Novel control mechanisms for water borne pathogens

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Environment Network

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Great Ormond Street Hospital for Children NHS Trust

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Contents

Introduction – The need to control

- Emergence of antibiotic-resistant organisms is a major public health concern, particularly in hospitals and other healthcare settings
- Antibiotic-resistant organisms are capable of causing life-threatening infections
- Difficult to manage because treatment options are limited
- New antibiotic discovery and development has slowed
- Increased fatality from once preventable diseases
- Looking at new options to decontaminate equipment to prevent disease

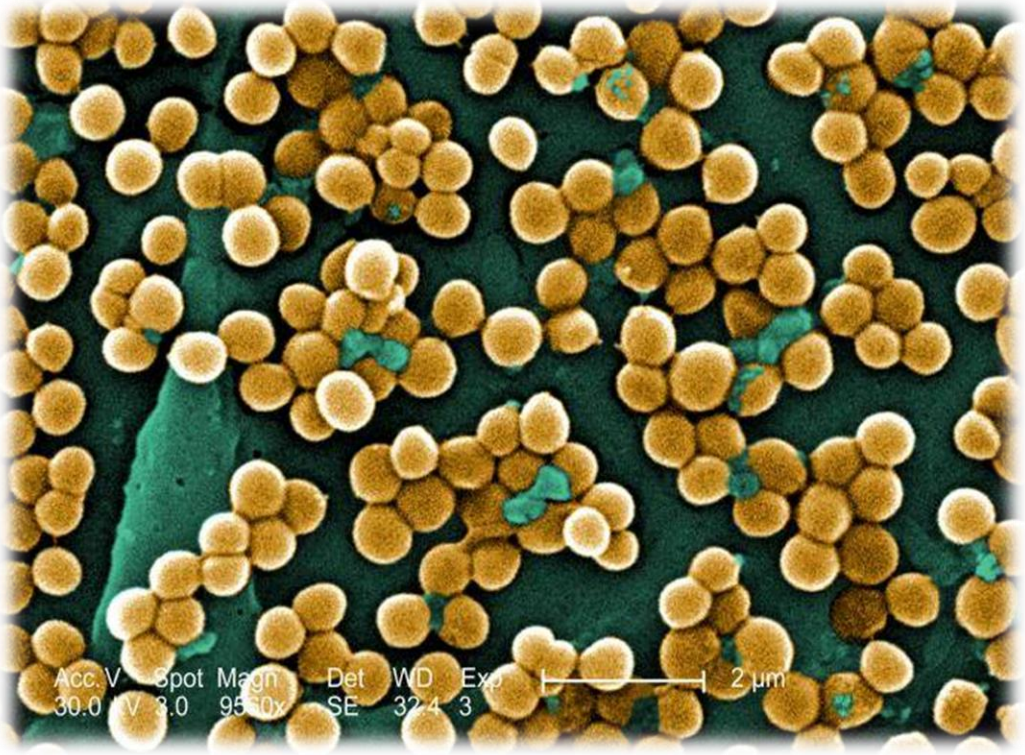
Introduction – The need to control

- There's a lot of evidence linking the hospital water supply to infections in high-risk patients.
- *Pseudomonas* can be transmitted by drinking, bathing, contact with wounds, splashing from water outlets, inhalation of aerosols, equipment rinsed in contaminated water, etc.
- It's usually present in biofilm that's formed in pipes, taps, shower heads, dead legs, etc.
- This biofilm can withstand temperatures of 85°C
- It's temperature tolerant, growing best at 37°C, but able to multiply at temperatures as low as 4°C and as high as 42°C.

Introduction – *P. aeruginosa*

- Gram negative
- Rod shaped
- Size: 0.5 to 0.8 µm x 1.5 to 3.0 µm
- Opportunistic pathogen and colonize and infect vulnerable patients
- VAP, endocarditis, gastrointestinal, urinary tract infections, septicaemia
- Tap water appears to be a significant route of transmission in hospitals, from colonization of plumbing fixtures.

Introduction – *S. aureus*



- Gram positive
- Cocci (spherical)
- Size: 1.5µm
- Highly resistant organisms
- Major contaminant of surgical equipment and surgical site infection

Water treatment using silver and copper ionisation

Authors: Vanessa Onuogu, Radhika Patel, Yuan Yihang, Wang Sunyin, Diego Jimenez, Ma Zhibin

Supervisors: Dr Lena Ciric, Dr Mel Canales

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The Orca

- Incoming water first flows through the turbine of a flow sensor.
- This sends a signal to the Orca control unit, which then passes a low DC current between two copper and two silver electrodes located in an electrode chamber (the ‘Pod').
- The current causes the release of electrically charged copper and silver ions from the electrodes. The system is designed so that ion release is proportional to the flow rate, maintaining a constant concentration.

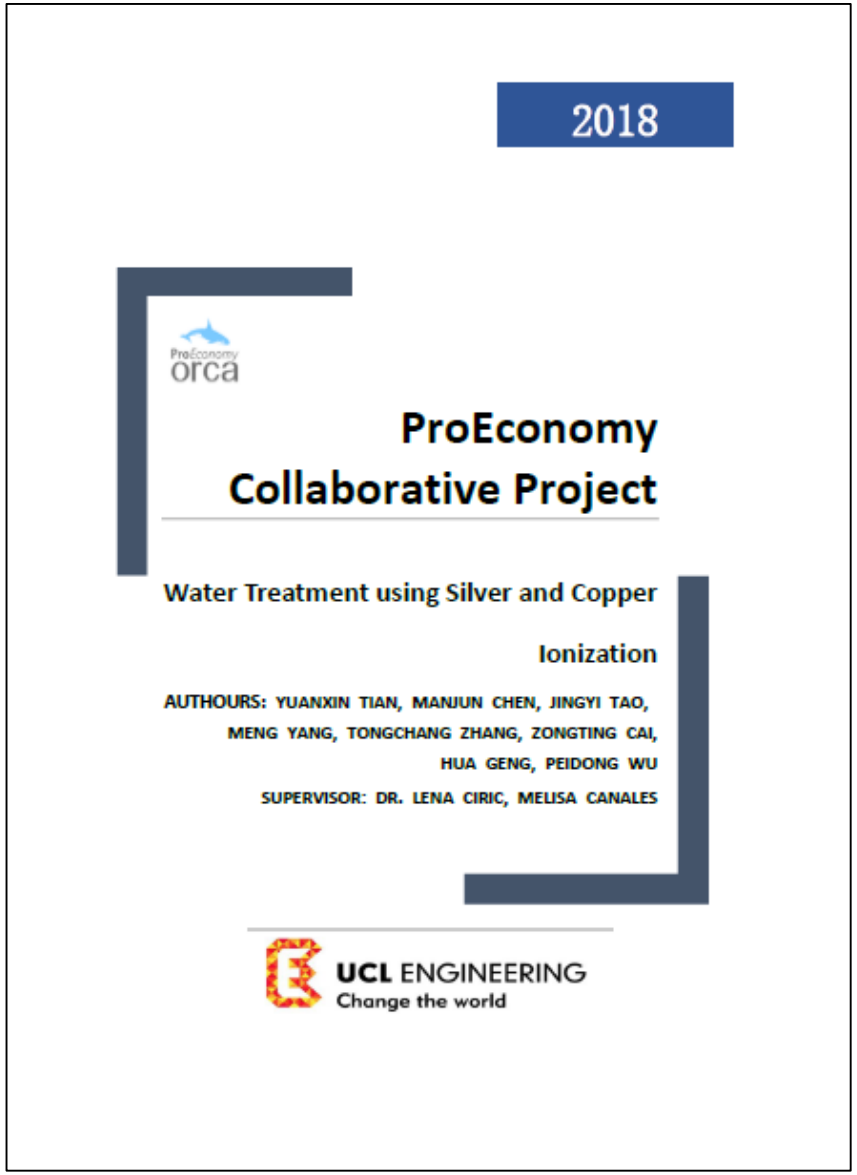
The Orca

- Positively charged ions meet bacteria, it's thought that copper reacts with negatively charged molecules on their surface, weakening the cell wall and allowing silver ions to enter. The silver (and copper) ions then react with biomolecules such as DNA and enzymes, killing the bacterium.

- The copper and silver gradually cause the breakdown of any biofilm present in the system. If this didn't happen *Legionella* and *Pseudomonas* would quickly return

Collaborative project - The Orca

- Collaboration between ProEconomy and UCL HIRG
- Funding of MSc projects
- Effect of silver and copper water treatment
- Inactivation of *P. aeruginosa* and biofilms



Collaborative project - The Orca

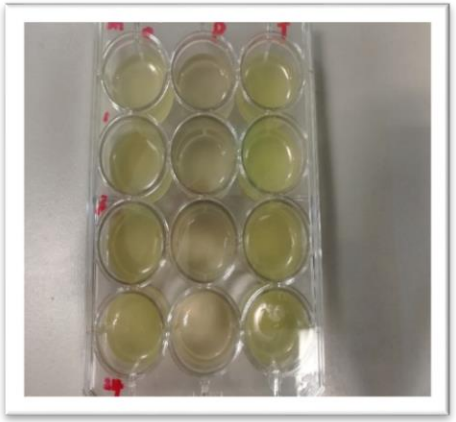
- 1. Inactivation of *P.A.* by Orca system (Leo)
- 2. Prevention of biofilm formation (Radhika)
- 3. Disruption of mature biofilm (Wang)
- 4. Staining on ceramic surface (Peggy)
- 5. Tarnishing of medical equipment (Vanessa)
- 6. Carbon footprint and energy savings (Diego)

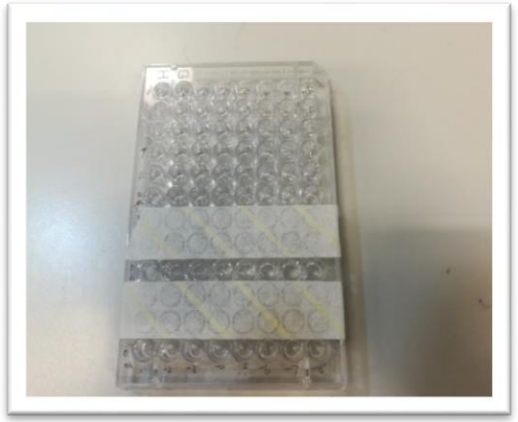
Inactivation of *P.A.* by Orca system (Leo)

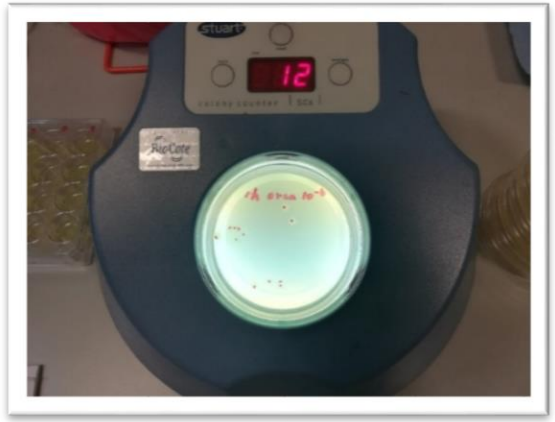
- Determine how effective the Orca system is at inactivating *P. aeruginosa*

- Incubating specific concentrations of *P. aeruginosa* with treated and untreated water over 24 hours.

