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Bioaerosols: From Detection to the Canopy Solution

Mauro Sousa de Almeida

Bioaerosols

What are bioaerosols?

- A suspension of particles of **biological origin** in the air.
- It includes **microorganisms** such as **bacteria, viruses, fungi**, and **pollen**, as well as particles derived from living organisms, like skin cells or plant debris.
- Bioaerosols represent up to **5–10%** of **Particulate Matter** by mass.
- Particles larger than the cut-off **(~ 5 µm)** are considered droplets and those smaller are considered aerosols.

https://www.wellairsolutions.com/news/understanding-the-air-we-breathe-bioaerosols-explained

Bioaerosols

Humans inhale and ingest microscopic life every day:

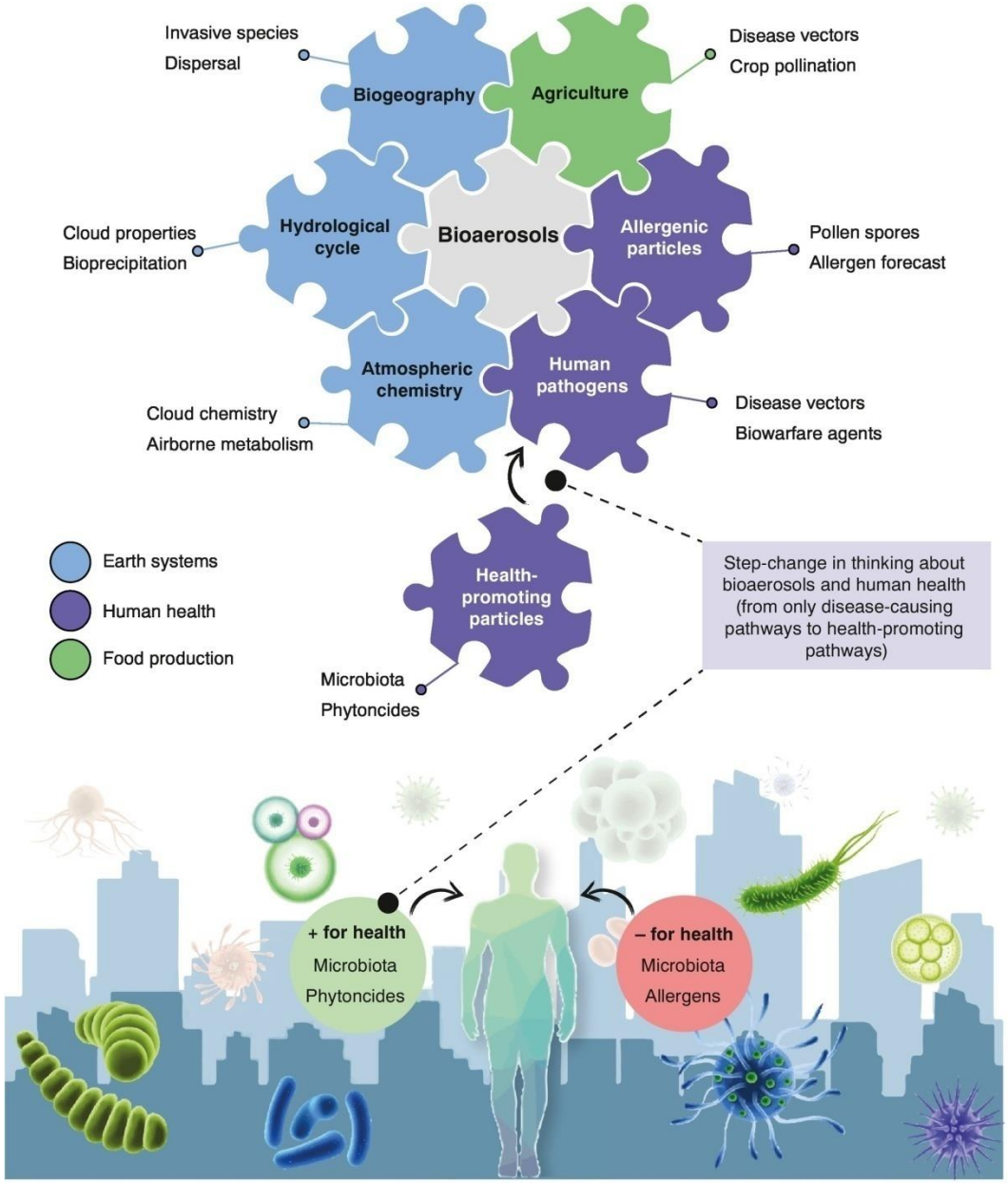
- Up to **60 000 fungal spores.**
- Around **6 million bacteria.**
- Around **6 million viruses.**
- **2 500 – 20 000 pollen grains.**

A single person in a room can release up to **37 million bacteria** into the air (through emission and displacement).

Our bodies and environments are in a **continuous biological exchange.**

New paradigm: beneficial environmental exposure

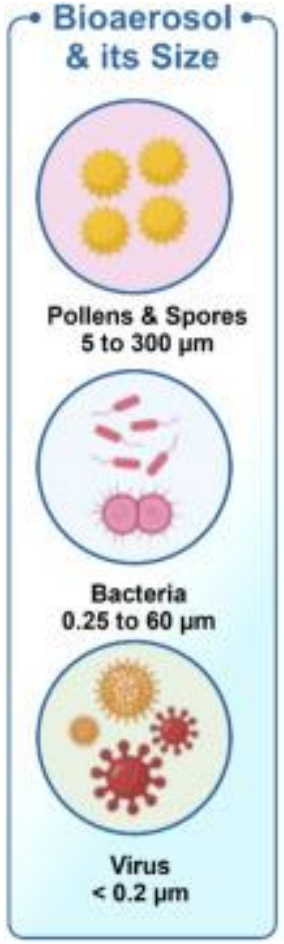
- Aerobiome and early-life microbial contact support immune regulation.



