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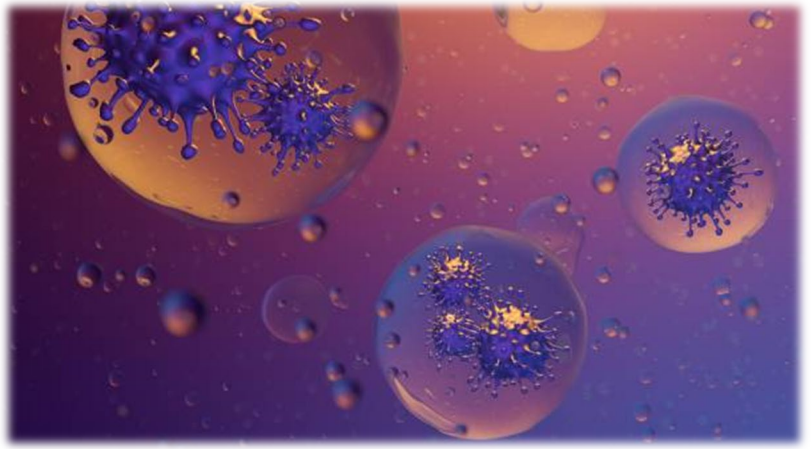
Air-filtration around hospital beds to prevent viral aerosol spread

Mauro Sousa de Almeida

Bioaerosols

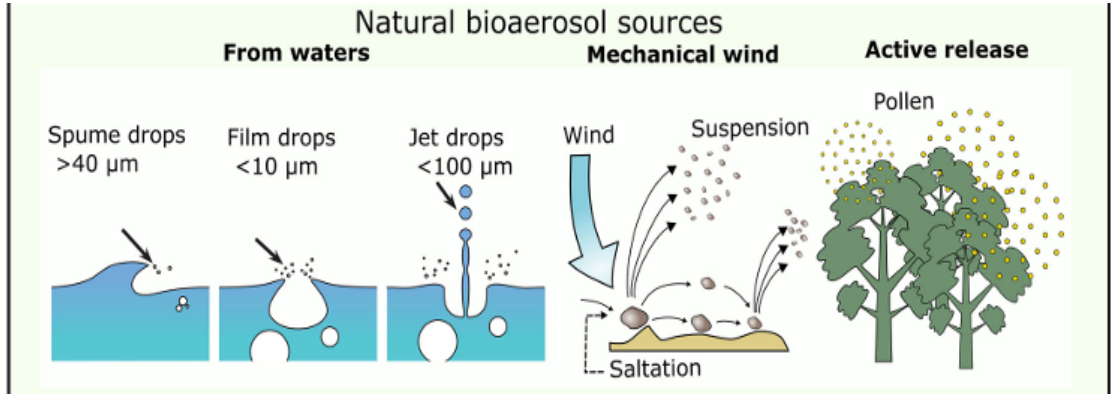
What are bioaerosols?

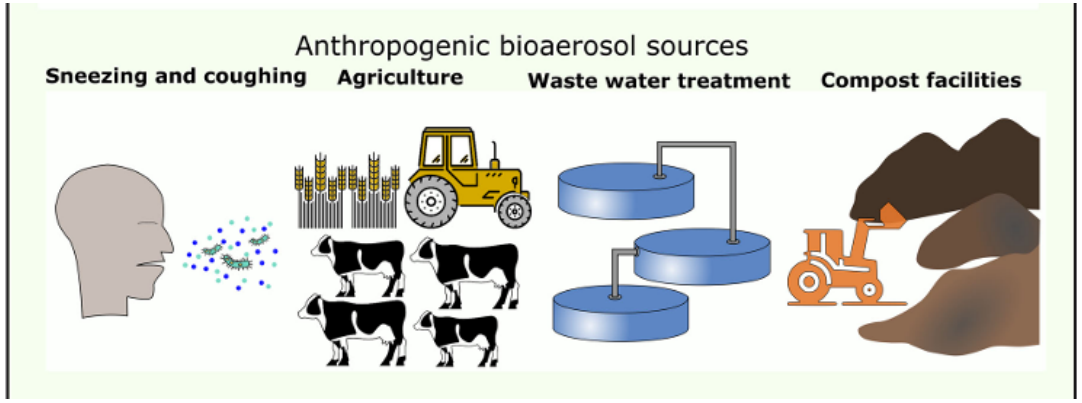
- A suspension of particles of **biological origin** in the air.
- It includes **microorganisms** such as **bacteria, viruses, fungi**, and pollen, as well as particles derived from living organisms, like skin cells or plant debris.
- The differentiation between **droplets** and **aerosols** by the World Health Organization (WHO) is based on an arbitrary cut-off in **aerodynamic diameter**; particles larger than the cut-off **(~ 5 µm)** are considered droplets and those smaller are considered aerosols.



https://theconversation.com/covid-how-the-disease-moves-through-the-air-173490

What are the main sources?

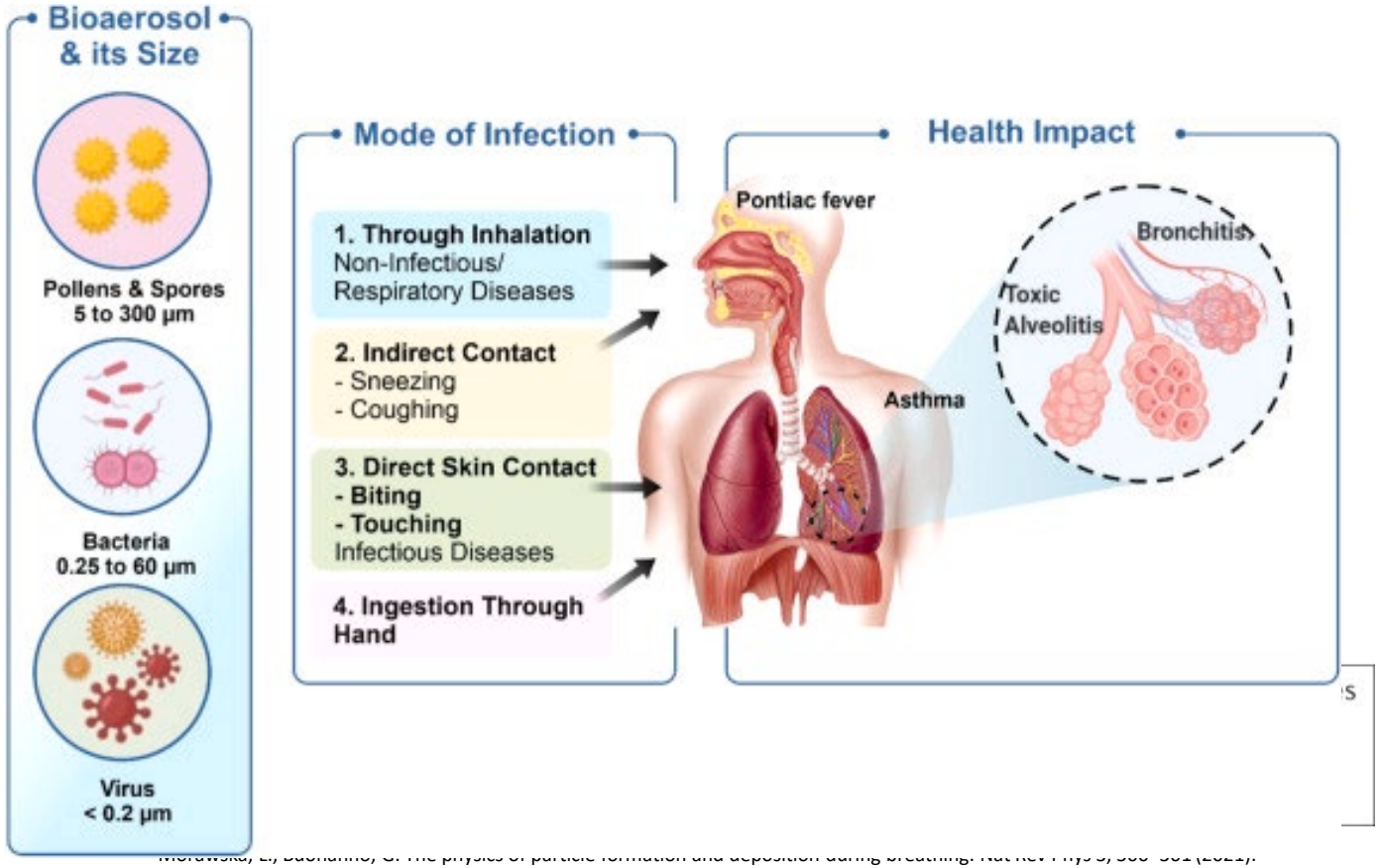




Alsved, Malin *et al.* Natural Sources and Experimental Generation of Bioaerosols: Challenges and Perspectives. *Aerosol Science and Technology* 54, 5:547–71. (2020)