Inactivation of *P.A.* by Orca system (Leo)







Orca water sampling time(h)	No. of colonies	Dilution factor	(cfu/mL)	Percentage of inactivation (%)
0	102	10^{-5}	1.02×10^{8}	0.00
1	86	10^{-5}	0.86×10^{8}	15.69
3	55	10^{-5}	0.55×10^{8}	46.08
24	18	10^{-5}	0.18×10^{8}	82.35

Table 1. *Inactivation percentage of P.A. with 0.6/0.06 mg/L Cu/Ag concentration*

Inactivation of *P.A.* by Orca system (Leo)

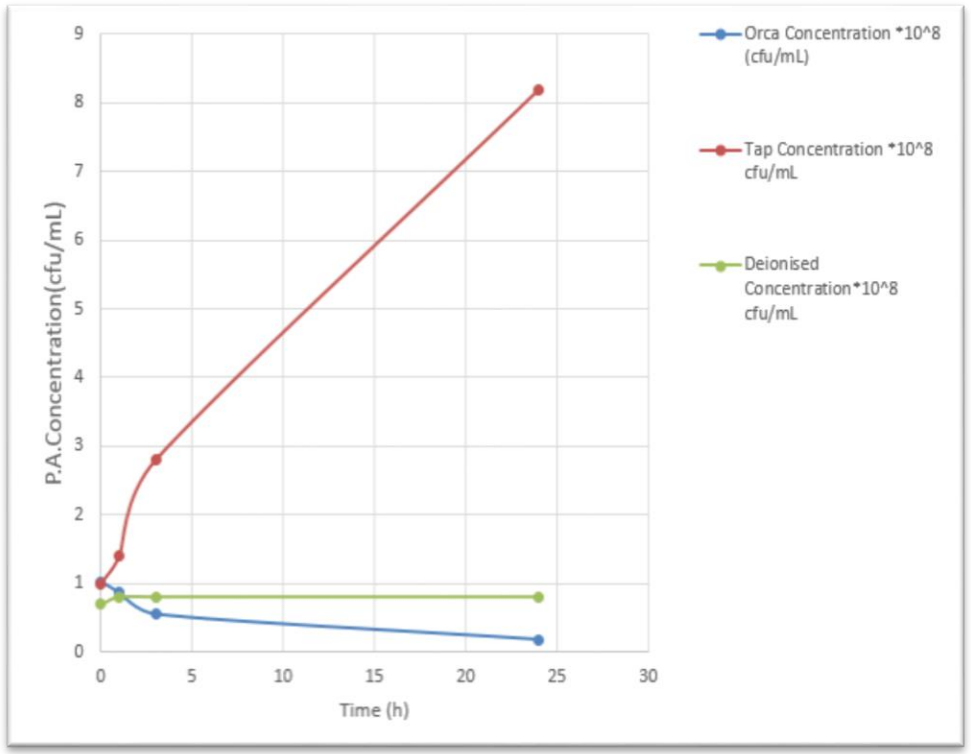


Figure 1. *The P.A. concentration versus time (0.6/0.06 mg/L Cu/Ag)*

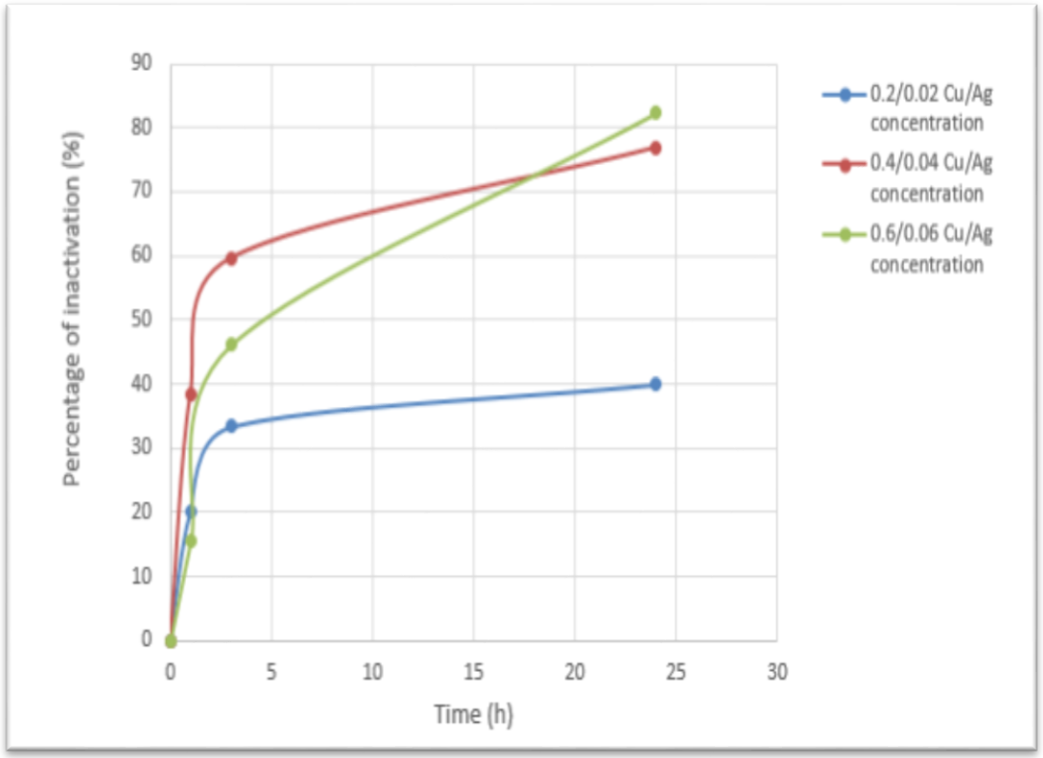
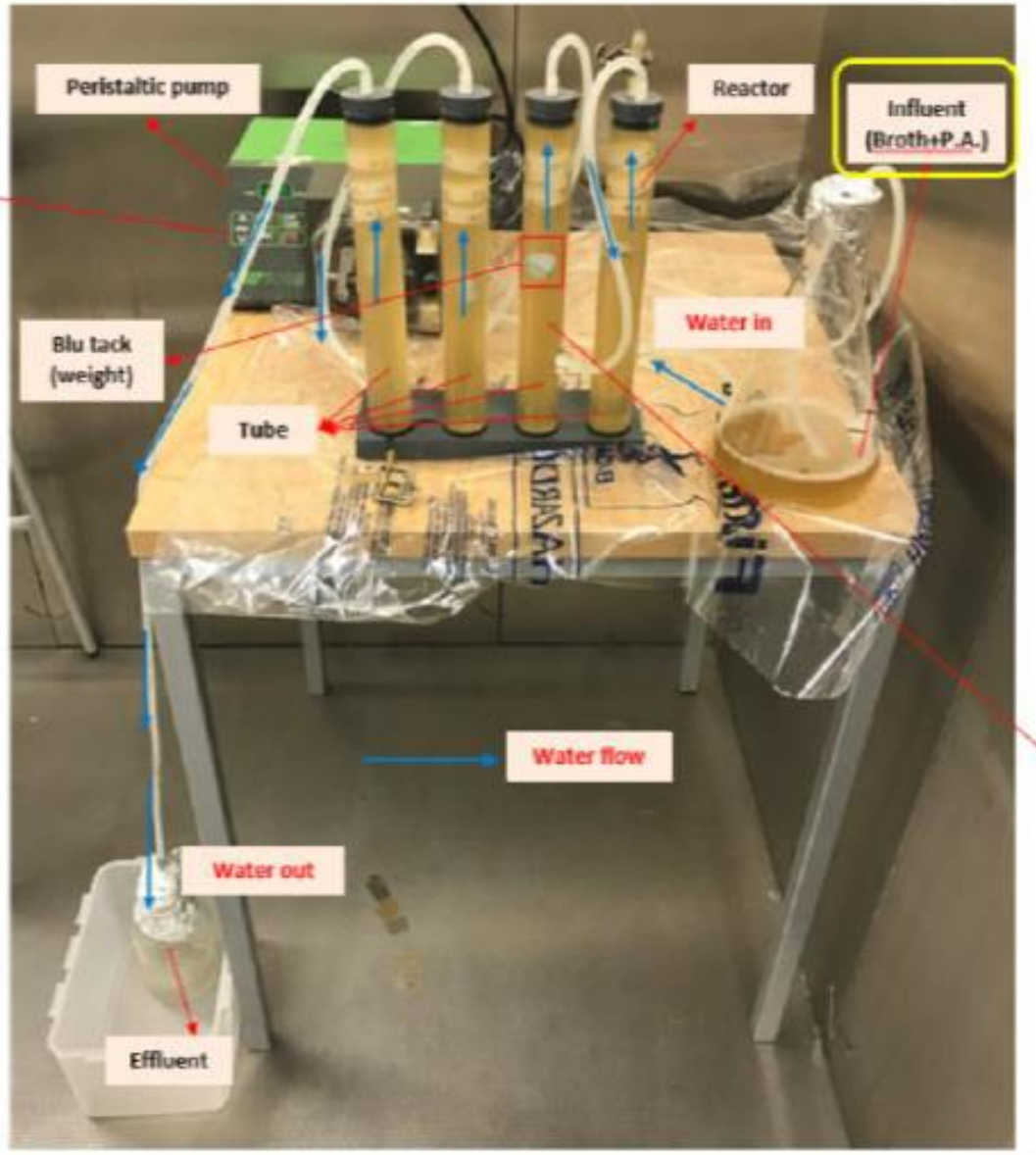
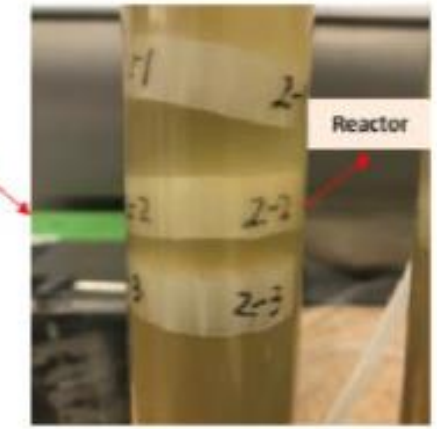