Robinson, J. M., & Breed, M. F. The aerobiome-health axis: a paradigm shift in bioaerosol thinking. *Trends in microbiology*, *31*(7), 661–664. (2023)

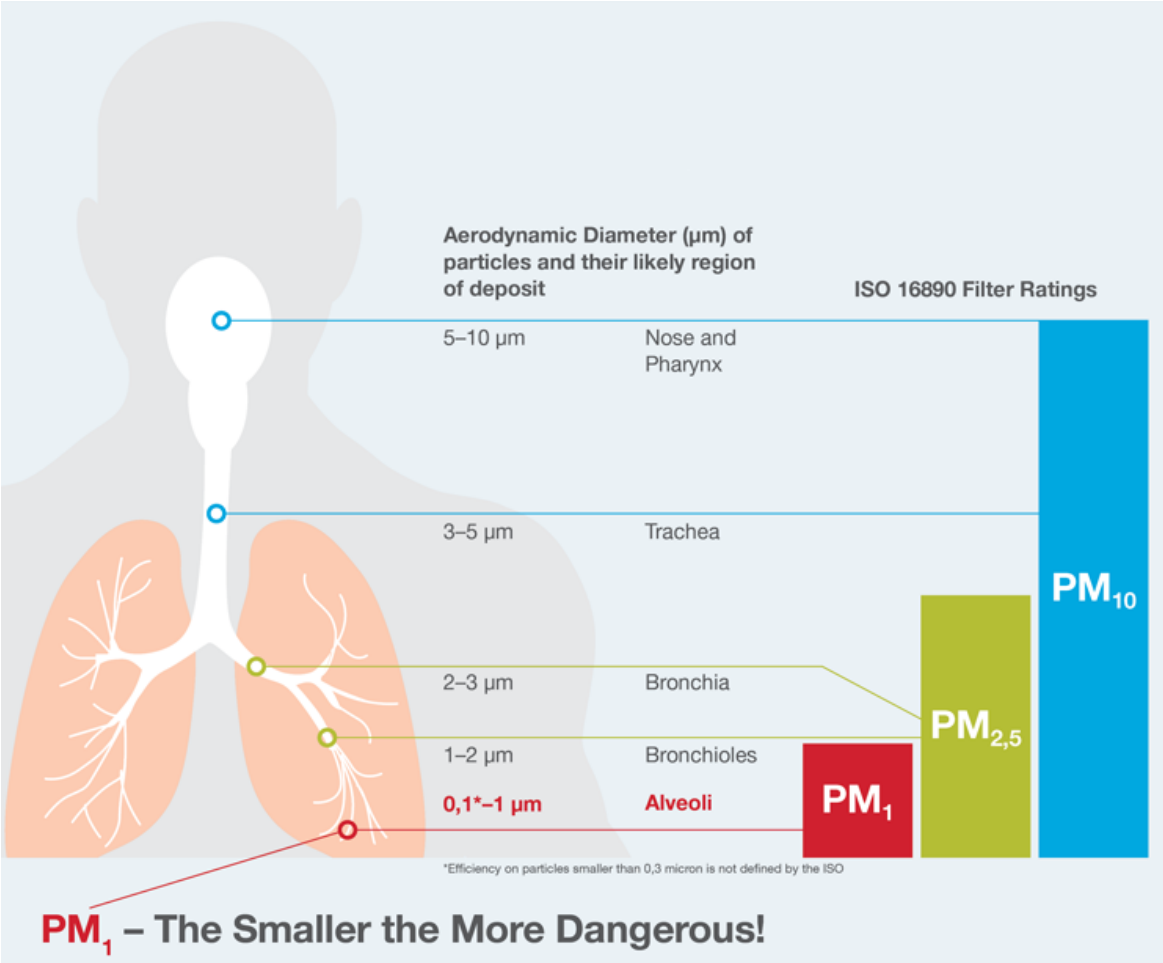
Bioaerosols

Health effects



Singh, N. K., Sanghvi, G., Yadav, M., Padhiyar, H., & Thanki, A. A state-of-the-art review on WWTP associated bioaerosols: Microbial diversity, potential emission stages, dispersion factors, and control strategies. *Journal of hazardous materials*, *410*, 124686. (2021).

The thinner they are, the deeper they go



https://www.how2shout.com/news/are-pm1-particles-are-more-dangerous-than-we-think.html#google_vignette

