Validation of the bio-contamination model in closed habitat

Anniina Salmela1,*, Ilpo Kulmala2, Aku Karvinen2, Virginie Taillebot3, Peter Weiss3, Audrey Berthier4, Vincenzo Guarnieri5, Stephanie Raffestin6, Pertti Pasanen1

1 University of Eastern Finland (UEF), Kuopio, Finland
2 Technical Research Centre of Finland (VTT), Finland
3 Compagnie Maritime d’Expertises (COMEX SA), Marseille, France
4 Institute for Space Medicine and Physiology (MEDES), Toulouse, France
5 Thales Alenia Space SpA (THAS-I), Turin, Italy
6 European Space Agency (ESA/ESTEC), Noordwijk, The Netherlands

*Corresponding email: anniina.salmela@uef.fi

Keywords: Bioaerosol, Modelling, Space, Wet generation

1 Introduction

Bioaerosols such as bacteria, fungi, viruses and all other particles that contain living organisms or were released from living organisms are recognized as important contributors to the impairment of indoor air quality (Reponen et al. 2011). Crewmembers are a major source of microorganisms on spacecraft, although most of the microbes released are generally harmless along with some opportunistic pathogens (Pierson 2001). Microorganisms are constant ecological partners of humans, materials and devices also during manned space flight and in other hermetically sealed environments. In the envisioned future long-duration flights, it is mandatory to prevent and control bioaerosol contamination, which needs understanding of the contamination mechanisms from sources to deposition of the aerosolized particle. The behavior of bioaerosols can be modelled with computational fluid dynamics (CFD) which offers detailed predictions for airflows and particle transport in mechanically ventilated enclosed spaces. By modifying the gravity force in the CFD model, it can be applied also for prediction of deposition of bioaerosols on the surfaces in microgravity environment. However, validation of the deposition model is practically possible only under normal gravity conditions.

2 Materials/Methods

In this study, validation tests were done in hermetically sealed 26.4 m³ hyperbaric chamber of COMEX, which was divided into three sections (D = displacement ventilation zone, M = mixing ventilation zone and E = exhaust ventilation zone).

Figure 1. COMEX’ Test chamber: hermetically sealed 26.4 m³ container.

The tests were carried out with non-biological diethylhexyl sebacate (DEHS) particles and with wet generated Bacillus bacteria aerosol. Bacteria suspension was prepared from Bacillus aerius/licheniformis grown on tryptic soy agar.
(TSA) and potato agar (PA) media. *Bacillus* cells and spores were harvested into sterile water and the suspension was diluted to a volume of $10^8$ cells and spores/ml using a haemacytometer. Diluted *Bacillus* suspension was wet generated by using 6-jet Collison nebulizer at airflow 6 L/min. Stability of bioaerosol generation and total particle concentration in air were measured with an optical particle counter. Deposition of bacteria cells and spores were studied in 34 different sampling points with contact agar (Petrifilm AC, 3M, U.S.) and cultivation (Quantiswab, Copan, IT) methods. Agglomeration stage and possible presence of other particles of generated bioaerosol were analysed by using filter sampling (MB PCB $\Phi 25$ mm, 0.2 µm, Merck KGaA, DE) and high vacuum scanning electron microscope.

3 Results and Discussion

The generation of bioaerosol was stable for two hours needed for sufficient deposition of the particles on the surfaces. There were particles in air mostly in particle sizes 0.3 to 3 µm.

![Figure 2. Stability of two hours wet generation with Collison nebulizer.](image)

Culturable surface concentrations varied between 0 to 109 cfu/cm² in swab samples and in contact agar samples between 0 to 44 cfu/cm². The results showed that particles deposited mostly on the floors. Nevertheless, there were also high deposition concentration onto supply air diffusers. In this study, the results of both methods, cultivation method and contact agar method, were similar.

SEM analysis showed that the *B. aerius/licheniformis* spores were released mostly as single spores, which were size of 1-2 µm, during the wet generation. The analysis showed that there were also some agglomerates but less than 20% and some smaller particles such as particles in size 0.3-0.5 µm.

![Figure 3. Averages of culturable concentrations of cultivation (n=3) and contact agar (n=3) samples from all sampling points.](image)

![Figure 4. Agglomerate (A), spores and nanoparticles (B) on filter.](image)

4 Conclusions

This study showed that wet generation with Collison nebulizer can be used for the production of stable bioaerosol and for sufficient deposition of the particles on the surfaces from microbial suspension for model validation. Both the validation measurements and modelling resulted similar deposition sites, which showed a good performance of the developed CFD model.

5 Acknowledgement

This study was supported by European Space Agency Basic Technology Research Programme BIOMODEXO.

6 References