Figure 2. *The percentage of inactivation versus time with different Cu/Ag concentration*

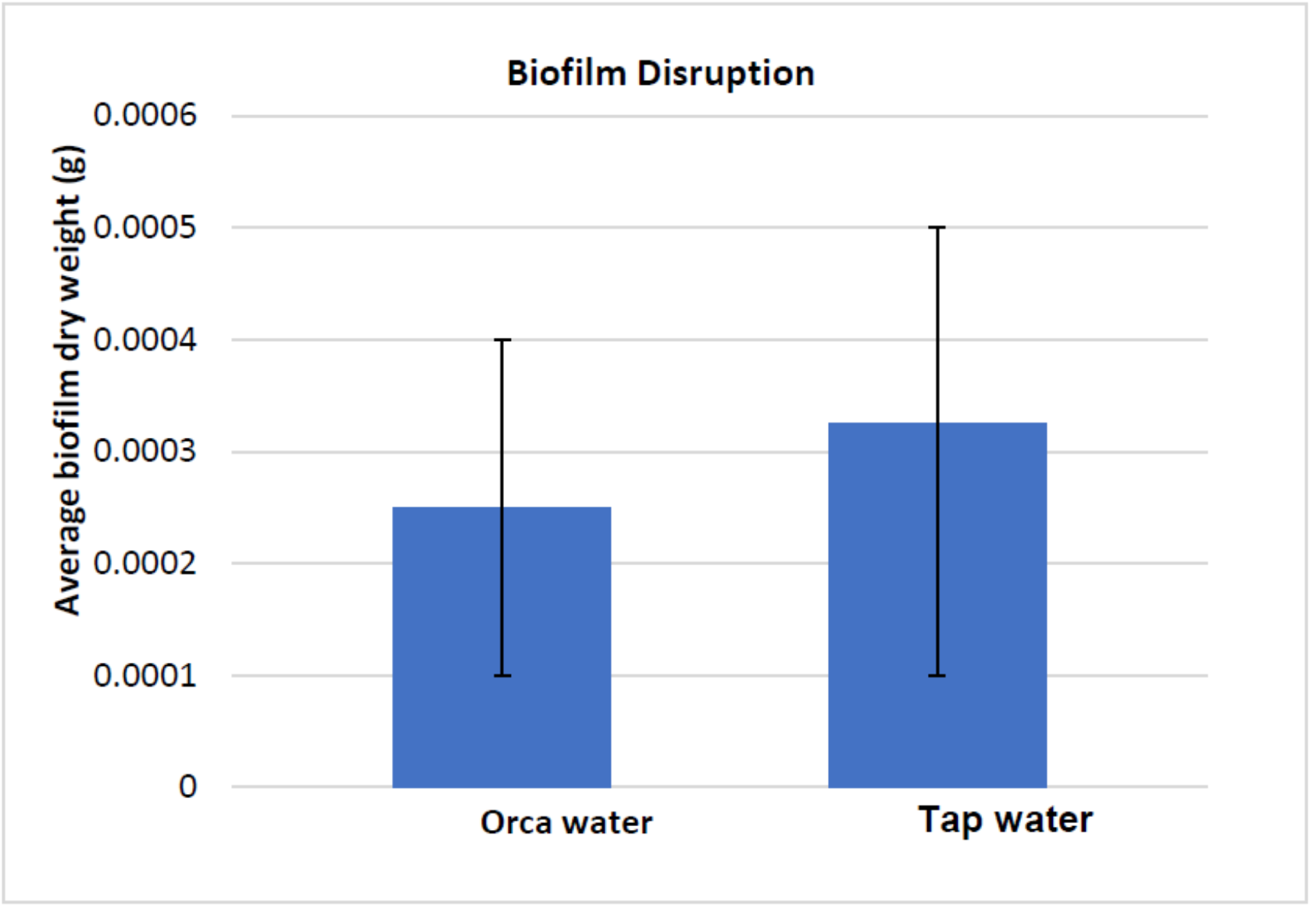
Prevention of biofilm formation (Radhika)





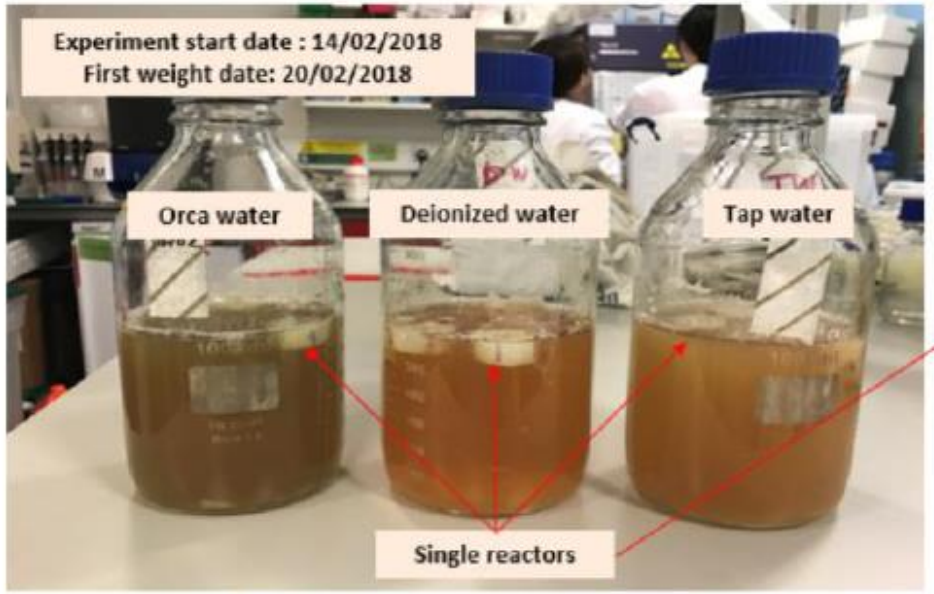
Flowing water system

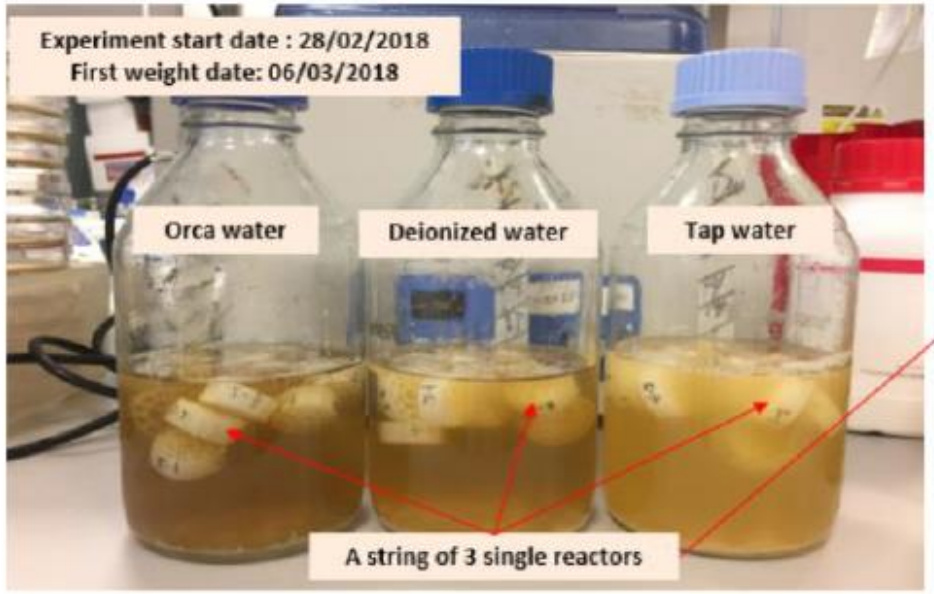
Prevention of biofilm formation (Radhika)



Prevention of biofilm formation (Radhika)

Static water system





Prevention of biofilm formation (Radhika)