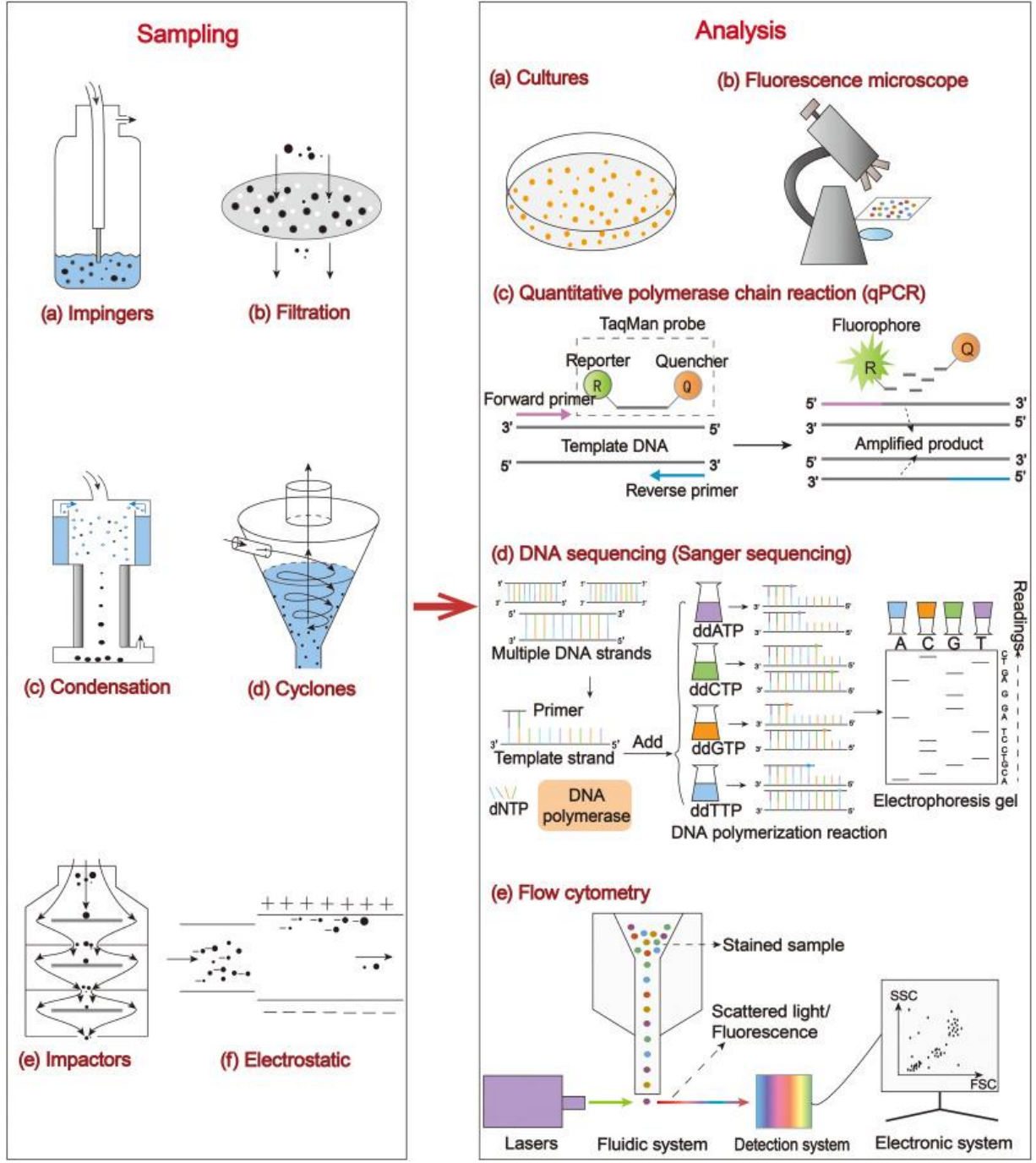
Bioaerosols

Sampling Methods

- Impaction.
- Impingement.
- Filtration.
- Cyclone sampling.
- Electrostatic precipitation.

Analysis Methods

- Culture-based.
- Microscopy.
- Molecular methods.
- Immunological assays.

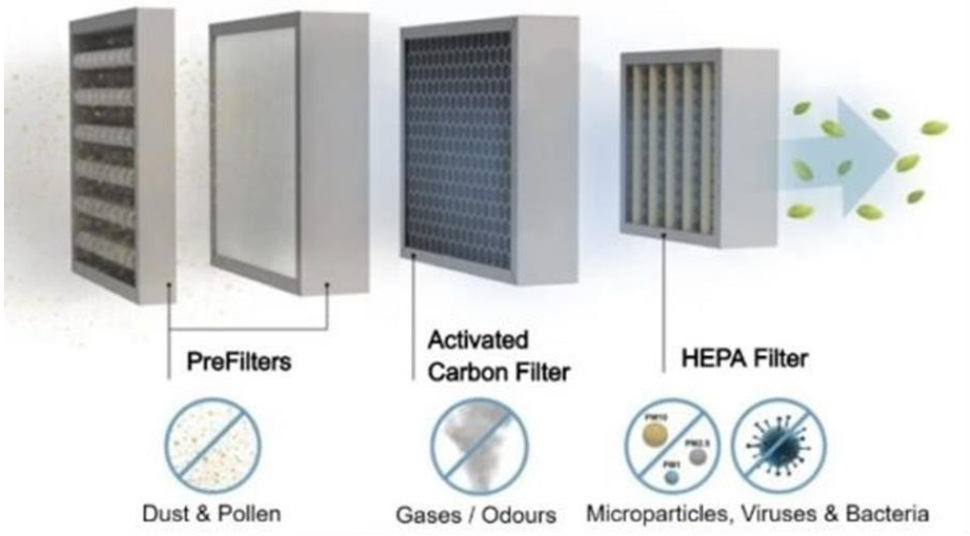


Huang, Z., *et al.* Bioaerosols in the atmosphere: A comprehensive review on detection methods, concentration and influencing factors. *The Science of the total environment*, *912*, 168818. (2024)

Filtration

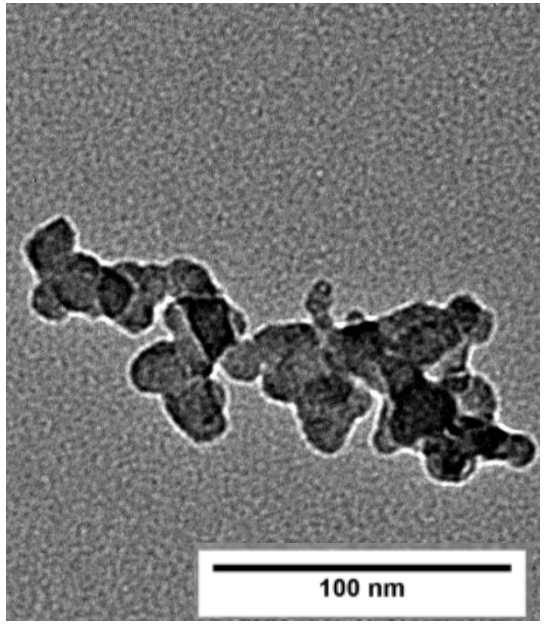
Which bioaerosols must be filtered and in which context?

- Particle size
- Pollen, virus, bacteria?
- Home-based filters?
- Hospital settings?



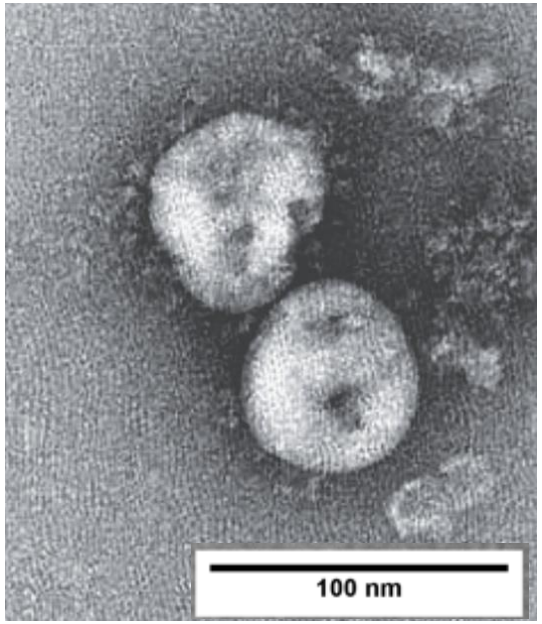
https://engineeringlearn.com/7-types-of-air-filters-home-pros-cons-and-sizes-of-filters-complete-details/ (adapted)