Bioaerosols – Impact on human health

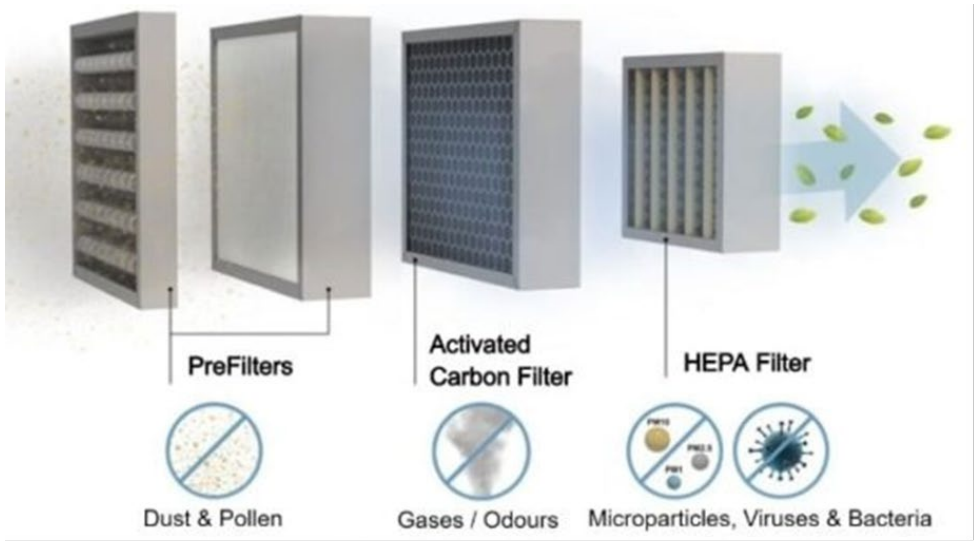
- Small aerosols are more susceptible to be inhaled deep into the lung.
- Large droplets are mainly trapped in the upper airways.



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).

Filtration of bioaerosols

- **Purpose:**
  - Which bioaerosols must be filtered (particle size, virus, bacteria)
- **Procedure:**
  - Which type of filters to be used (many bioparticles are flexible structures)
  - Which detection system of the bioaerosols is suitable to measure the efficacy



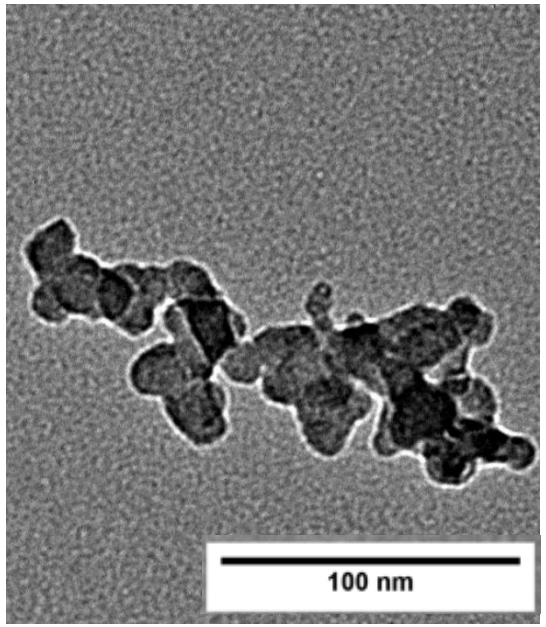
https://engineeringlearn.com/7-types-of-air-filters-home-pros-cons-and-sizes-of-filters-complete-details/ (adapted)

https://smartairfilters.com/en/blog/comparison-mask-standards-rating-effectiveness/

Escherichia coli bacteriophage MS2

- **Bacteriophage MS2** is morphologically and structurally **similar** to human viruses such as SARS-CoV-2.
- Is a practical **surrogate virus** and can be used together with biological safety laboratory strains of ***Escherichia coli*** as target cells which are **safe** for humans and the environment.
- MS2 is one of the **smallest viruses** with a diameter (~30 nm) about **2–4 times** smaller than **SARS-CoV-2**.