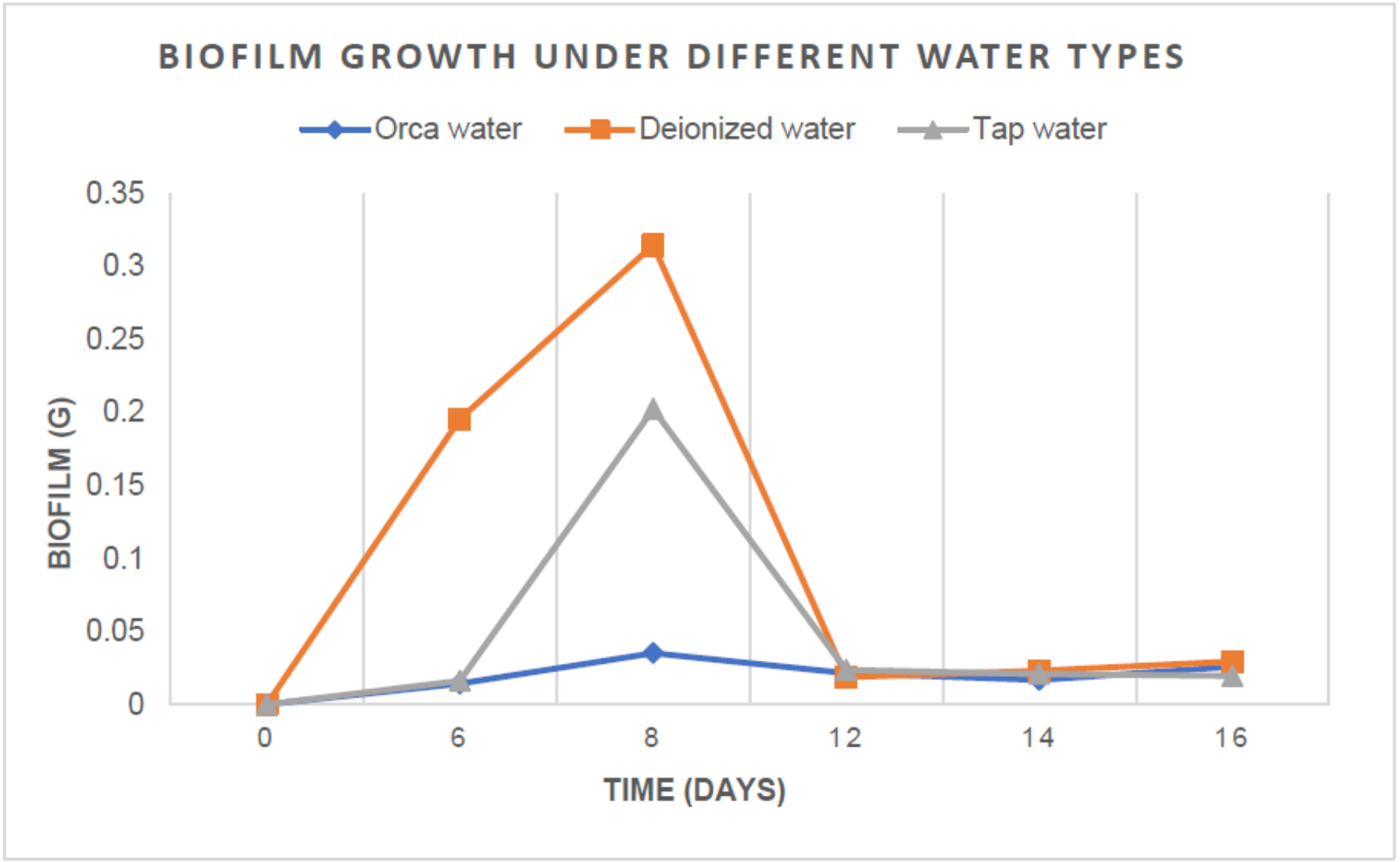
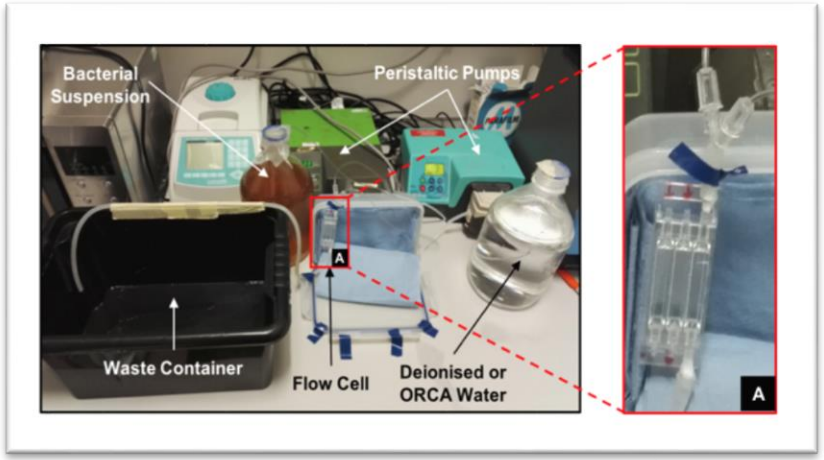
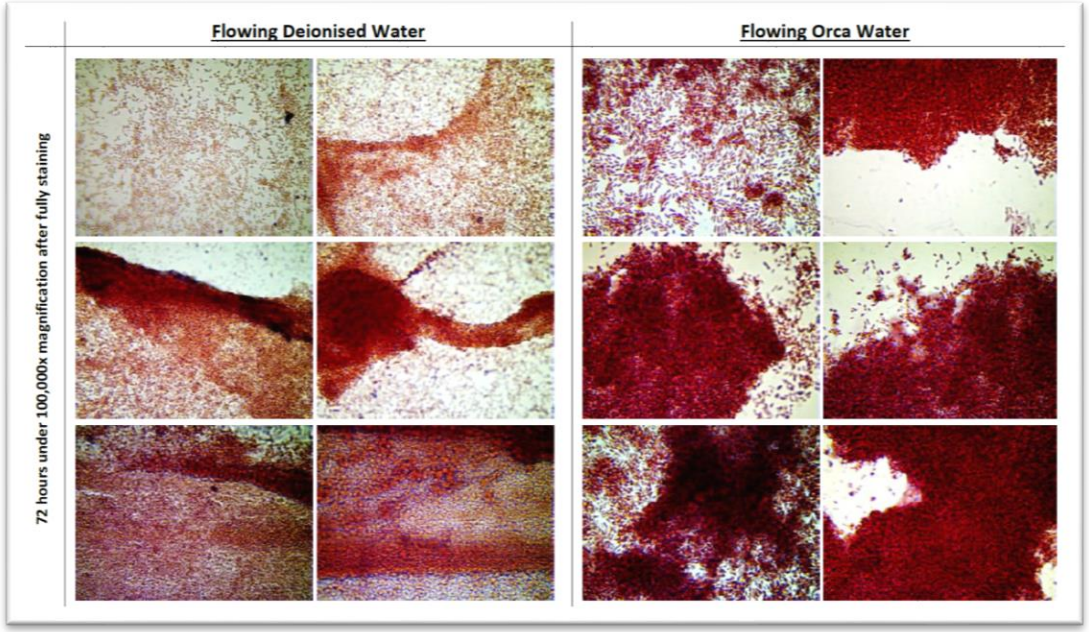


Figure 17.Biofilm growth rate using 3 different water types (stagnant water experiment, single reactors)

Prevention of biofilm formation



- Flow Cell
- Flow Rate = 1ml/min
- Duration = 72 hours
- Control = Deionised Water



- Gram-Staining indicated presence of *P.A.*
- Biofilm formation observed using both water types
- Ionised water exhibited greater biofilm formation
- Differences due to ion-content

Conclusions

- Increased concentrations of Ag+ and Cu+ ions increases efficiency against *P. aeruginosa*
- Biofilm growth is lower in deionised water than in ionised water
- Presence of ions in the water can cause staining of ceramic surfaces
- Orca does not cause tarnishing of medical equipment
- Reducing water temperature can cut carbon emissions by 33% by using the Orca system instead of heating water
- Softer water increases the efficiency of the Orca system

Novel water filtration systems

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2nd July 2018

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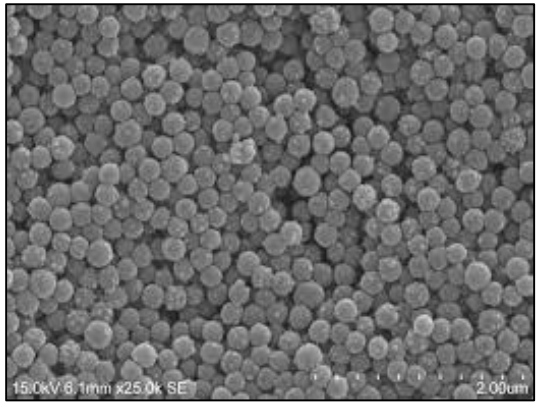
Great Ormond Street Hospital for Children NHS Trust

Prevention rather than cure!

- Current filtration technology only traps particles, however we have developed a filter that kills bacteria as they pass through it
- Analysing the antimicrobial effect of custom designed nanoparticle composites embedded within polymer fibres
- Scaled down water and air ventilation systems
- Introduces a novel approach to use antimicrobial components to improve current filtration systems