Diesel particle



Steiner et al. Arch Tox 2016

SARS-CoV-2

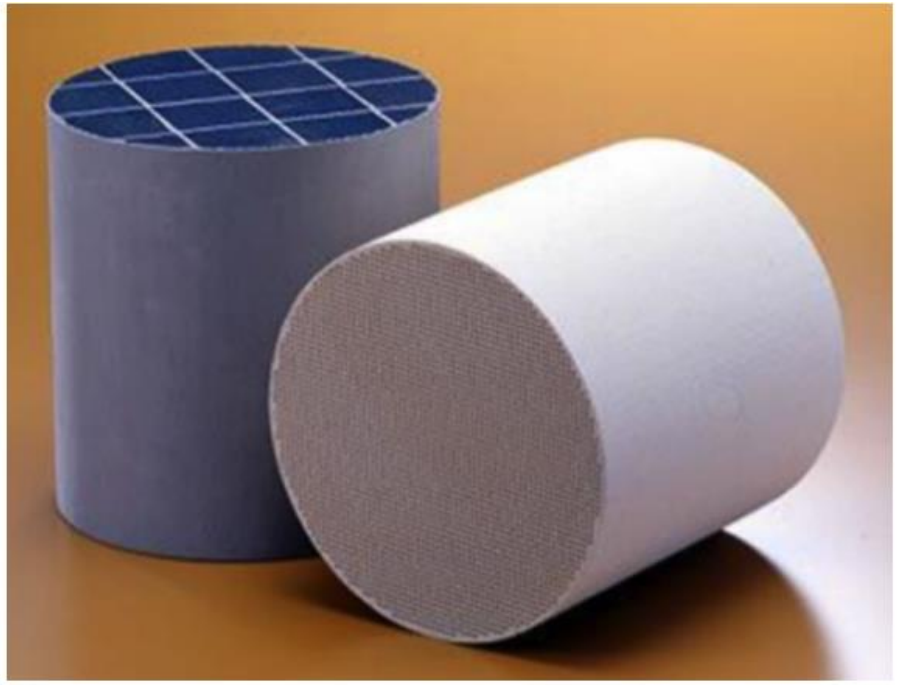


Zhu et al. N Engl J Med. 2020

Filtration Efficiency at 0.3 µm

Case study

- Are the diesel particulate filters also capable of filtering bioaerosols?



2000 SUVA introduces mandatory filters; VERT certified.

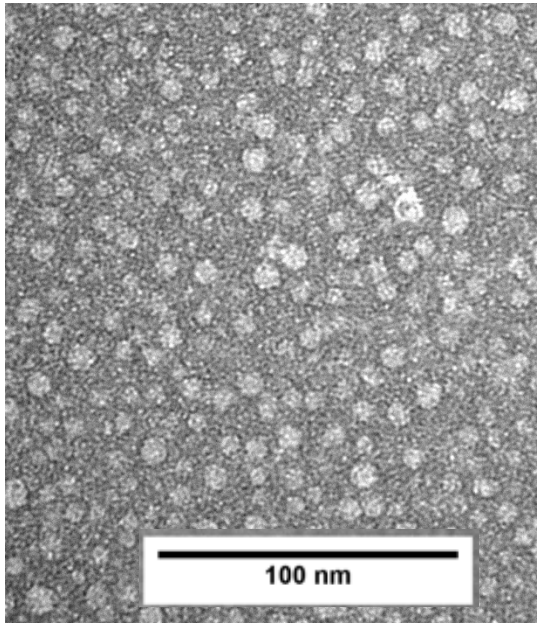
Case study

- How do we test the efficiency?