Diesel particle

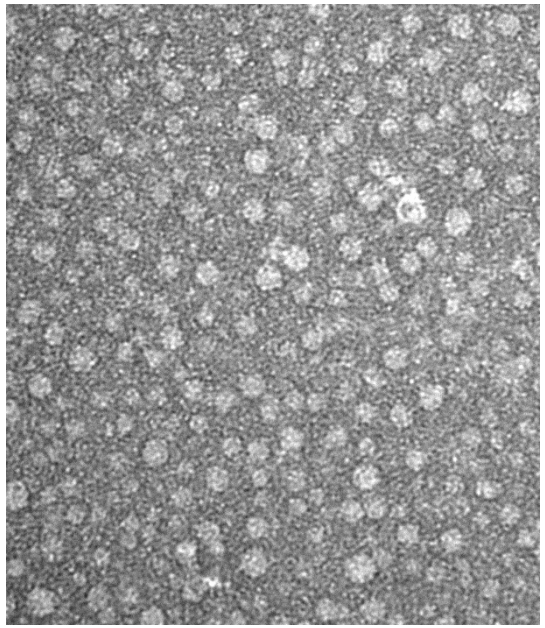


Steiner et al. Arch Tox 2016

SARS-CoV-2

Zhu et al. N Engl J Med. 2020

Bacteriophage MS2

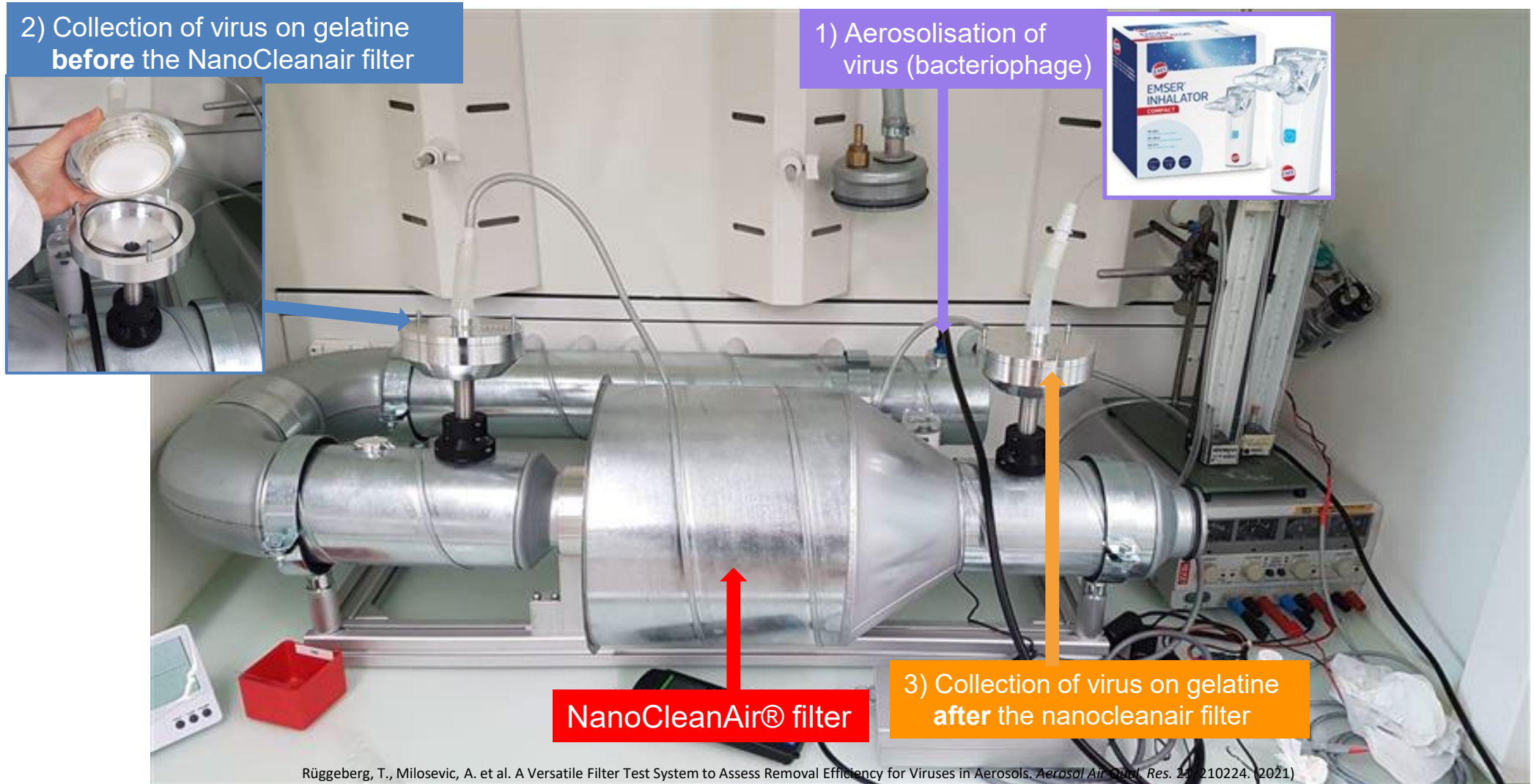


C. Loussert-Fonta

Air Filter Testing

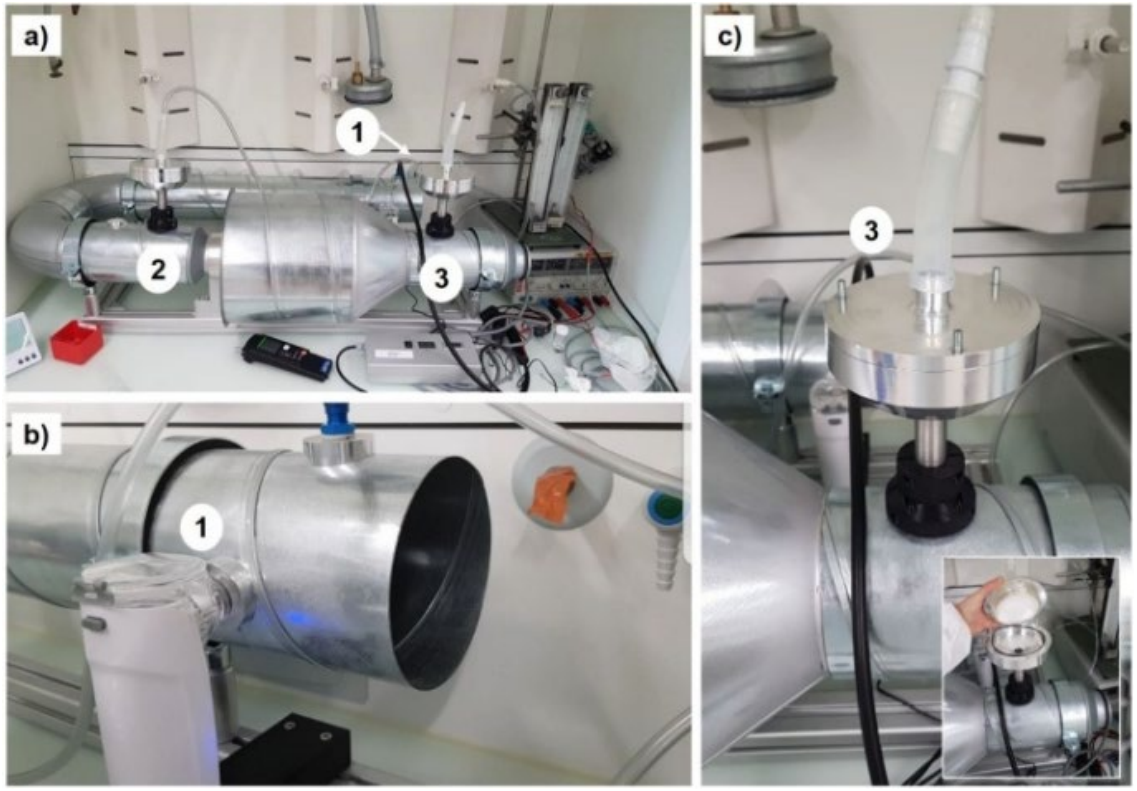
How do we measure the efficiency of air filters against airborne bioaerosols?

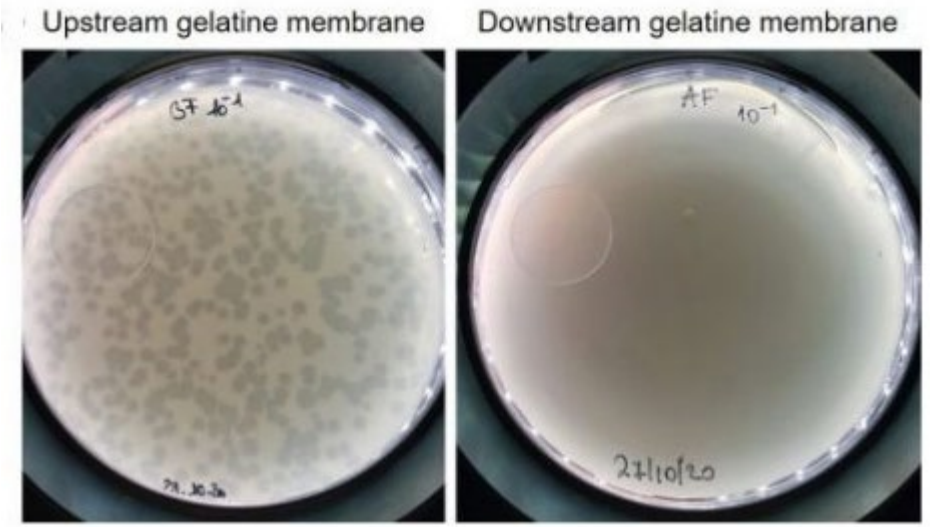
NanoCleanAir – Filter Test System to Assess Removal Efficiency for Viruses in Aerosols



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.