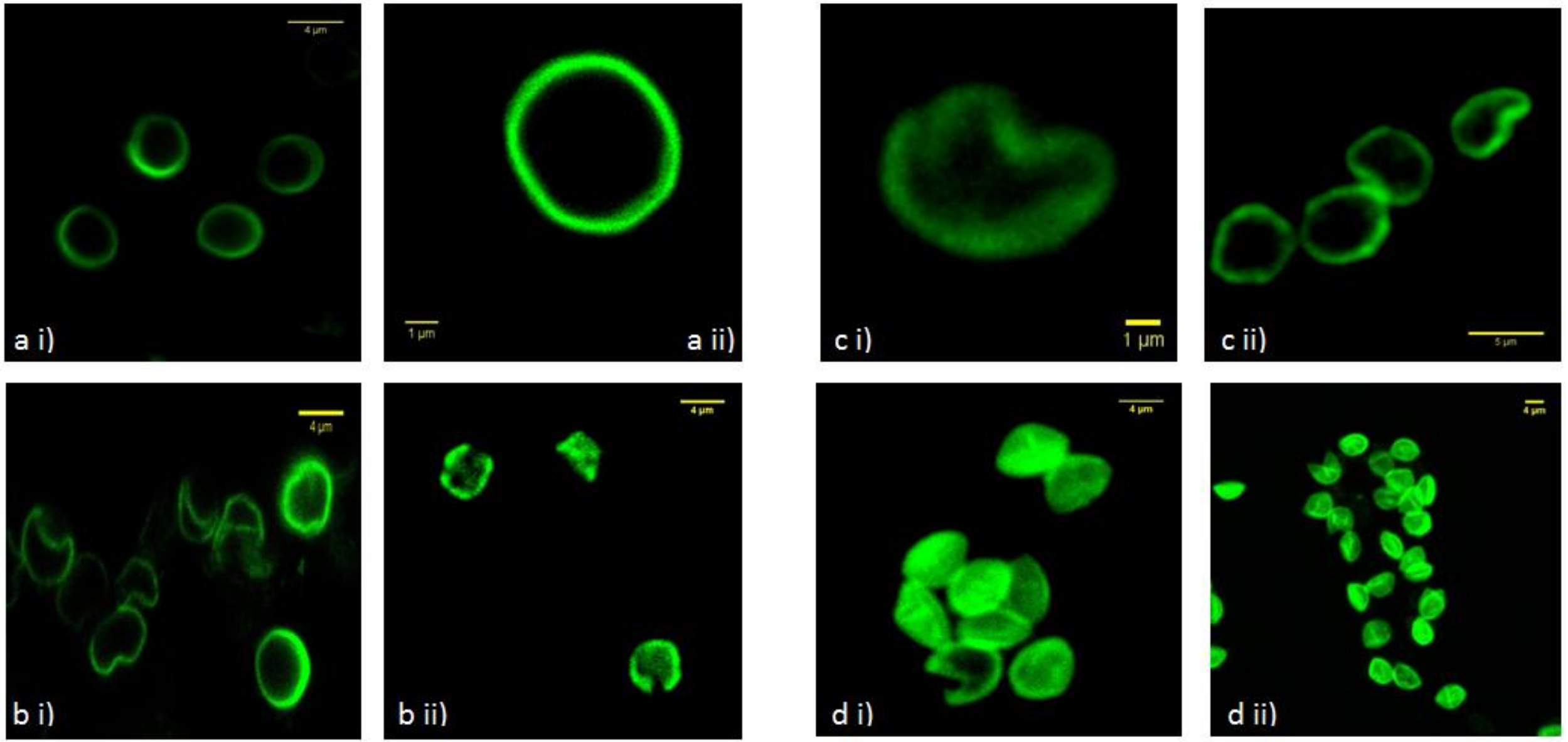
Methods – nanoparticles



- Nanoparticles (NPs) are widely used in healthcare industries
- Unique physical properties (e.g. a high surface to volume ratio) make them extremely useful for many biological applications
- Metallic NPs are widely accepted as having antimicrobial properties
  - Silver
- Reduce the cost and use of multiple disinfectants and procedures
- Collaborators at UoH selected and prepared our NP combinations

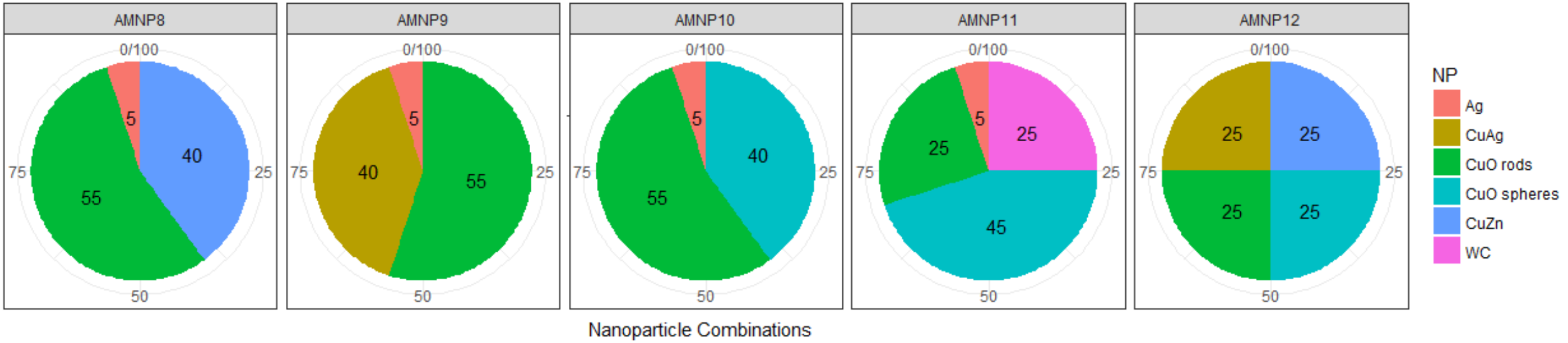
Methods - Nanoparticles

- Using a combination of metallic NPs that are broad spectrum could be an effective solution for devices used in healthcare.
- NPs can form pores on the surface of the membrane = causes free radical formation which can also destroy the cell membrane
- Ions from the NPs can interfere with enzyme production and generate reactive oxygen species (ROS).
- DNA transcription has also been shown to be affected

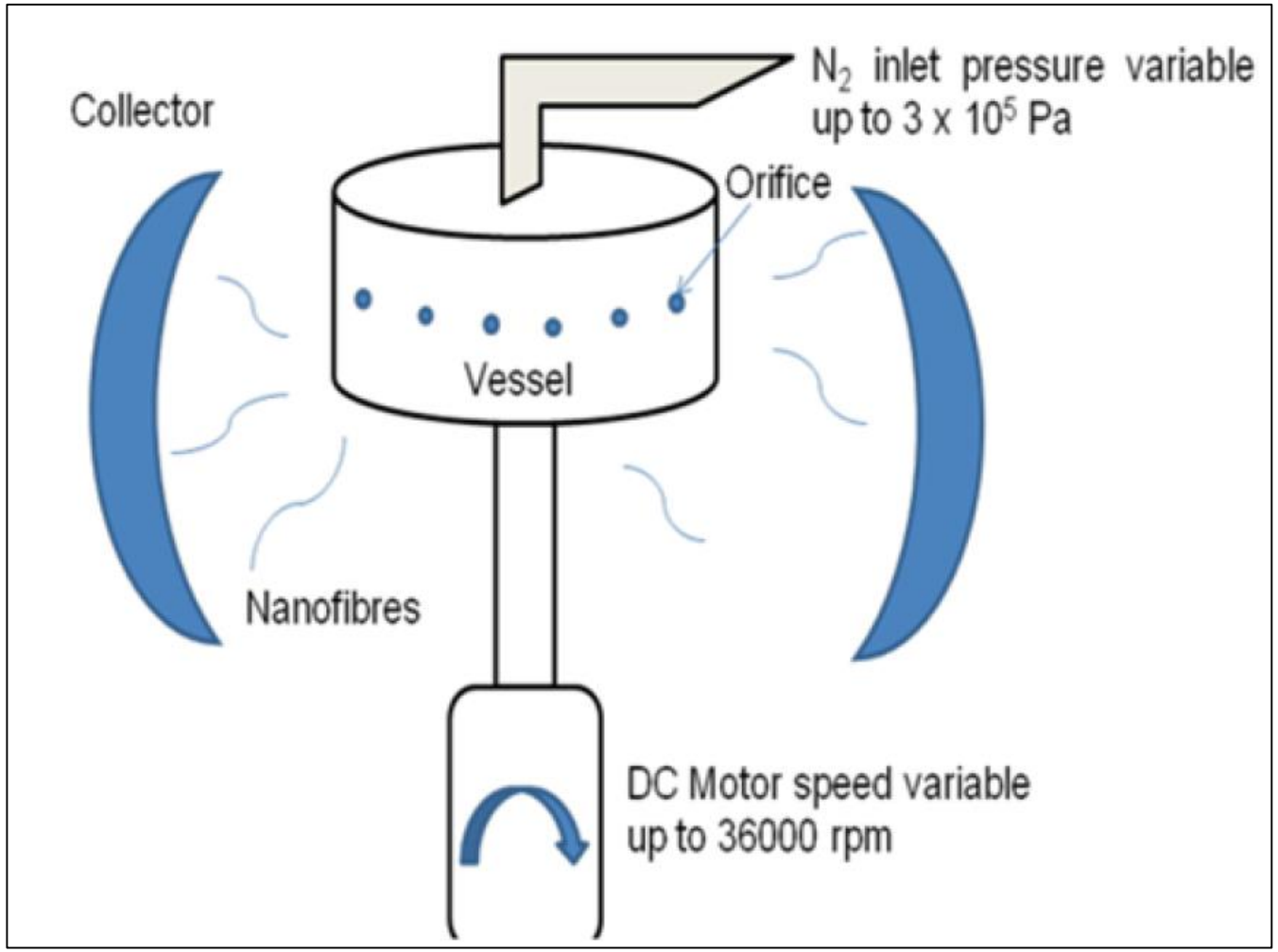


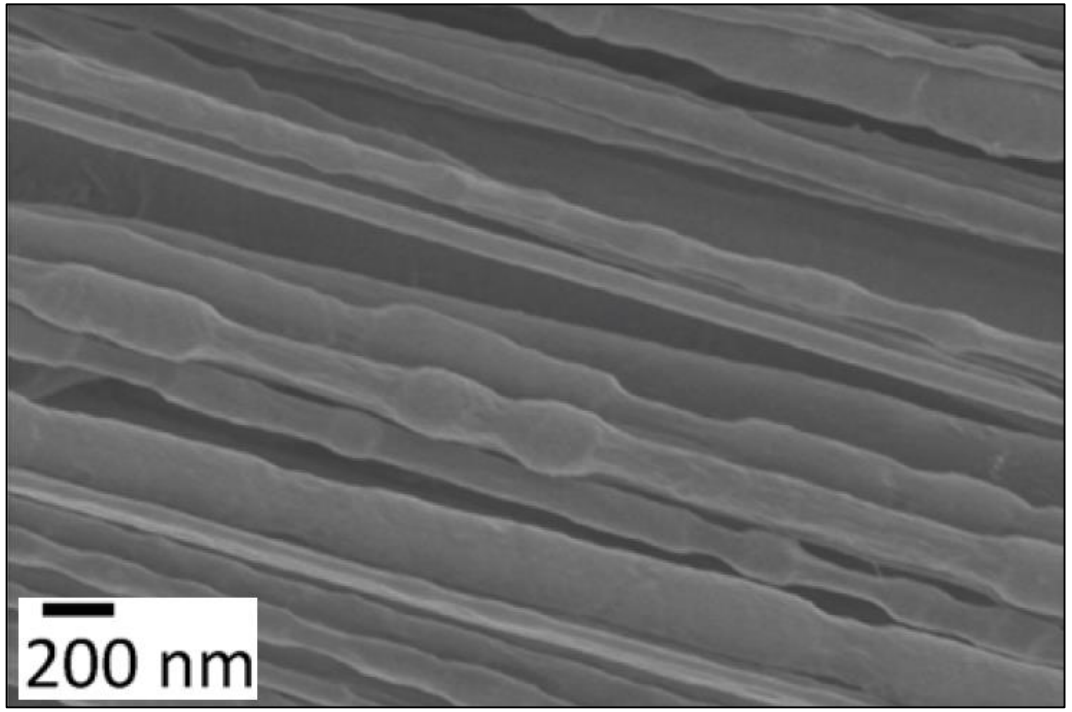
Bankier, C., Johnson, H et al., (2018) *Applied and Environmental Microbiology* (under review)

