A simple model to predict bioaerosol dispersion in transport hubs

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Epidemiology and Modelling

Emergency Response:
- Real-time modelling
- Expert Advice
- Visualisation

Emergency Preparedness:
- Contingency Planning
- Risk Mapping/Assessment
- Framing Exercises
PANDHUB Scope

- Aid transport operators and relevant actors in transport hubs in the development of their current pandemic and dangerous pathogen preparedness and response plans.
- The project is intended to cover the extraordinary aspects specific to pathogen threats in the transport environment by providing accurate, reliable and validated information for the incident threat assessment, preparedness and response phases.

Specific aims:
- deepen the understanding of disease transmission mechanisms and control measures in transport environments thus allowing effective mitigation strategies.
- create a toolbox and Guidelines to prepare for and efficiently respond to pandemics and intentional release of pathogens in transport hubs.
# PANDHUB Toolbox concept

## Preparedness Tools
- Risk assessment tools
- Biocontamination modelling
- Airflow evaluation
- Epidemiological transmission modelling

## Early detection tools
- Biocontamination monitoring
- Rapid epidemiological data collection

## Response Tools
- Contact tracing
- Cross-border collaboration
- Decontamination
- Surveillance

## Communication Tools
- Data management system
- Next generation real time communication
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Test site: 40m long, 8m wide, 5 m high
Experimental parameters

- Tracer gas used was sulphur hexafluoride, $\text{SF}_6$.
- Measurement device Binos IR analyzer.
- Impulse release was achieved by bursting air balloons filled with a mixture of air and tracer gas.
- Balloons were filled with 1500 cc $\text{SF}_6$ and 4500 cc compressed air.
- Time dependent tracer concentration was measured and recorded continuously at the measurement point.
- 10 air changes per hour in room.

- Can we predict concentration over time in room?
Dispersion modelling

- CFD
- Mean field approach
- Turbulent flow model

...lit review conducted...
- 3 articles found, plus 1 further article from check of article citations.

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Rasouli and Williams, 1995, modelled a ground level release of gas into a room with ceiling mounted ventilation. However, it is unlikely that strong advection would be present in general indoor releases.

Cooper and Horowitz, 1986, solve the diffusion equation assuming isotropic diffusion.

In this setting is exposed individuals dwelt in the area for sufficient time and this time is similar to the deposition/air exchange rate then find the limiting dose received is:

\[ D_0 \approx \frac{Q}{4\pi rK} \]
Drivas, Valberg et al. 1996 showed that if the surface is reflective, the dose can be modelled with an infinite number of imaginary sources being placed on the other side of the wall.

\[ C = \frac{Q e^{-\gamma t}}{(4\pi Kt)^{3/2}} C_x C_y C_z \]

where

\[ C_j = \sum_{m=-\infty}^{\infty} \exp \left( - \frac{(j + 2mL_j - j_0)^2}{4Kt} \right) + \exp \left( - \frac{(j + 2mL_j + j_0)^2}{4Kt} \right). \]

This form was considered by Cheng, Acevedo-Bolton et al. 2011, for a naturally ventilated, domestic room, where they simplified the Drivas model to consider only the closest surfaces.
The test parameters in the test room were: volume 33m³, air exchange rate 3 times/hour, test aerosol DEHS (Di-Ethyl-Hexyl-Sebacate). Measurement location 1 m from the source.
There is limited evidence of reflection for biological material and good evidence of resuspension being surface dependent.

Let us assume that some fraction $\theta$ of bio-aerosol is deposited on walls and other surfaces during contact. Then we find

$$C_j = \sum_{m=-\infty}^{\infty} \theta^{2|m|} \exp \left( - \frac{(j + 2mL_j - j_0)^2}{4Kt} \right) + \theta^{2|m|+1-a} \exp \left( - \frac{(j + 2mL_j + j_0)^2}{4Kt} \right)$$

where $a = 2$ if $m \geq 0$ and zero otherwise.
Summary

• We have been able to fit a model to experimental data for tracer gas.
• We have been able to extend model for partial reflection.
• There is wide scatter in concentrations typical to air flows with turbulent fluctuations but the overall exposure pattern is quite well predicted.
• The results suggest that the model can be used to estimate the exposure near the impulse source.

• Will this hold for bioaerosols?
• How generalizable is approach? …Eddy diffusion, air exchange, reflection…
• Impact of pedestrian movements in space and time on flow?
Participants

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