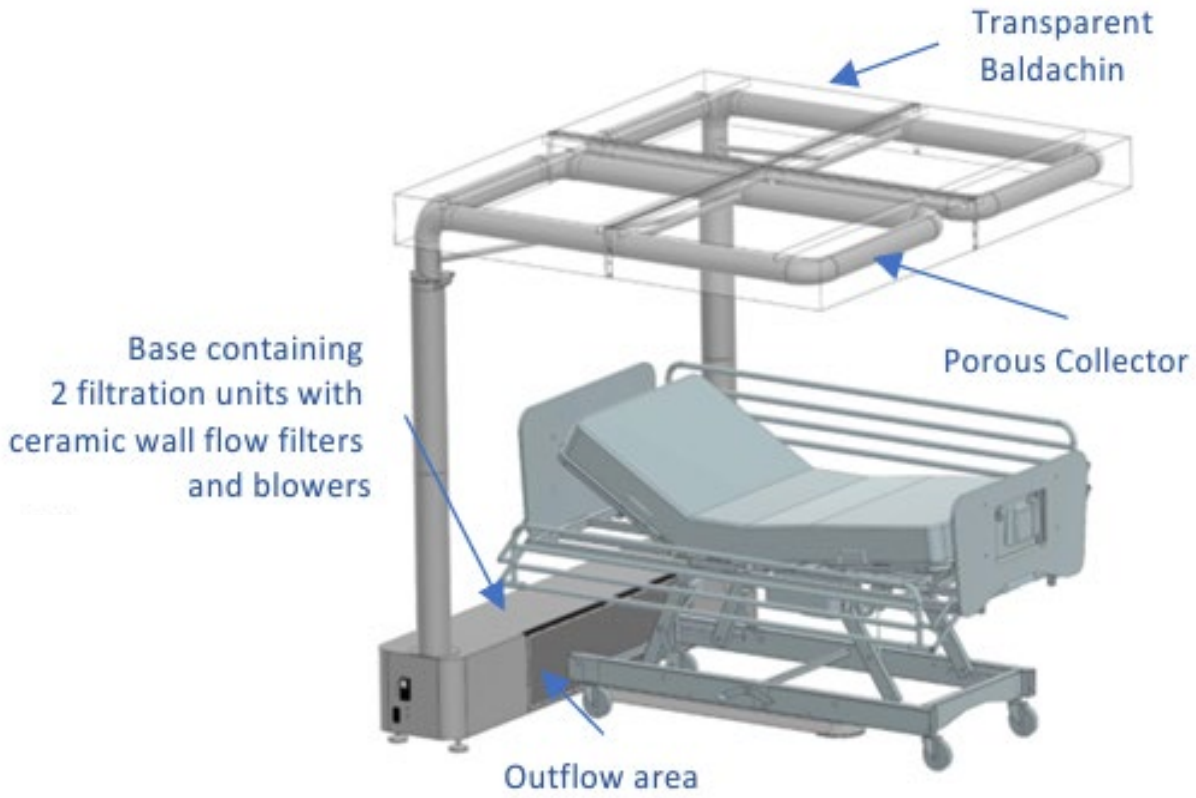
A new filter test system was successfully developed.

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)

Cleaning performance of bioaerosols on a real Baldachin

Main Goals

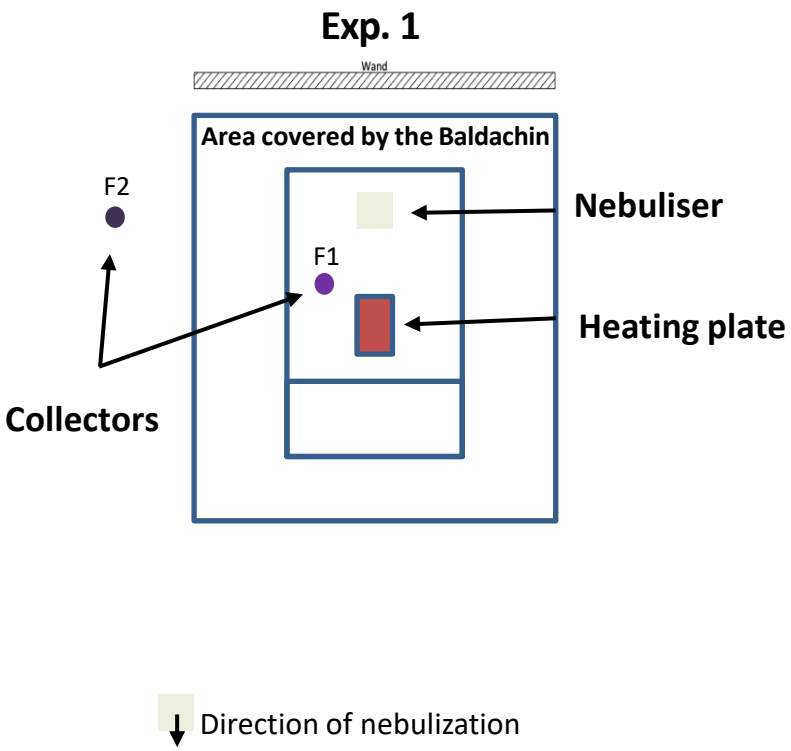
- Install the system in Intermediate Care Unit (IMC) of hospitals to protect patients and staff from infectious patients.
- Keep patients comfortable without complicating their care.