Nanoparticle choice

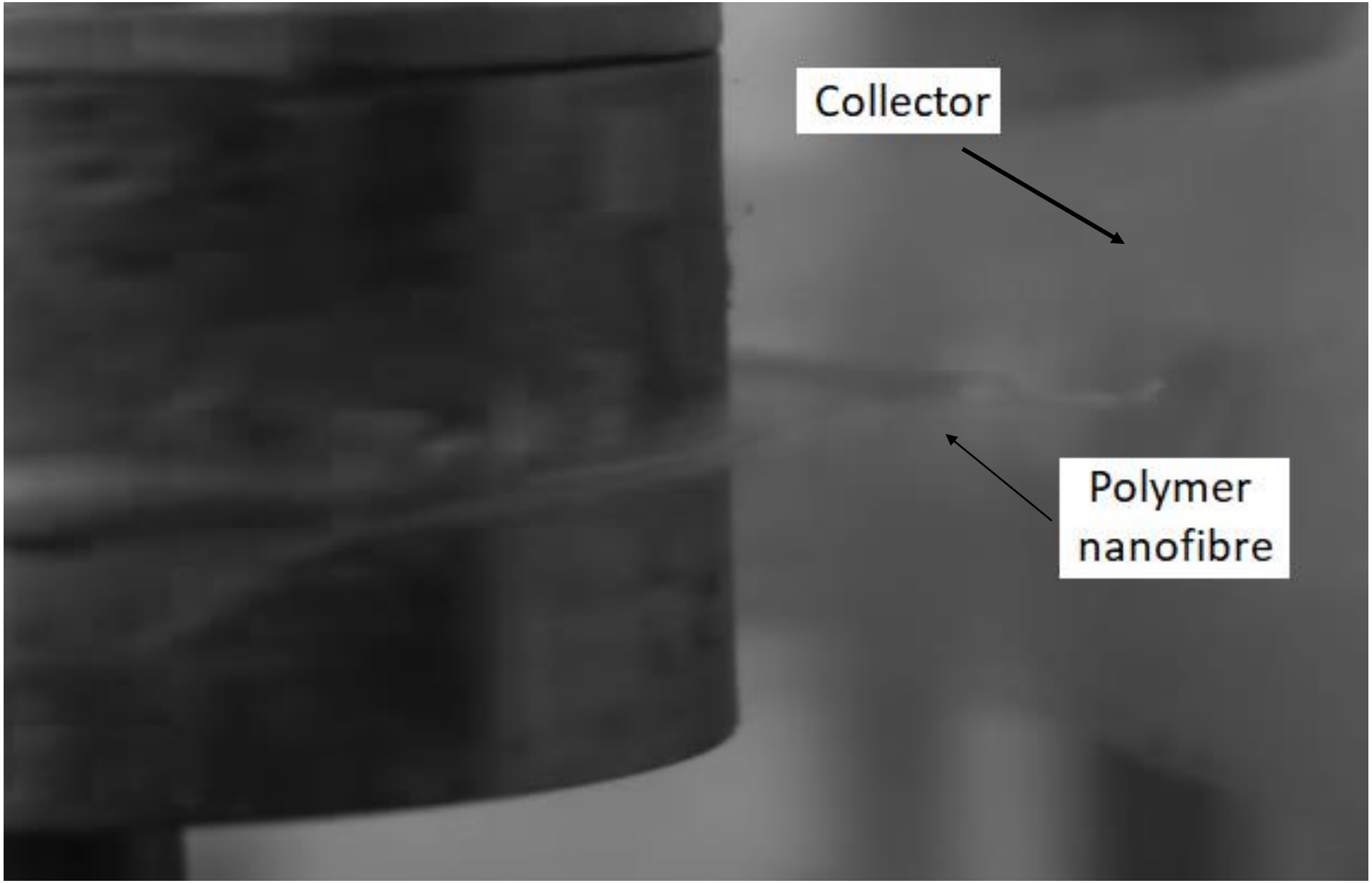


Pressurised gyration – UCL Mech Eng

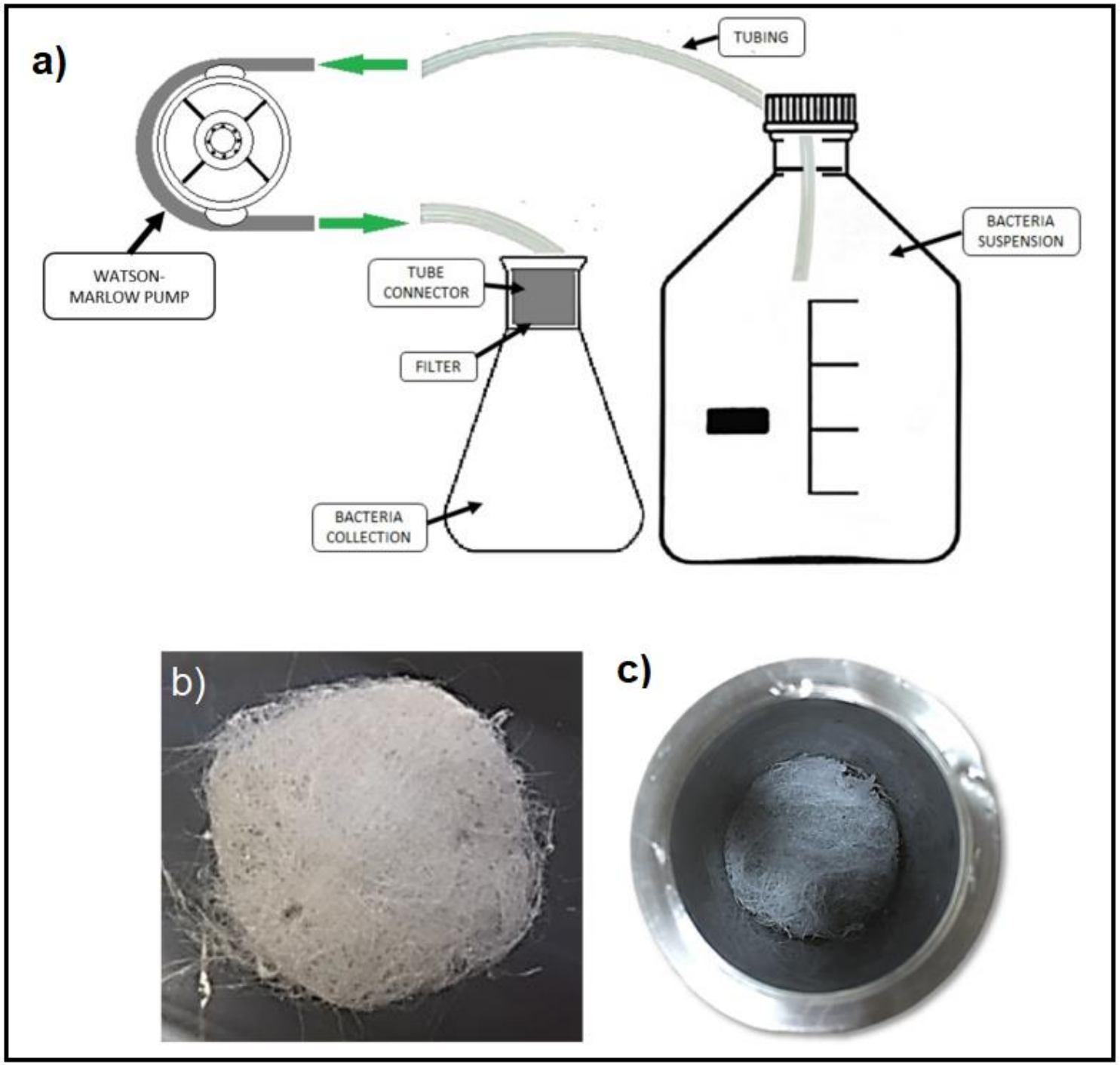




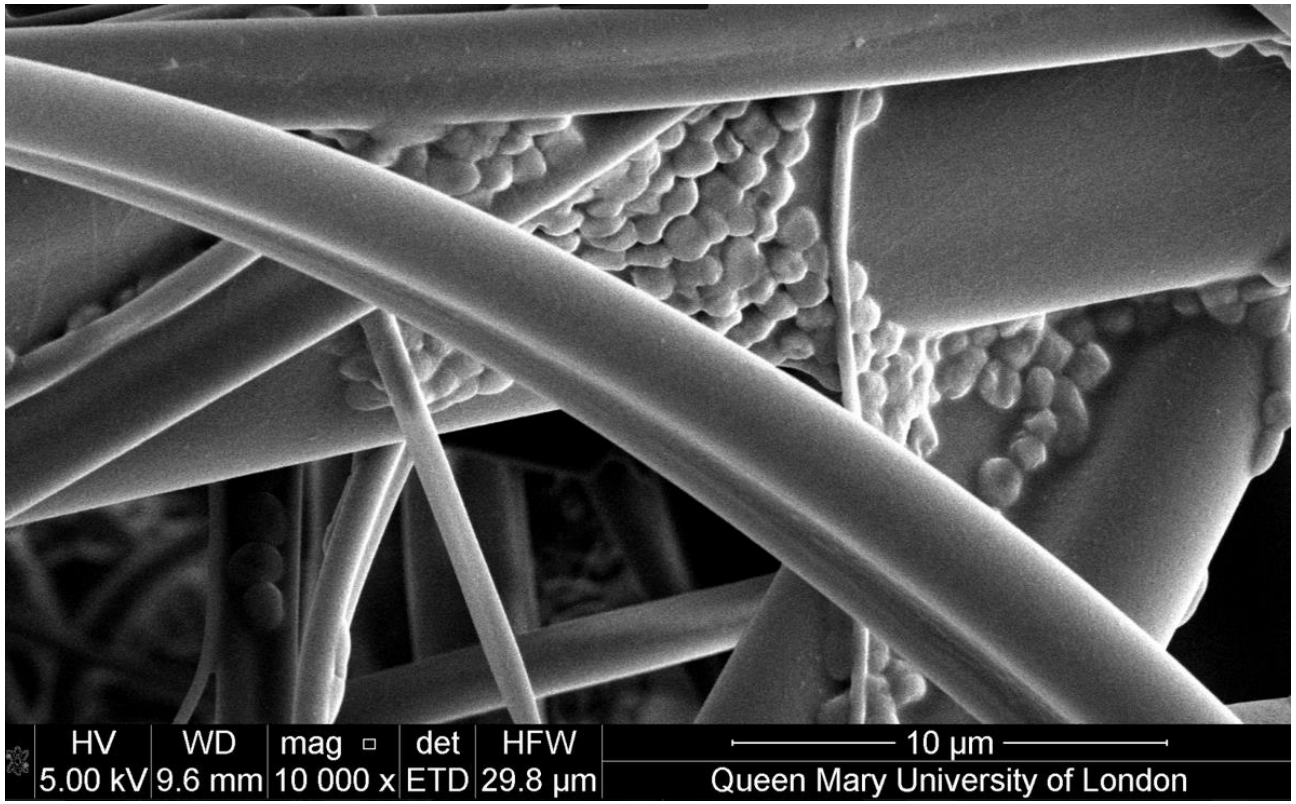
Mahalingam, S et al., (2013) Macromol Rapid Commun.