Aerosolisation

Type of bioaerosol

Bacteriophage MS2



C. Loussert-Fonta

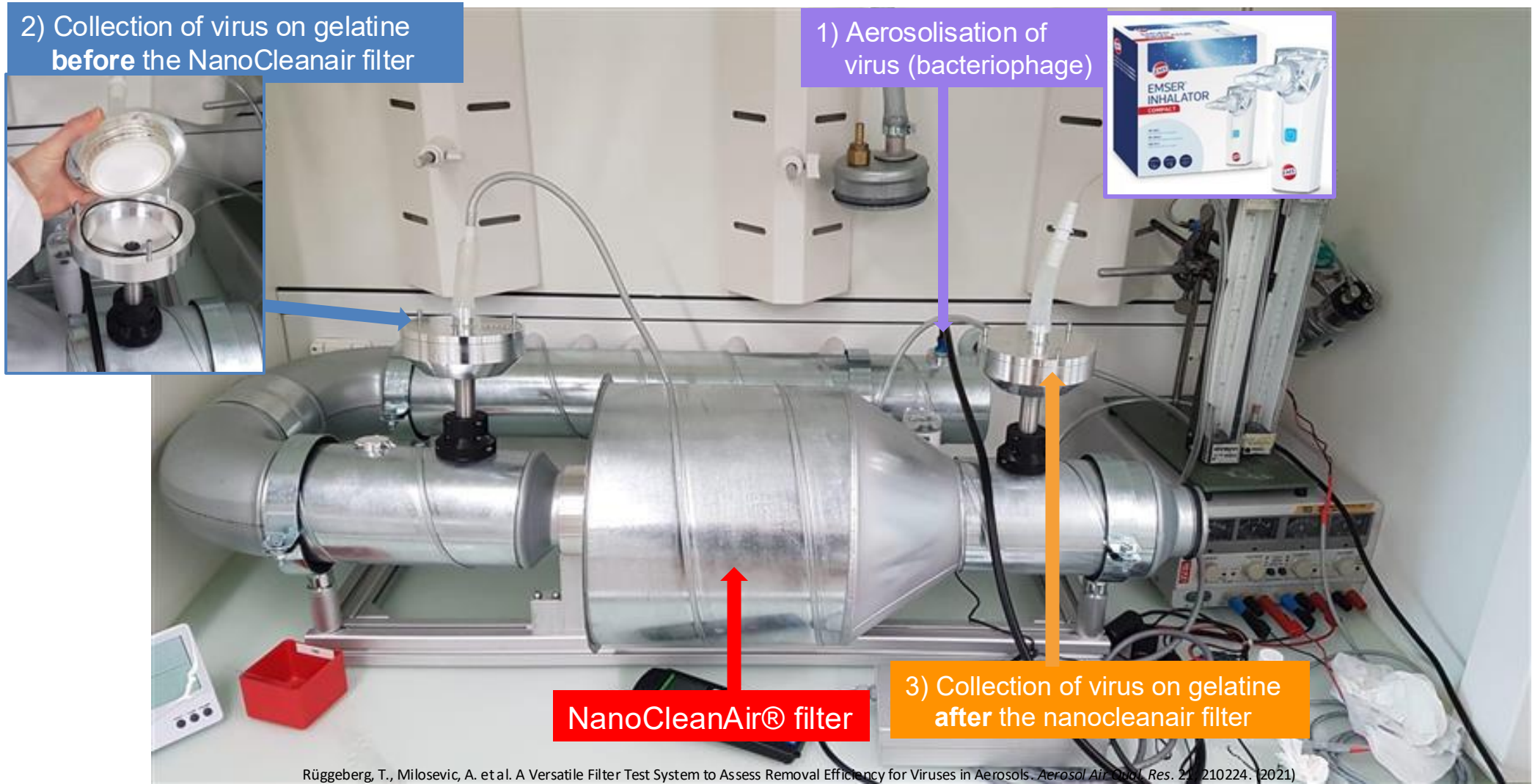
Collector

Gelatine filters

Air Filter Testing

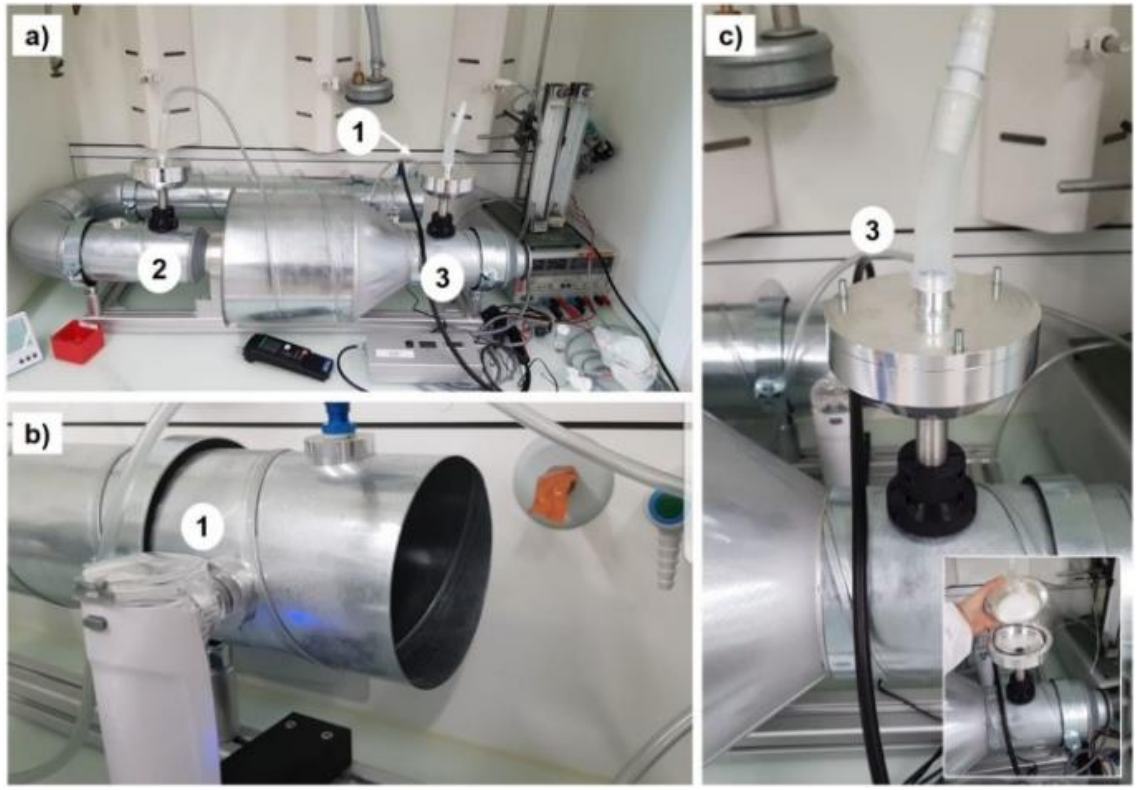
How do we test the efficiency of air filters against airborne bioaerosols?

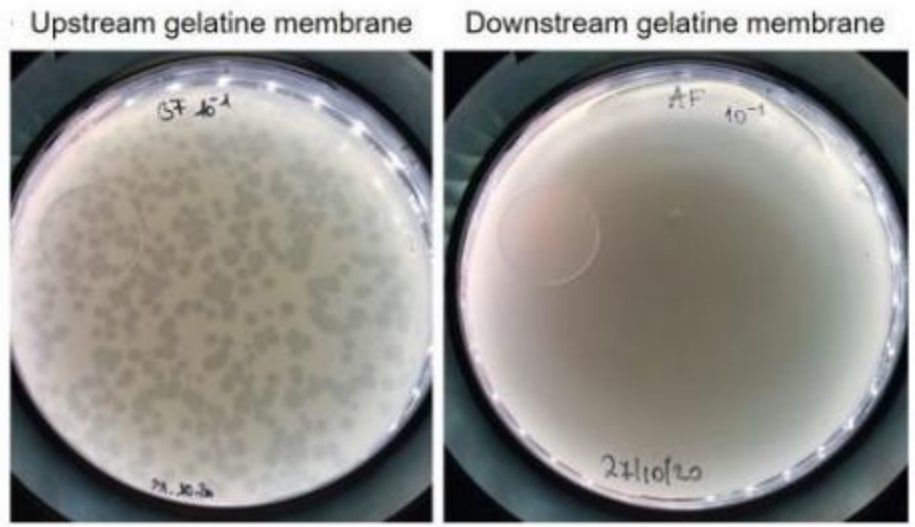
NanoCleanAir – Filter Test System to Assess Removal Efficiency for Viruses in Aerosols



Rüggeberg, T., Milosevic, A. et al. A Versatile Filter Test System to Assess Removal Efficiency for Viruses in Aerosols. *Aerosol Air Qual. Res.* 21: 210224. (2021)

Filter Test System to Assess Removal Efficiency for Viruses in Aerosols





Gelatine filters represent a good system to capture viruses from aerosols.

NanoCleanAir® filter showed a high efficacy (> 99%) to eliminate virus from aerosols.

A new filter test system was successfully developed.