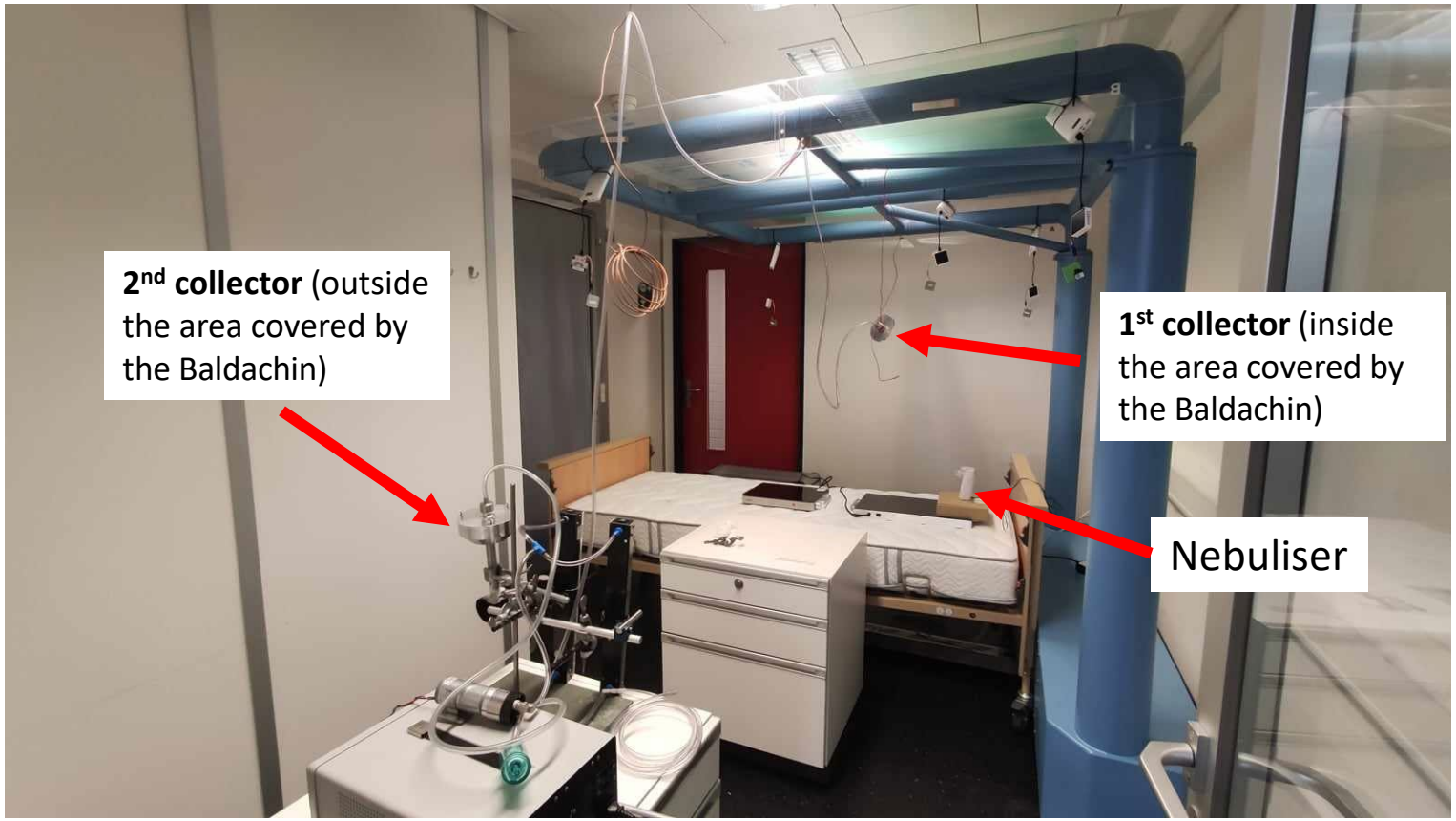


Cleaning performance of viral aerosols

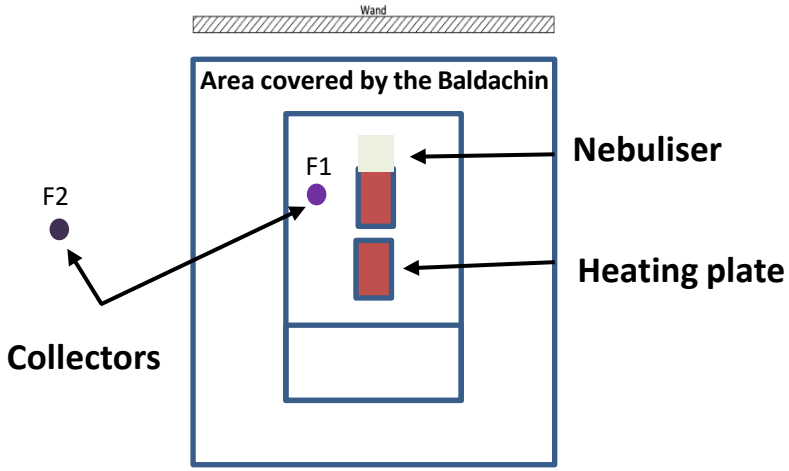
Experiment 1

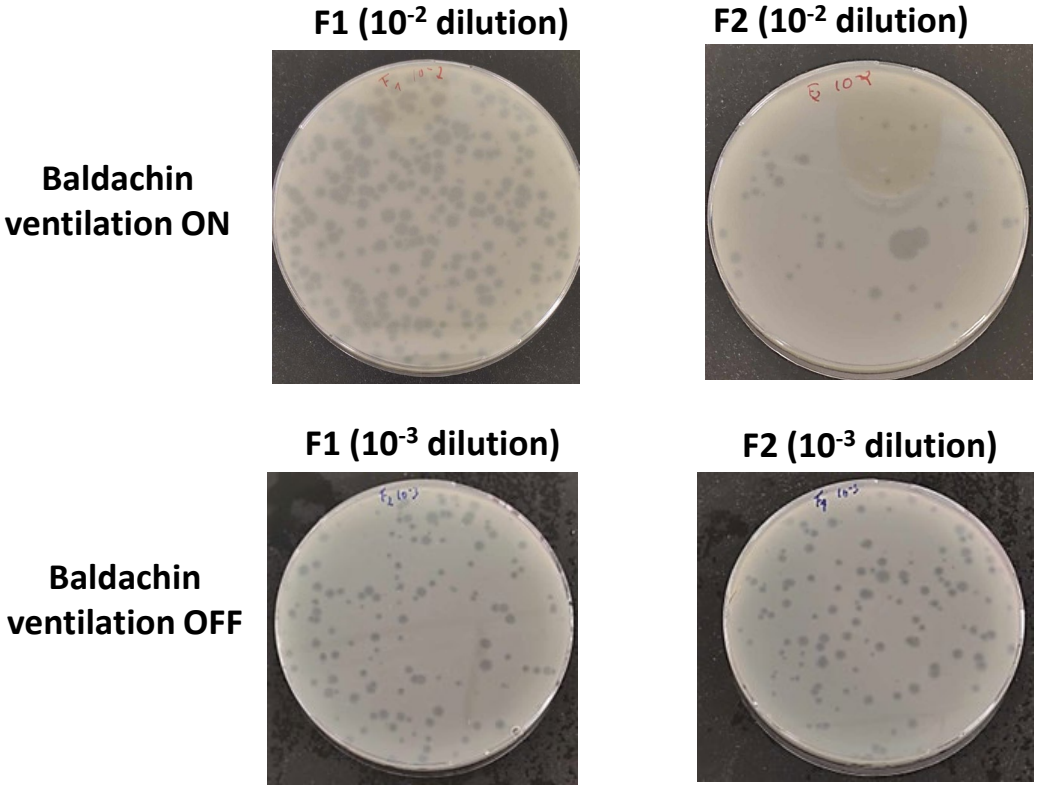
MS2 Bacteriophages are nebulised at the location of the head, and collected at defined locations in the room (protection of others from an infected person in the bed under the baldachin).





Results – Experiment 1





	Filter 1 (PFU/mL)	Filter 2 (PFU/mL)
Baldachin ventilation ON	5,0E+06	6,9E+05
Baldachin ventilation OFF	1,5E+06	1,6E+06

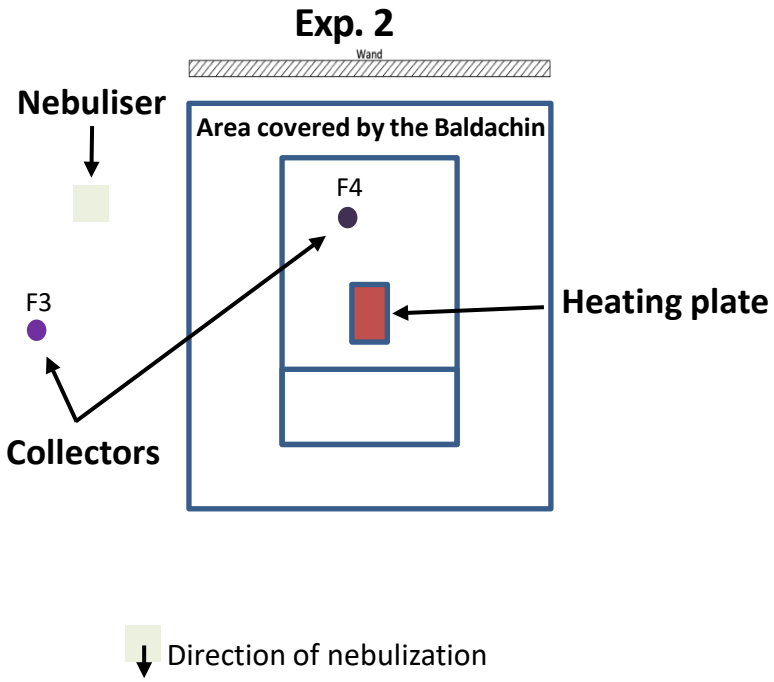
Baldachin ventilation ON: A lower number of PFU (~10 fold decrease) was observed in the filter placed outside the area covered by the baldachin.