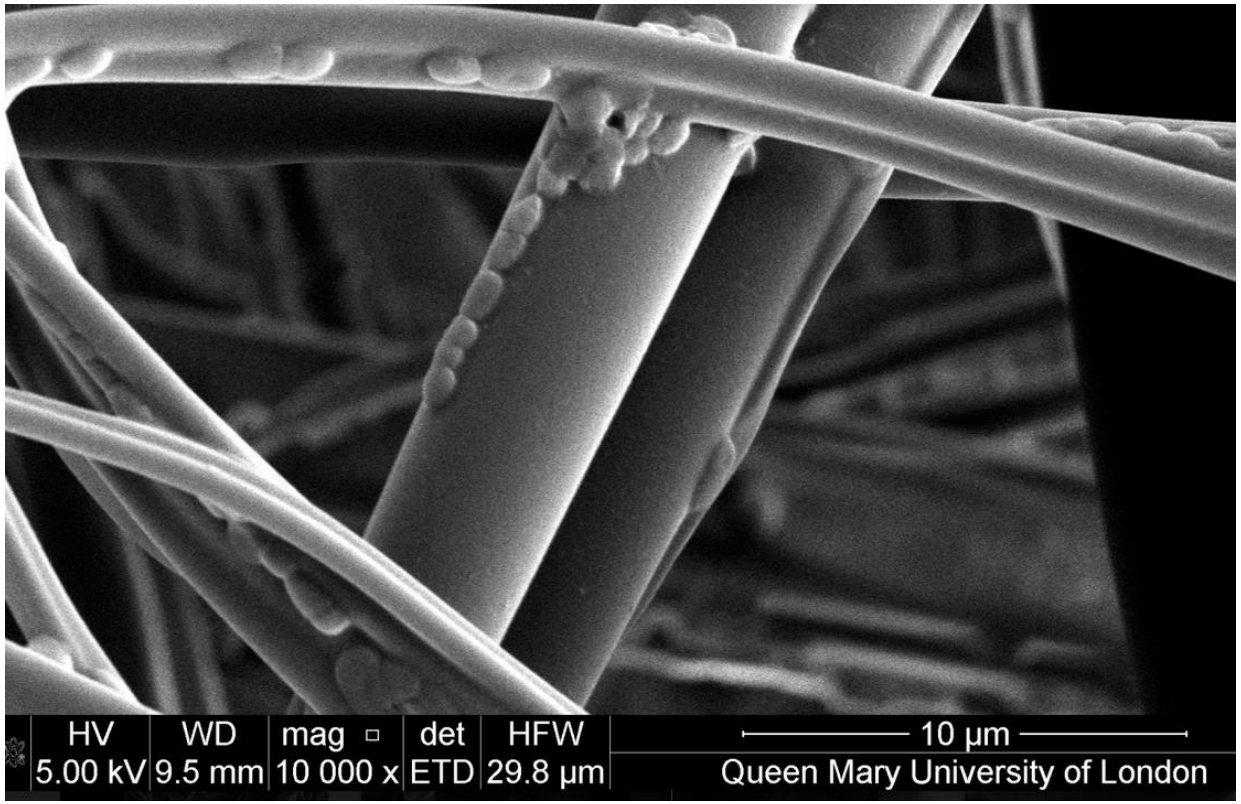

Collector
Polymer
nanofibre

,


a)
TUBING
WATSON-
MARLOW PUMP
TUBE
CONNECTOR
FILTER
BACTERIA
COLLECTION
BACTERIA
SUSPENSION
b)
c)