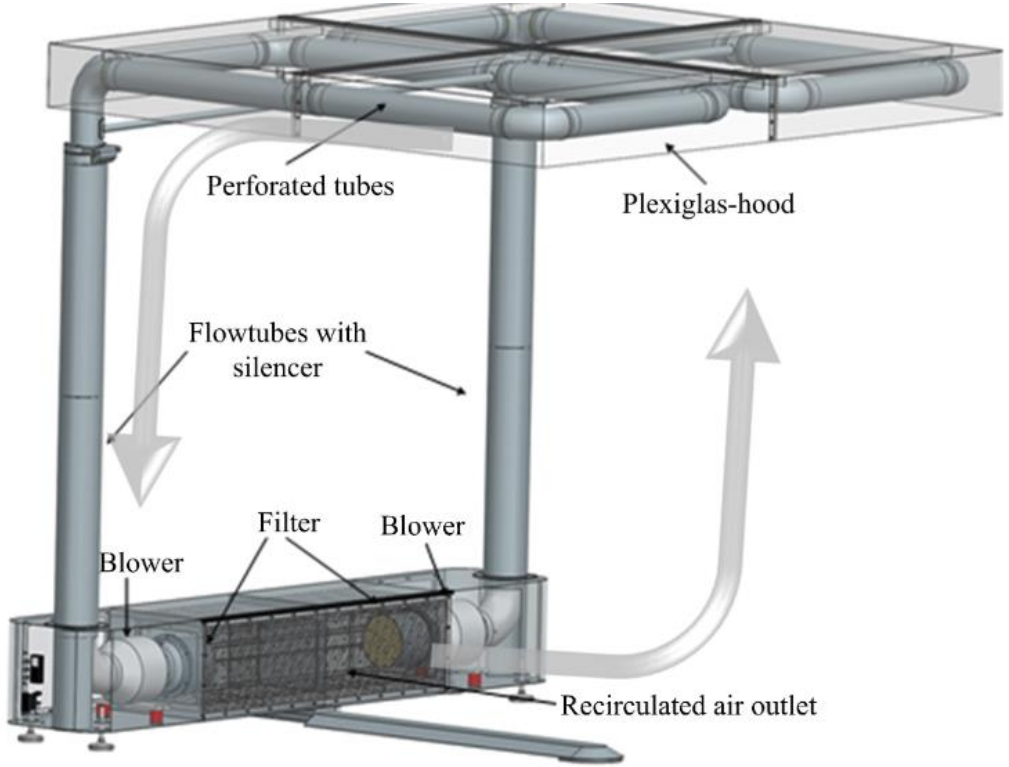
Rüggeberg, T., Milosevic, A. et al. A Versatile Filter Test System to Assess Removal Efficiency for Viruses in Aerosols. *Aerosol Air Qual. Res*. 21, 210224. (2021)

Bioaerosol filtration efficiency in the Canopy system

Vertical airflow system with ceramic wall flow filters designed to reduce the spread of airborne pathogens in hospital environments.

The system captures exhaled air above the patient, filters it via ceramic filters, and releases clean air beneath the bed.

A



B

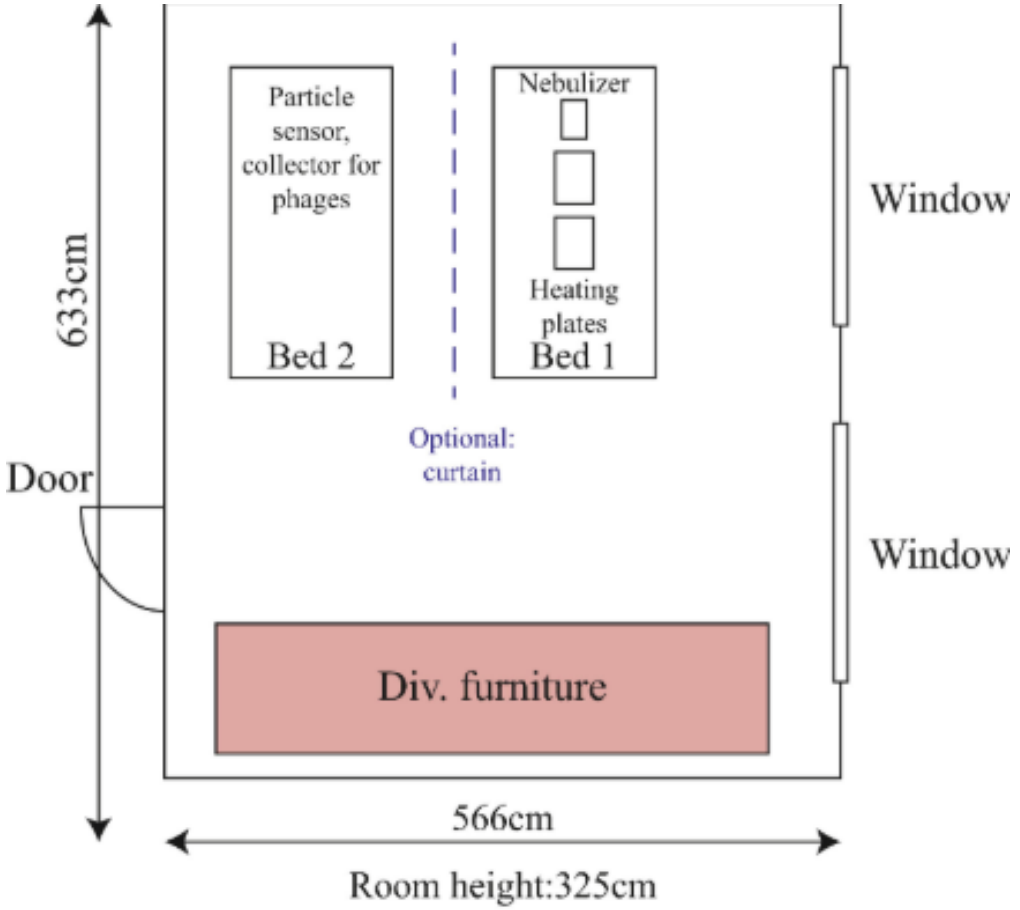
Sousa de Almeida, M., et al,. The canopy: a novel vertical airflow device with ceramic wall flow filters for reducing airborne pathogen spread in hospital rooms. *The Journal of hospital infection, 162*, 339–350. (2025)