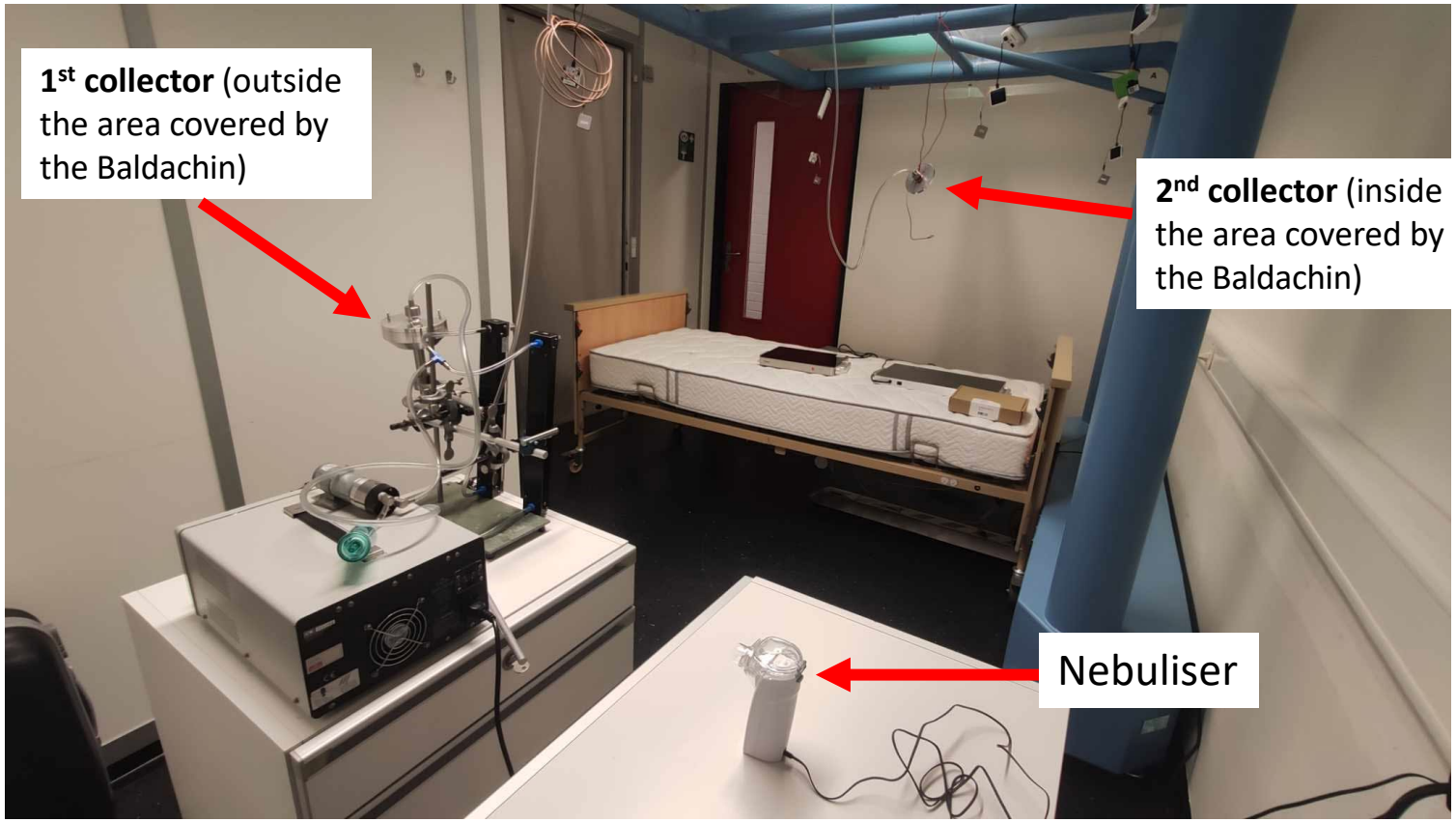
***Baldachin ventilation OFF*:** A similar number of PFU was observed in both filters.

Cleaning performance of viral aerosols

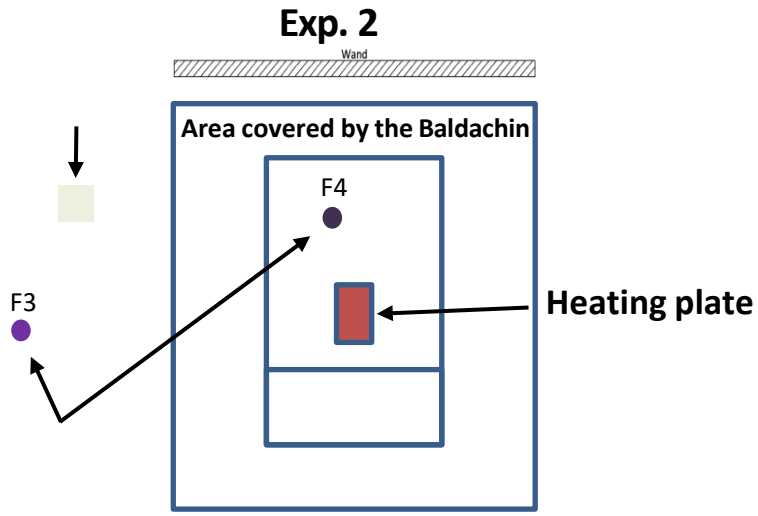
Experiment 2

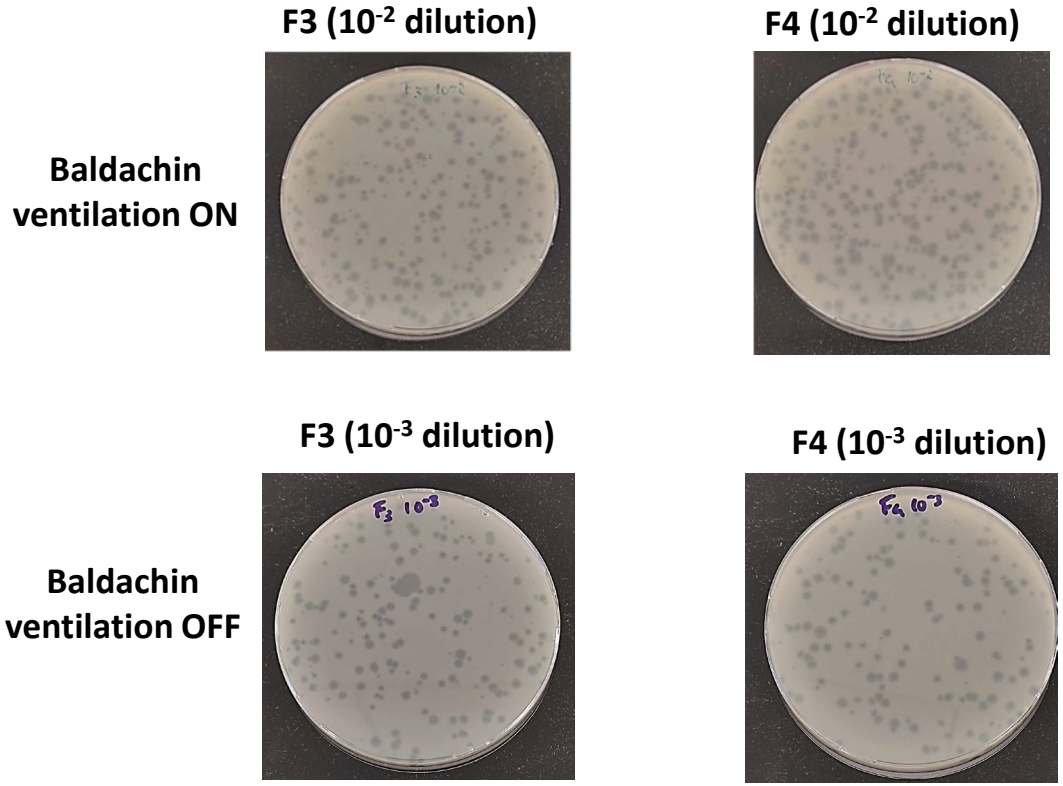
MS2 bacteriophages are nebulised in the room and collected at the location of the head (protection of person in the bed under the baldachin).





Results – Experiment 2





	Filter 3 (PFU/mL)	Filter 4 (PFU/mL)
Baldachin ventilation ON	4,2E+06	5,0E+06
Baldachin ventilation OFF	2,1E+06	1,8E+06

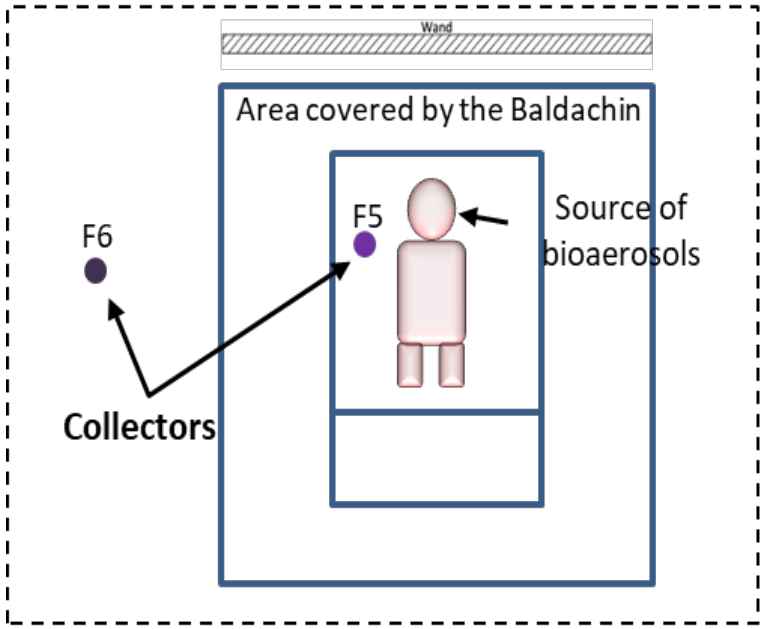
Baldachin ventilation ON: A similar but slightly higher number of PFU was detected on the filter located inside the area covered by the baldachin.