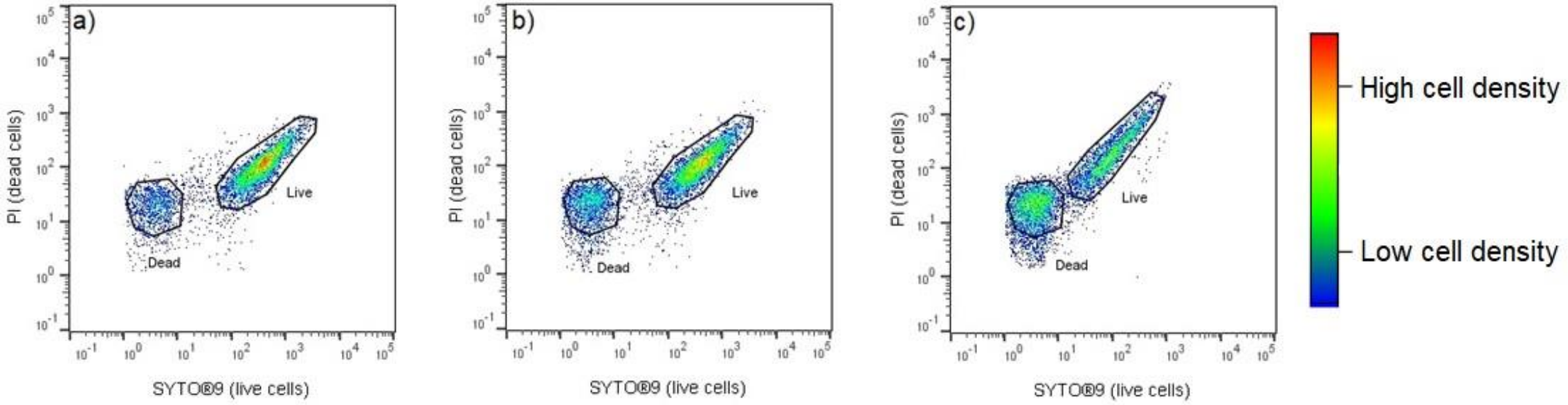
Methods – SEM



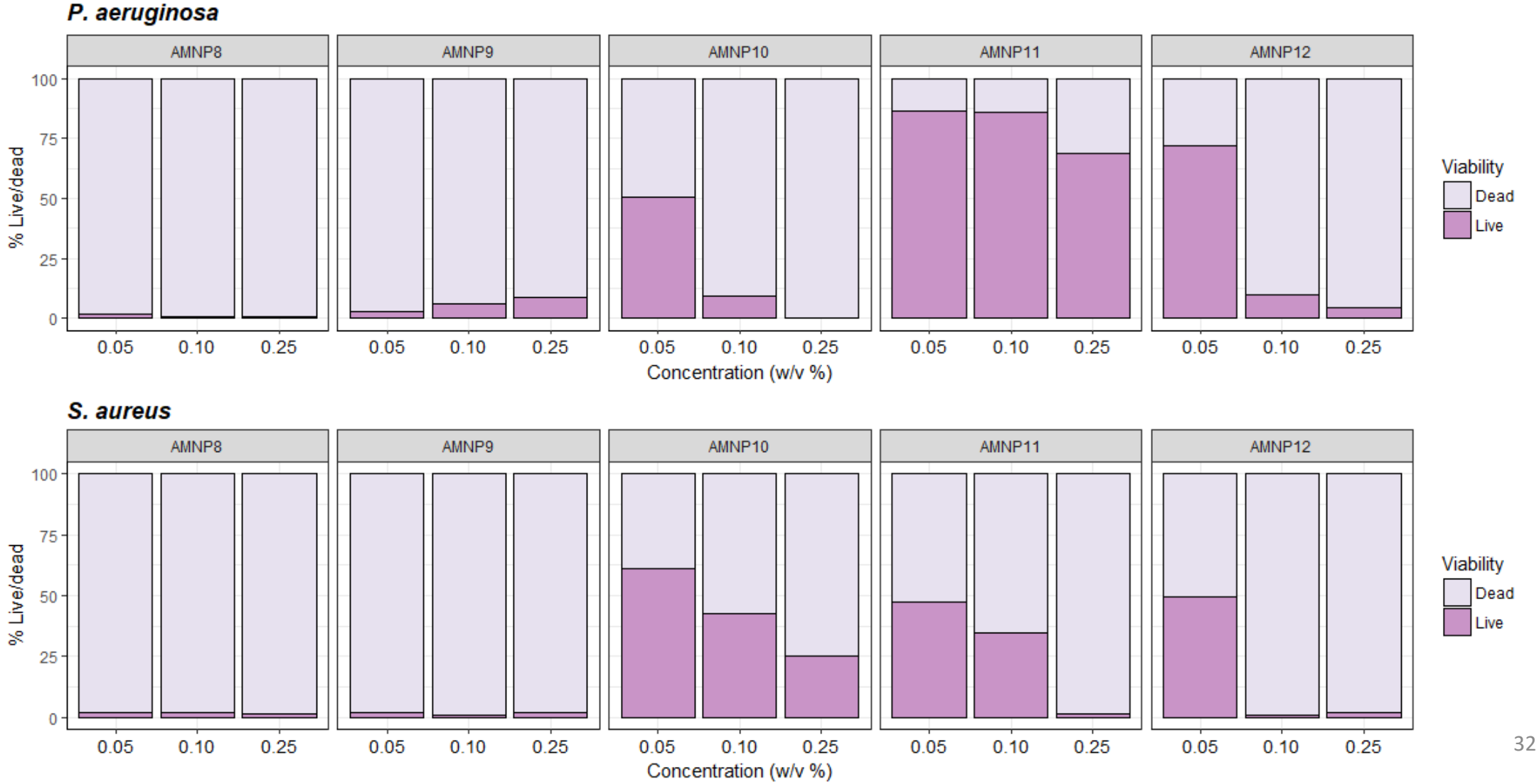


Matharu, R (2018) UCL

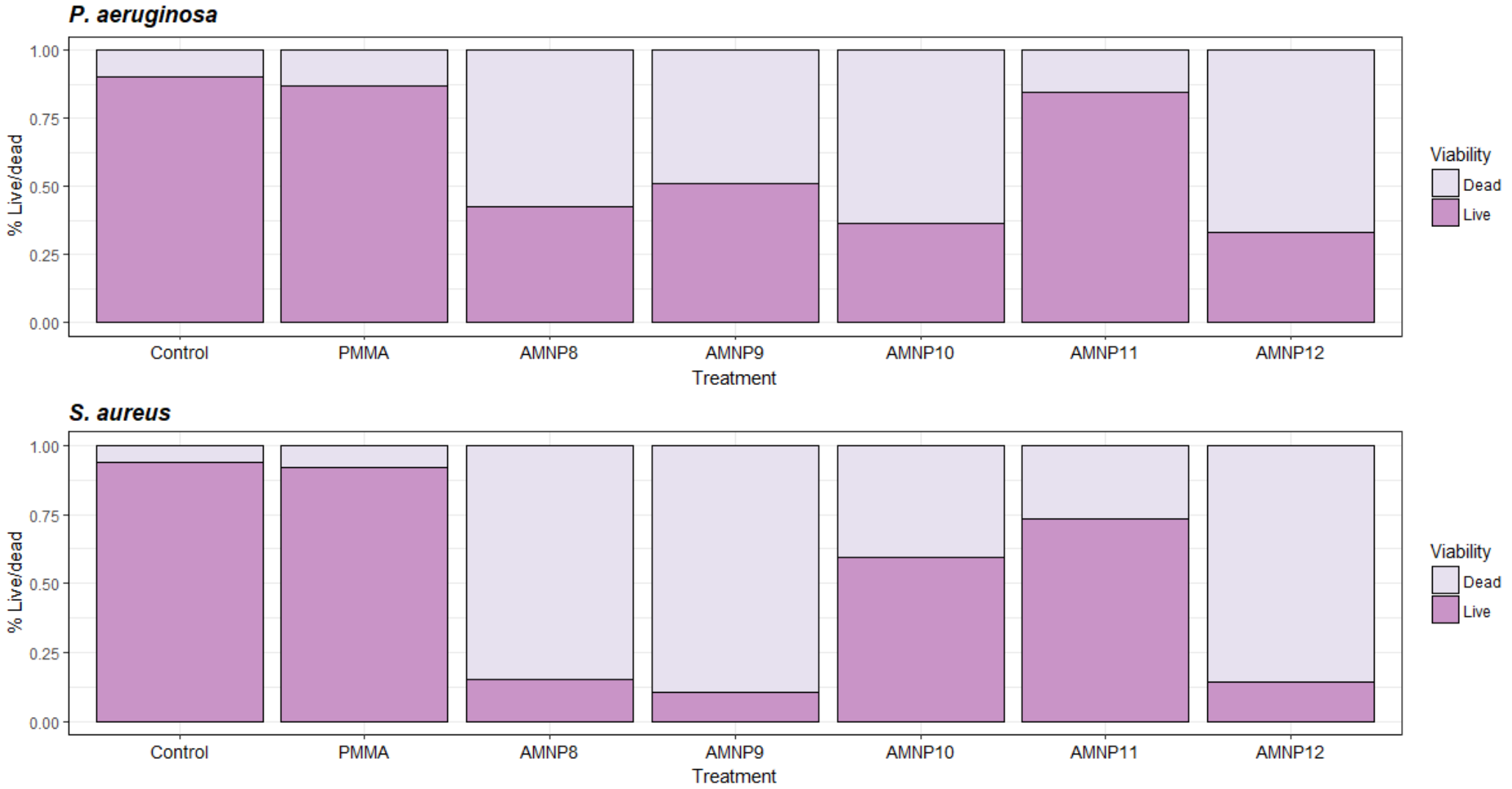
Methods – flow cytometry



Results – NPs and bacteria in suspension



Results – NP filters



Results – Filter validation over time

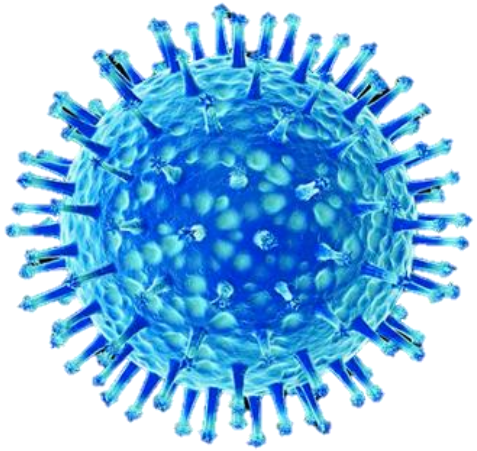
Conclusion

- Potential for several combinations of known antimicrobial metallic nanoparticles to be integrated into medical devices such as filters

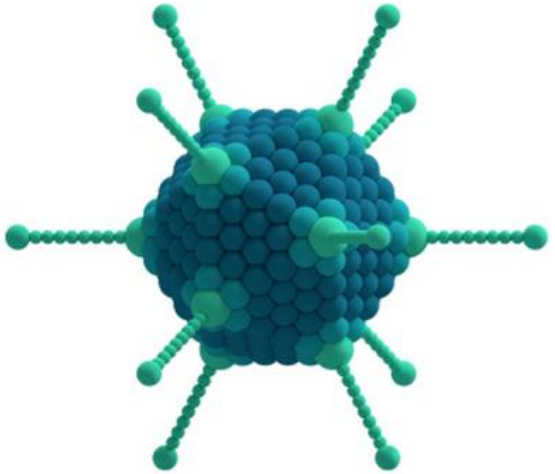
- Capture particulate matter but also destroy a broad spectrum of bacterial cells.

- the data presented here gives an overall assessment of the potential of these filters to be used in healthcare environment.

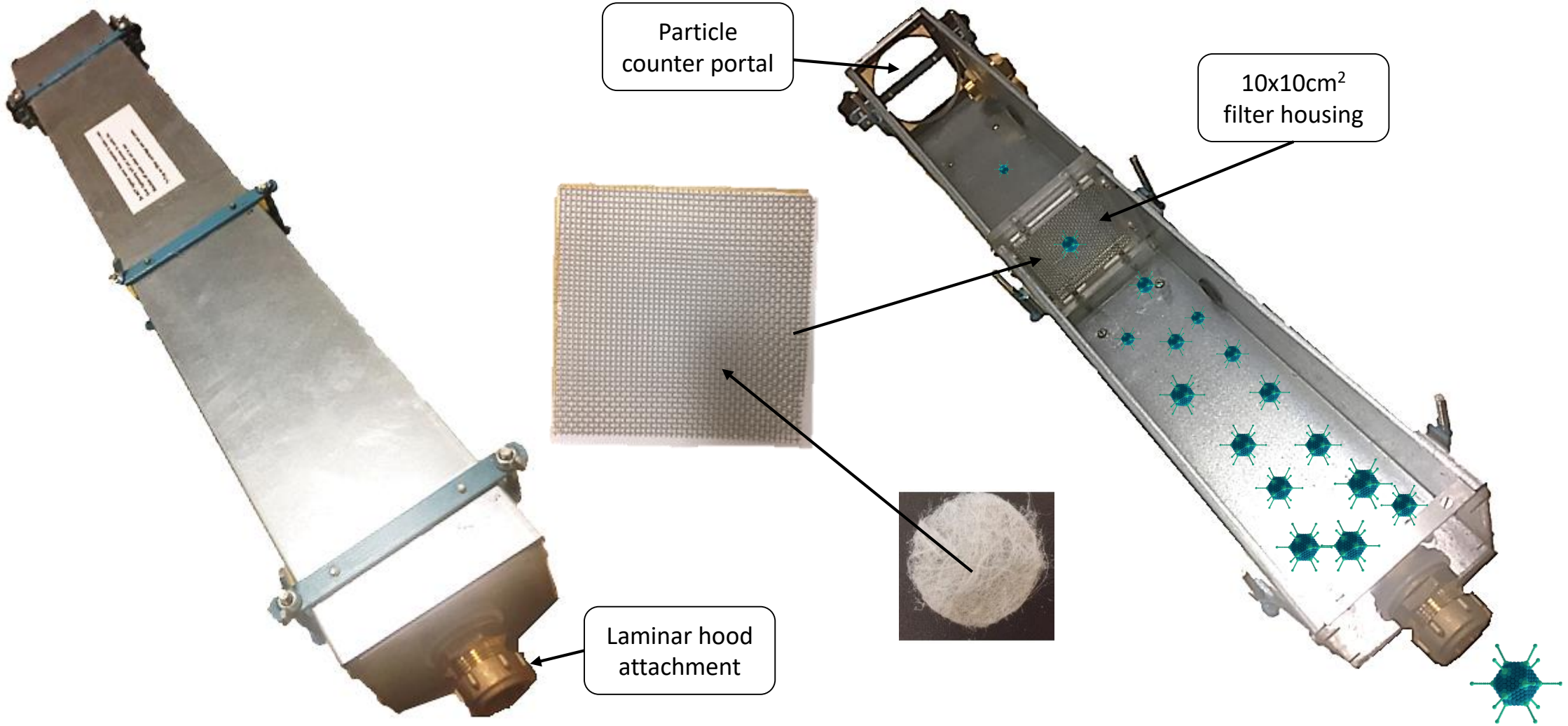
Future Work – air filtration



Influenza A
RNA virus
Enveloped with helical nucleocapsid
Size: 80 – 120nm



Adenovirus
DNA virus
Icosahedral capsids
Size: 80 – 120nm


Particle counter portal
10x10cm2 filter housing
Laminar hood attachment

Dr. Lena Ciric

Dr. Elaine Cloutman-Green

Prof. Mohan Edirisinghe

Dr. Guogang Ren

Dr. Yuen-Ki Cheong

Dr. Sunthar Mahalingam

EPSRC
Pioneering research and skills

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