmission, larger droplets (>5μm) that fall to the ground quickly and airborne transmission, smaller droplets (5μm<) evaporate quickly travelling large distances3.
- Airborne infection is a concern for people with Cystic Fibrosis (CF). This project focusses on two pathogens affecting those with CF: P. aeruginosa and M. abscessus.
- It is hypothesised that microorganisms and drug treatments can affect the potential for the microorganism to be released in aerosol as well as the size of the aerosol formed and hence the risk of transmission.
- Using three different approaches to gain an enhanced understanding of this transmission process will aid in helping tackle infection control especially in respiratory wards.

Optimising Experiments

To model infectious aerosols experimentally a previous experiment has been adapted1. P. aeruginosa was nebulised down a pipe and sampled using a 6 Stage Anderson sampler. Figure 1 shows the schematic of the rig design.

A CFD study is being conducted to optimise the geometry of the experimental rig design. Simulations have been run using FLUENT to analyse the inlet and shape of the rig. The table below states the parameters used.

<table>
<thead>
<tr>
<th>Boundary conditions</th>
<th>Nebuliser inlet: Velocity inlet at 0.65ms⁻¹</th>
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<tbody>
<tr>
<td></td>
<td>HEPA filter inlet: Pressure inlet</td>
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<td></td>
<td>Pipe: No slip walls</td>
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<td></td>
<td>Outlet: Velocity inlet at ~3.03ms⁻¹</td>
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<tr>
<td>Turbulence model</td>
<td>Coarse mesh: Standard k-ε with standard wall functions</td>
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<td></td>
<td>Fine mesh: Transition kkl-ω</td>
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Several inlet designs were modelled. Figure 2 shows the difference between two inlet designs, with figure 2a) being the original inlet. Recirculation is reduced when modelling the pipe within a pipe inlet and this geometry is used for the optimised rig design.

Figure 2. Comparison of inlets a)T junction b) Pipe within a pipe

Bio-aerosol Decay

- Knowing the decay rate can improve the CFD model of the experiment.
- Bio-aerosol concentration follows a first order decay process
  \[
  \frac{dC}{dt} = -kC \Rightarrow C = C_0 e^{-kt} \quad (1)
  \]
  - \(k\) is a decay rate, \(k\) is a sum of the decay due to deposition and survival.
  - Decay rate due to deposition can depend on several factors such as: particle size, electrostatics and surfaces.
  - Decay rate due to survival depends on: temperature, humidity and species.
- Figure 4. shows the concentration of P. aeruginosa over time. Using this data figure 5 plots time against the log of the concentration, the gradient of the line of best fit is \(k\).
- Figure 5 shows that decay rate also depends on the base fluid used with P.aeruginosa surviving best in 10% FBS.

Future Work

CFD approach
- Model evaporating droplets down the optimised rig geometry.
- Using the CFD results find the decay rate \(k\) due to deposition.
- Find the particle residence time using the CFD model and see how this changes with the rig design.

Experimental approach
- The effects on rheology and evaporation by the pathogens will be explored experimentally.
- Viscoelasticity influences particles within an aerosol2.
- Varying base fluids will be used to represent CF mucus before and after medication.

Numerical approach
- An evaporating water droplet will be modelled using MATLAB.
- Adaptations will be made to include a pathogen at the centre.

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References