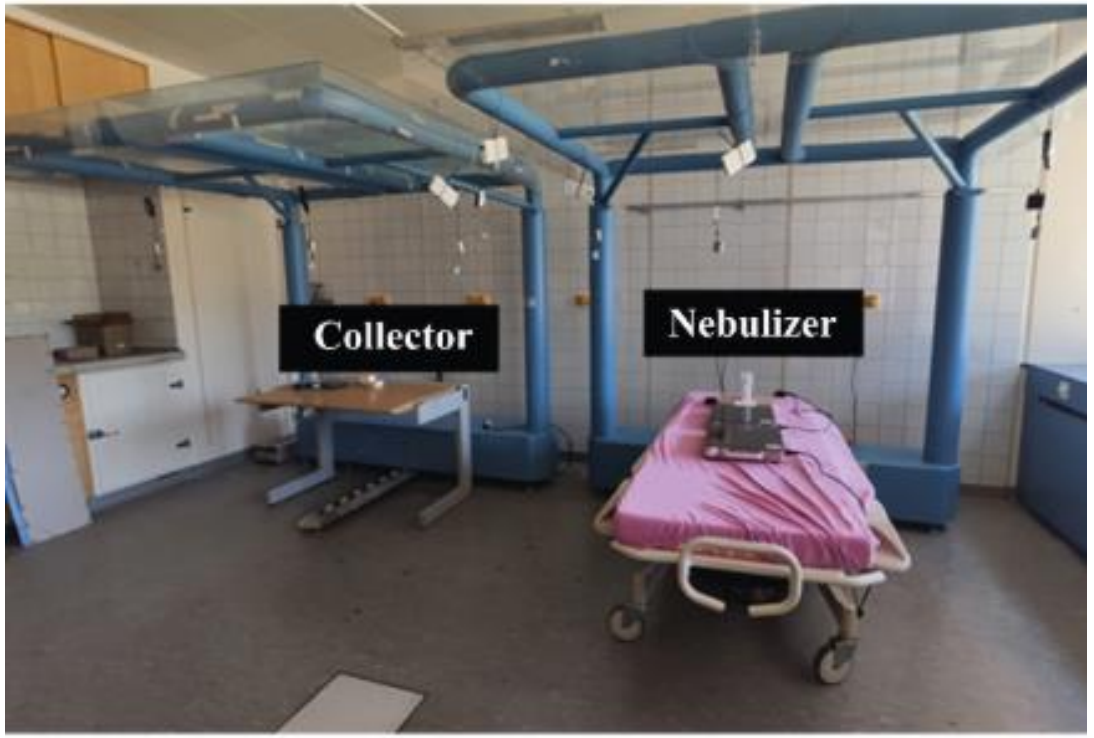
Bioaerosol filtration efficiency in the Canopy system

Dimensions and layout of the room test

Room with ~36 m^2 and 116 m^3 reflecting the dimensions of a standard four-bed hospital room.

Air exchange rate : 1 per hour





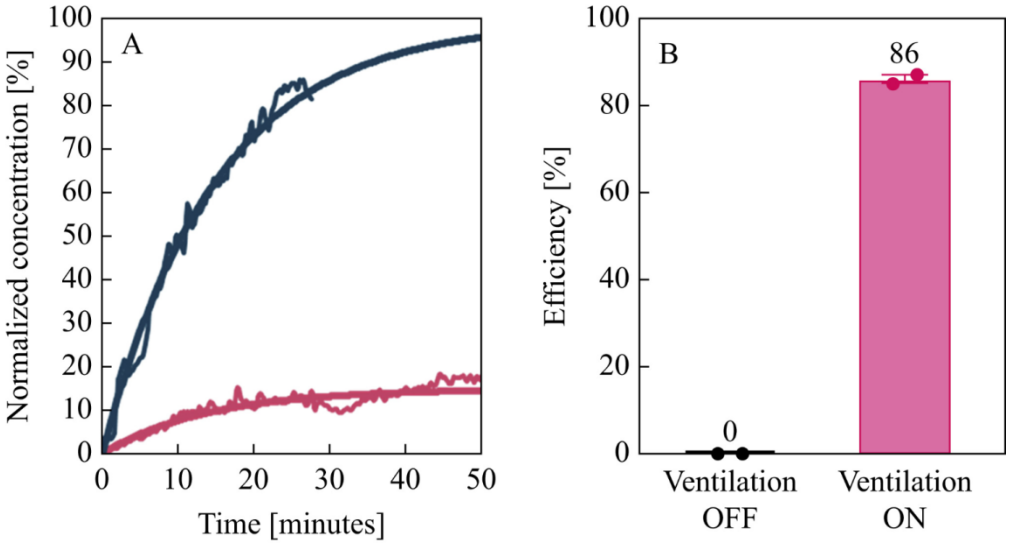
Sousa de Almeida, M., et al,. The canopy: a novel vertical airflow device with ceramic wall flow filters for reducing airborne pathogen spread in hospital rooms. *The Journal of hospital infection, 162*, 339–350. (2025)

Bioaerosol filtration efficiency in the Canopy system

Results

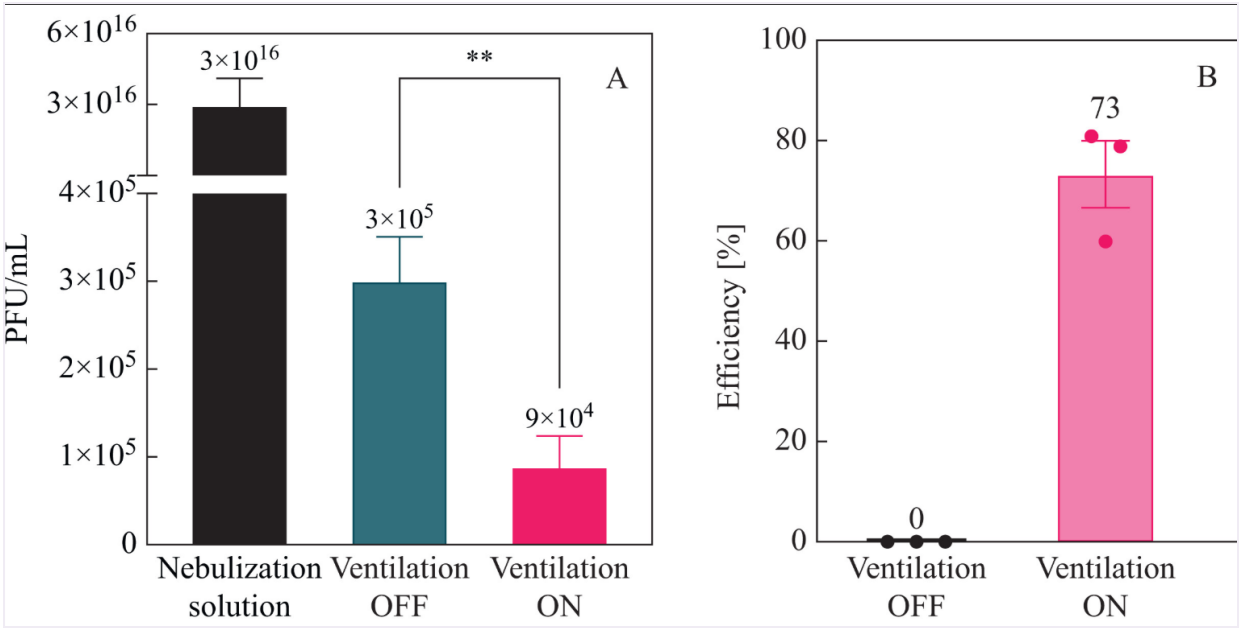
- NaCl particles – **86 %** Efficiency.
- Bacteriophages – **73 %** Efficiency.

