Comparison of simulation results with measurements in case of a bio–contamination in a closed habitat

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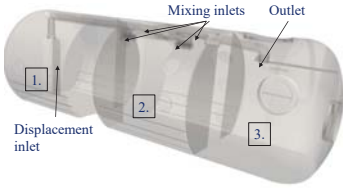
INTRODUCTION

- In manned spaceflight, crew health is threatened by microorganisms and their enhanced pathogenicity due to microgravity
- Human immune response is weakened in microgravity
- It is mandatory to better understand the mechanisms of bio-contamination in confined habitats
- Microbial aerosols can be used as model particles when the dispersion and deposition of particles and reliability of the simulation methods are studied
- Computational fluid dynamics (CFD) can be used for evaluation of indoor microbial contamination and possible spread of harmful microbes in hermetic environments
- Aim of this study was to compare the deposition results of the CFD simulation with the measured particle deposition

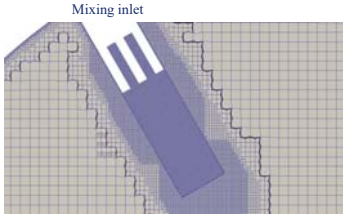
CASE

- Experimental chamber similar size with Columbus Laboratory (ISS module)
- Three zones:
  1. Displacement ventilation zone
  2. Mixing ventilation zone
  3. Outlet (exhaust) zone



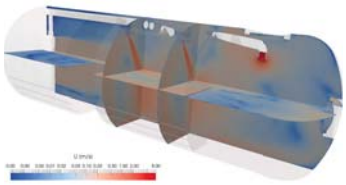
METHODS

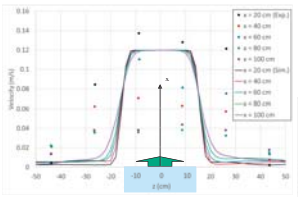
- Open source software:
  - Salome for pre-processing (www.salome-platform.org)
  - cfMesh for grid generation (cfmesh.com)
  - OpenFOAM for solution (www.openfoam.org)
  - Paraview for post-processing (www.paraview.org)
- Air field:
  - WALE turbulence model (LES, large eddy simultion)
  - Simulated 300 s to obtain statistically steady field
  - After that, simulated 300 s and time-averaged
  - Grid: 81.1 million cells
  - Simulation time: Ten weeks with 400 CPU cores
- Particle simulation:
  - Lagrangian method using time-averaged air flow field
  - Simulated first removing all particles hitting wall from the simulation (1800 s, 10000 particles per second, measured size distribution)
  - After that, all particles hitting the wall is considered stuck on the wall and simulation is continued 1200 s
  - Simulation time: Couple of days using one to tens of CPU cores

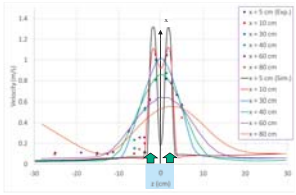


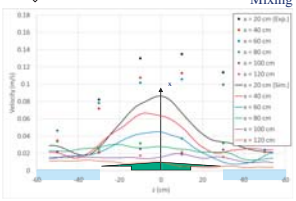
RESULTS

- Comparison of simulated time-averaged velocity with measured velocity in:
  - Close to displacement inlet
  - Close to mixing inlet
  - Outlet chamber

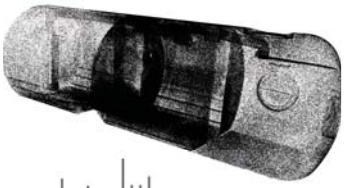


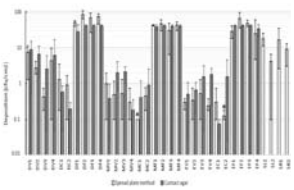

Displacement inlet

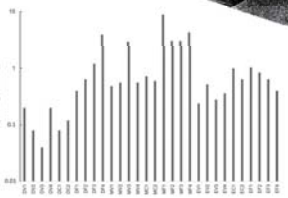

Mixing inlet


Doorway between zones 2 and 3

- Comparison of simulated deposition with the measured deposition




Measured


Simulated

d = displacement zone
m = mixing zone
e = exhaust zone
v = vertical surface
c = ceiling
f = floor

Conclusions

- **Particles mainly deposit on the floor surfaces but also to the supply air diffusers**
- **Both the CFD simulation and particle deposition in experiments with Bacillus particles resulted similar deposition sites**
- **Open source software tools are very capable simulation tools because of the three main factors:**
  - **Efficient and open implementation of the models**
  - **Heavy parallelization possible because absence of license fees**
  - **Possible customization because of open source code**

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