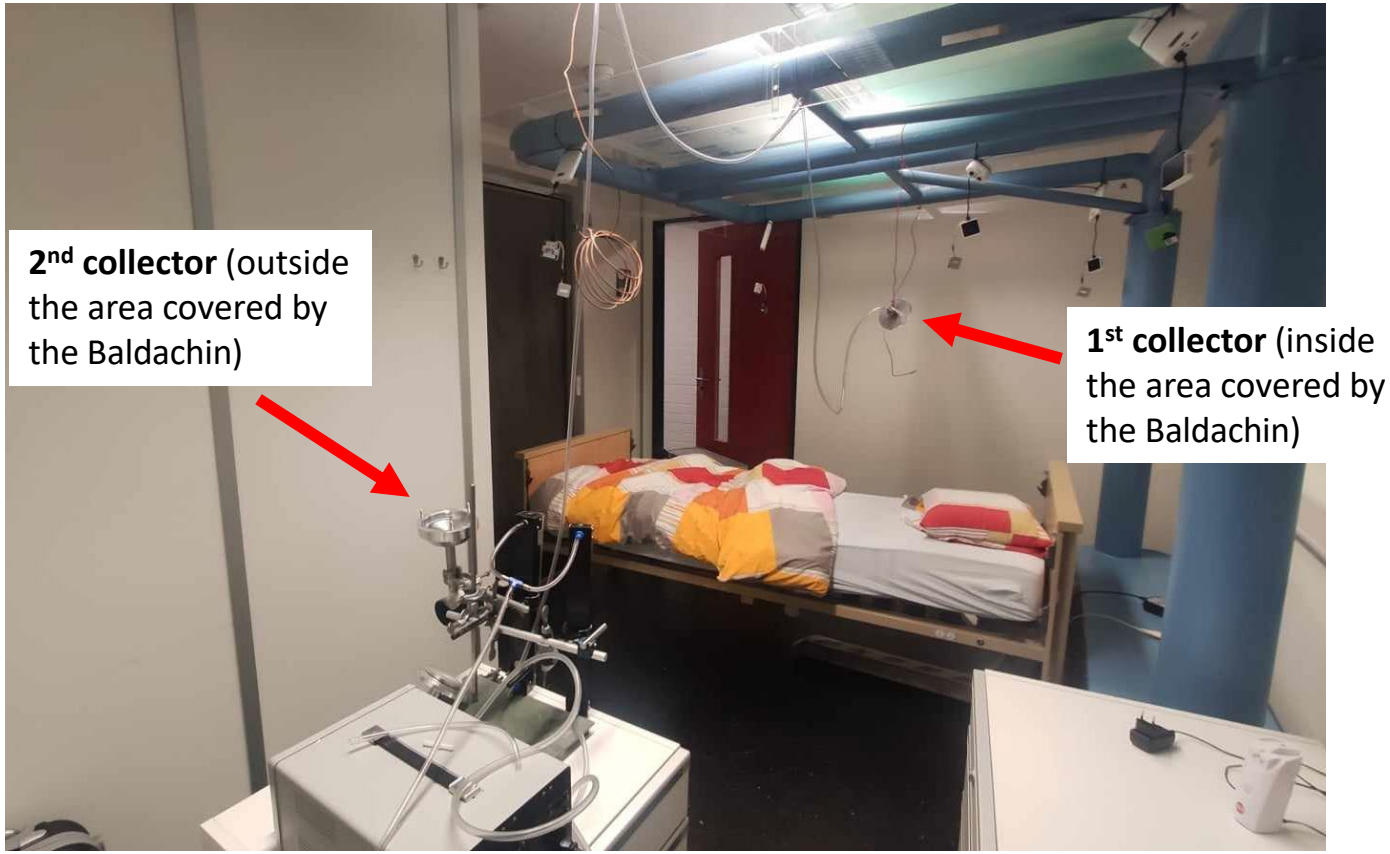
Baldachin ventilation OFF: A similar number of PFU was observed in both filters.

Cleaning performance of microbial aerosols

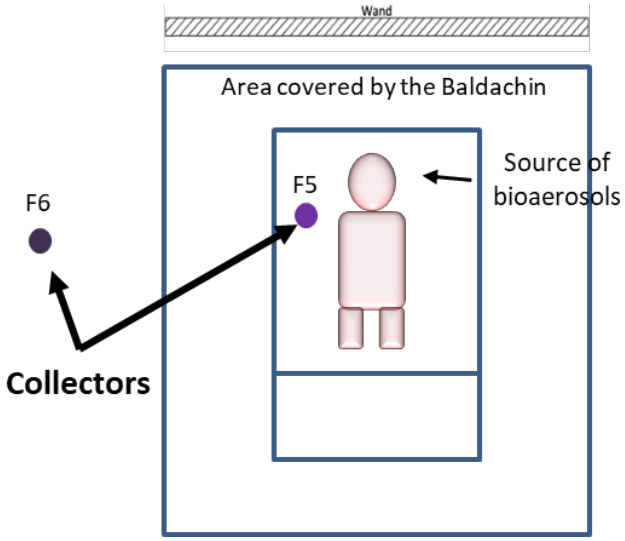
Experiment 3

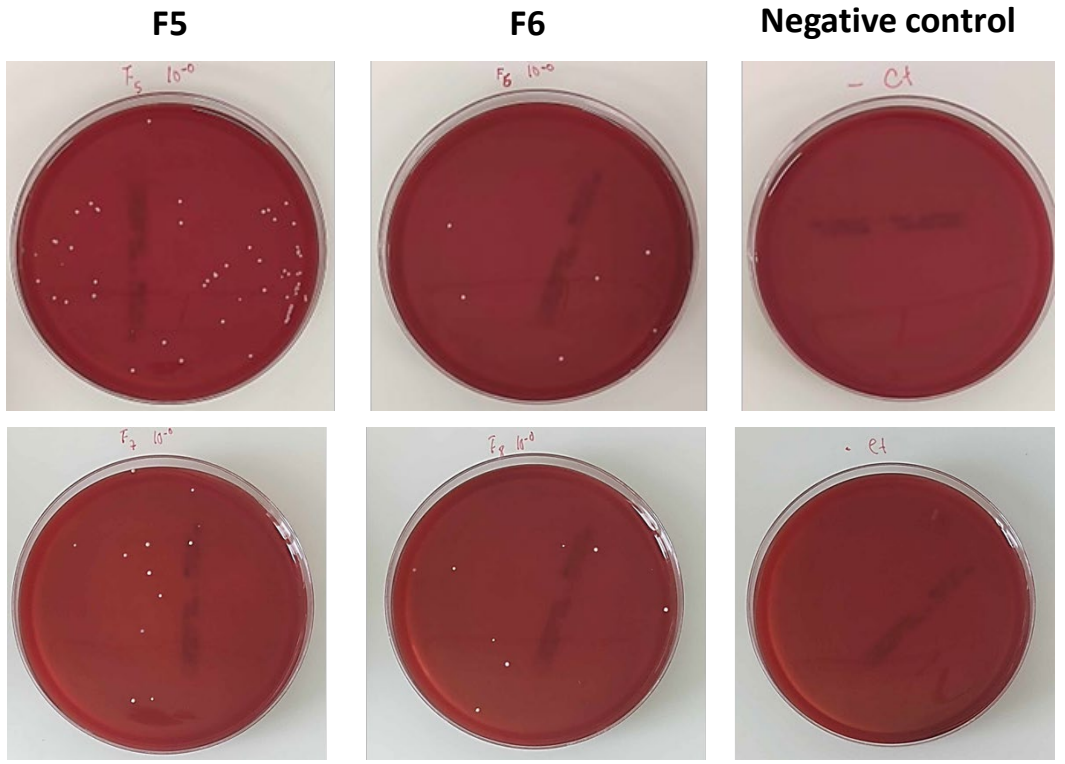
A person sleeps in bed under Baldachin, one night with ventilation on and one night with ventilation off. Bacteria emitted are collected and counted.