NaCl solution (Salt aerosols)



Mean ± SEM of n = 2.

Bacteriophages



Mean ± SEM of n = 3 . Differences between the groups were calculated with a paired *t-test: **P≤0.01.*

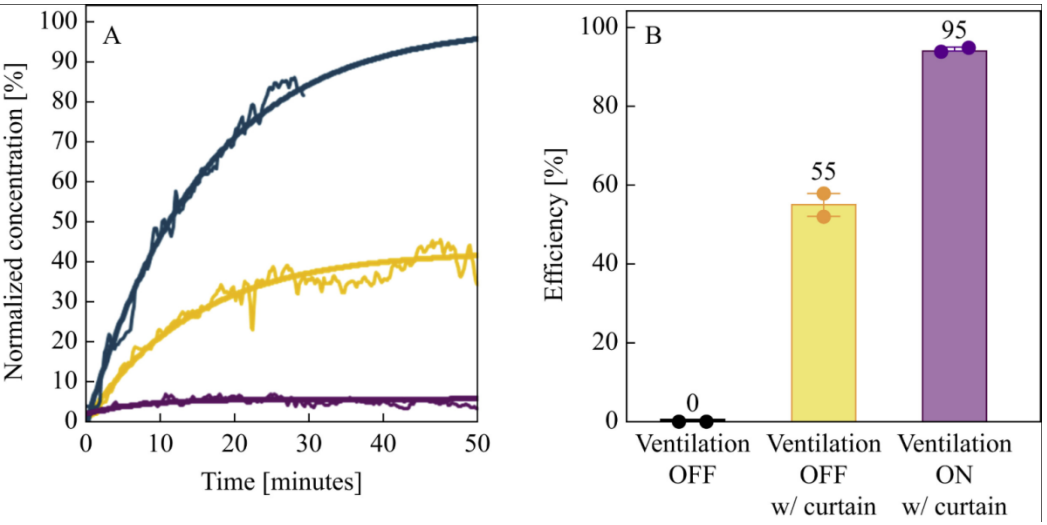
Sousa de Almeida, M., et al,. The canopy: a novel vertical airflow device with ceramic wall flow filters for reducing airborne pathogen spread in hospital rooms. *The Journal of hospital infection, 162*, 339–350. (2025)

Bioaerosol filtration efficiency in the Canopy system

Results

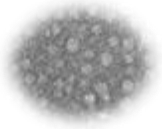
- NaCl particles – **55 %** efficiency with curtain and **95 %** with curtain and ventilation.
- Bacteriophages – **37 %** Efficiency with curtain and **54%** with curtain and ventilation.

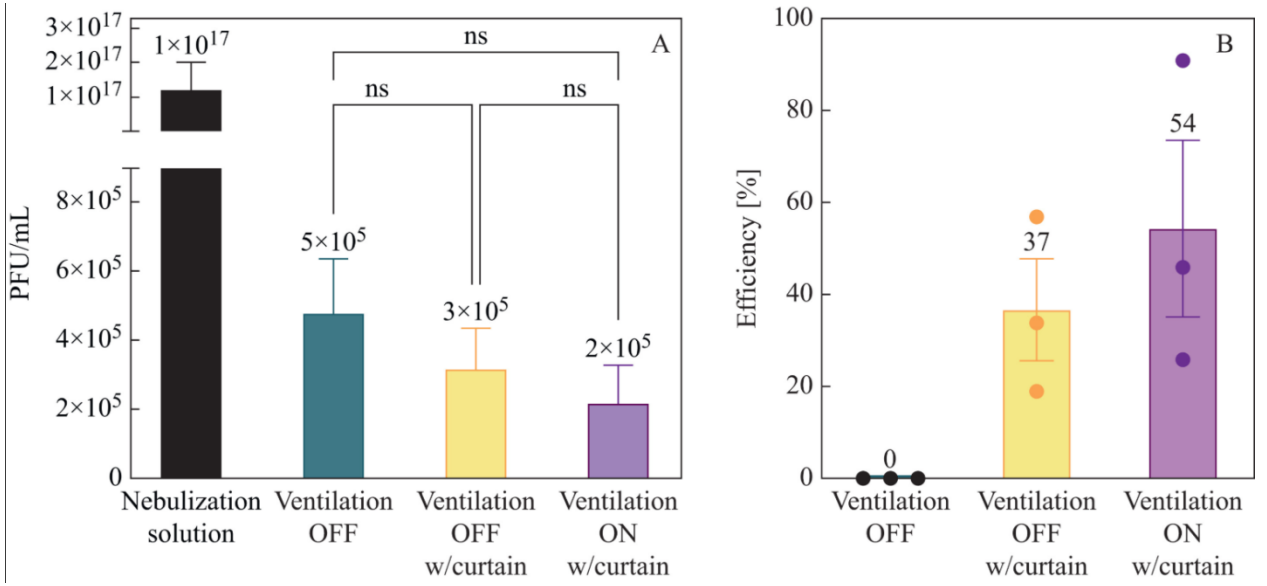
NaCl solution (Salt aerosols)



Mean ± SEM of n = 3.

Bacteriophages





Mean ± SEM of n = 3

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Take home messages

- Not all **bioaerosols** are **harmful**.
- Balanced exposure to diverse **aerobiomes can support immune health**, but their levels and composition must be carefully managed to **ensure beneficial** rather than adverse health effects.
- **Ceramic NanoCleanAir filters are efficient** against small airborne bioaerosols.
- Results in simulated environments (e.g., hospital rooms) reveal that the **combination of nanofiltration and vertical laminar flow** has the potential to **reduce nosocomial infections** by lowering aerosol concentrations; further clinical studies are ongoing.

Acknowledgements

SNA members

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