Results – Experiment 3





	Filter 5 (CFU/mL)	Filter 6 (CFU/mL)
Baldachin ventilation ON	585	50
Baldachin ventilation OFF	120	60

Baldachin ventilation ON: There is a decrease (~10 fold) in the number of bacterial colonies collected outside the area covered by the baldachin compared to those collected inside the area covered by the baldachin.

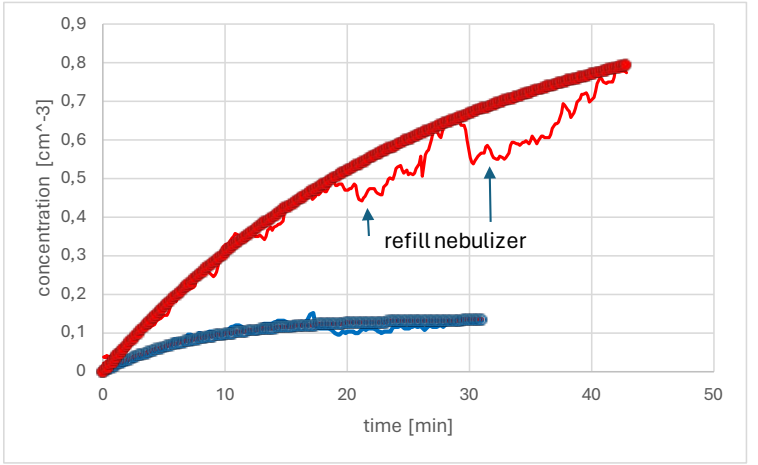
Baldachin ventilation OFF: There is a decrease (~2 fold) on the number of bacterial colonies outside the area covered by the baldachin in comparison with the ones collected inside the area covered by the baldachin.

Cleaning performance of salt particles

Experiments performed by Prof. Dr. Heinz Burtscher

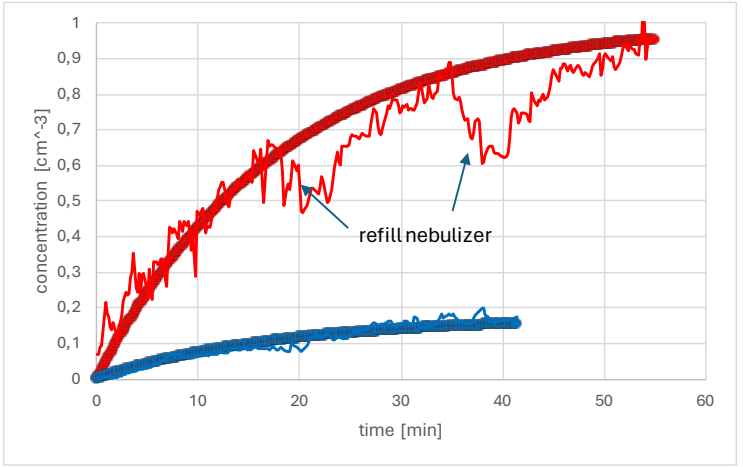
Salt solution

Nebulizer under Baldachin, at position of patient head, Sensor at neighbor bed



Concentration at neighbor-bed, normalized to final value of exponential fit, vent. off
Red: Ventilation off, blue ventilation on
(thin: measurement, fat: exp. fit)

Nebulizer at neighbor bed, measurement und Baldachin at position of patient head

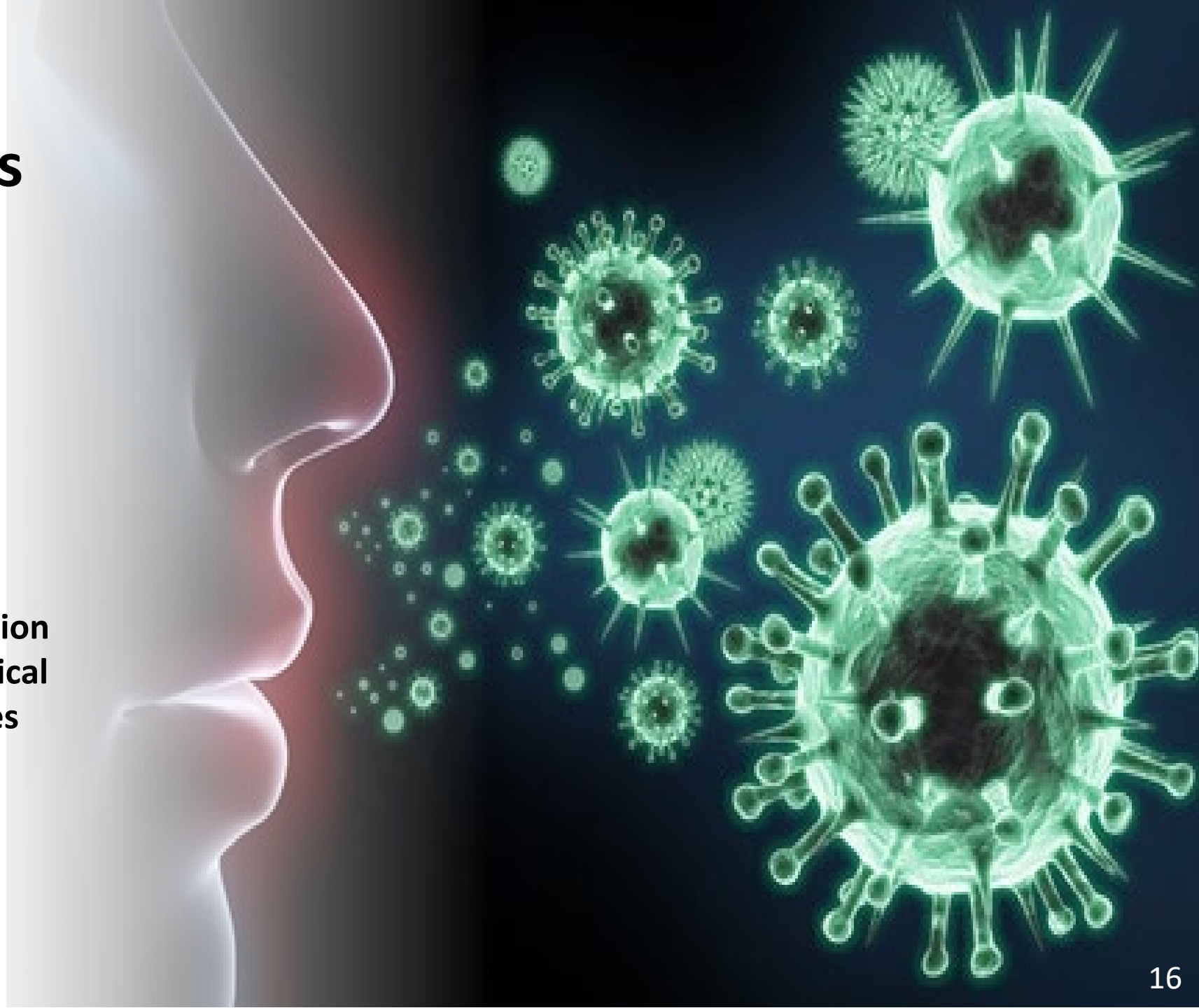


Concentration at position of patient head, normalized to final value of exponential fit, vent. Off)
Red: Ventilation off, blue ventilation on
(thin: measurement, fat: exp. fit)

Take home messages

- **Ceramic NanoCleanAir filters are efficient against small airborne bioaerosols.**

- **First results show that a combination of nanofiltration and laminar vertical flow is efficient and further studies are ongoing.**



Acknowledgements

SNA members

- Prof. Barbara Rothen-Rutishauser
- Prof. Alke Petri-Fink
- Dr. Amélie Bazzoni

NanoCleanAir members

- Dr. Andreas Mayer
- Prof. Dr. Heinz Burtscher
- Prof. Dr. Joachim Frey

All the NanoCleanAir team!