Dielectrophoretic collection of airborne particles

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Background

The COVID-19 pandemic is a strong reminder of the socio-economic burden that bioaerosols can carry. While systems to detect and monitor airborne particles exist, current methods have limitations, hence alternative novel collection methods are required.

Aim

To investigate dielectrophoresis as a mechanism for collection of bioaerosols.

Current methods

Electrostatic collection:

- ✗ Use of corona discharge reduces microbial viability[1].
- ✗ Additional step to wash collected particles off collection medium[2].

Cyclone sampler:

- ✗ Reaerosolization from inertia movement of liquid[3,4]

Proposed alternative

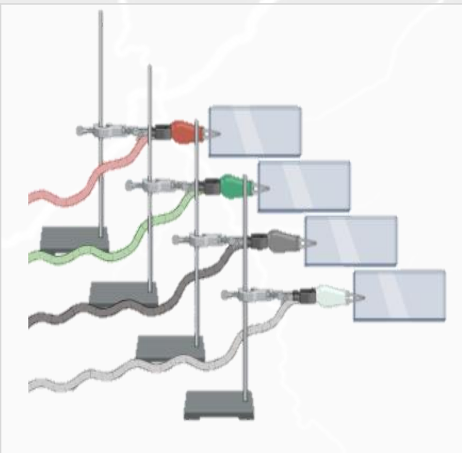
Dielectrophoresis collection:

- ✓ Use of single electric charge to attract particles within an electric field instead of corona discharge.
- ✓ Potential for collection directly into liquid.
- ✓ Collection does not require inertia movement.

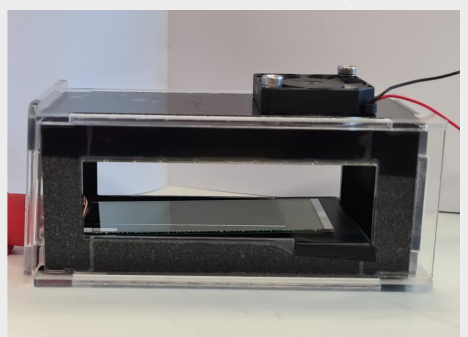
Methodology

Dielectrophoretic actuation was investigated using an 8m³ aerosol chamber, with 4 forced potentials: positive, negative, ground and float (no electric connection). Indium tin oxide (ITO) slides were connected and applied with voltages from ±2.5kV to ±10kV. Each collection was run in the presence of aerosolised fluorescent 1 µm (diameter) polystyrene latex microbeads for 15 minutes and an optical particle counter was used to monitor aerosol concentration. The average particle count was normalised against the chamber concentration.

A Dielectrophoretic actuation onto ITO slides which were clamped vertically to forced potential to avoid gravitational attraction.



B Dielectrophorectic actuation onto ITO slides with fan. Slide were connected to forced potential and horizontally placed inside a fan box.



8m³ aerosol chamber to aerosolise 1µm microbeads.

Collected microbeads on dry ITO slides were quantified using fluorescent microscope and analysed using Celleste™.

Figure 1: Experimental methodology to investigate dielectrophoretic actuation. A) Vertically clamped slides connected to forced potentials and B) horizontally clamped ITO slide connected to forced potentials under fan. Quantity of collected PSL particles were quantified using fluorescent microscope.

Results & Discussion

Dielectrophoresis increased the collection of aerosolised microbeads

Collected microbead concentration increased with the voltage

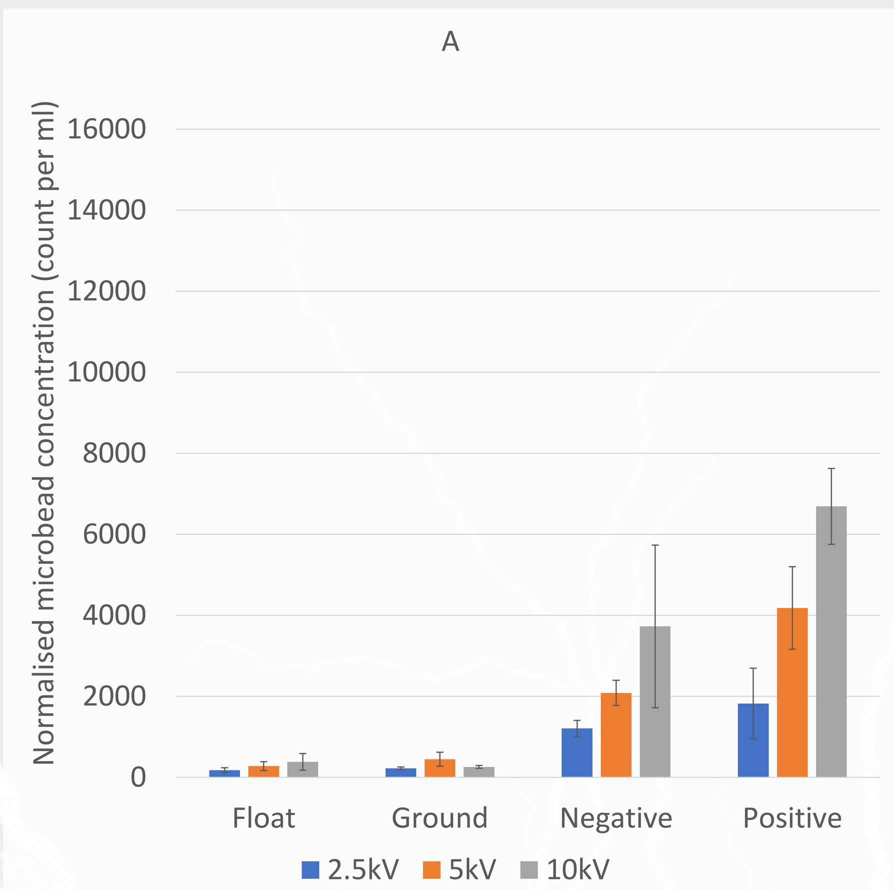
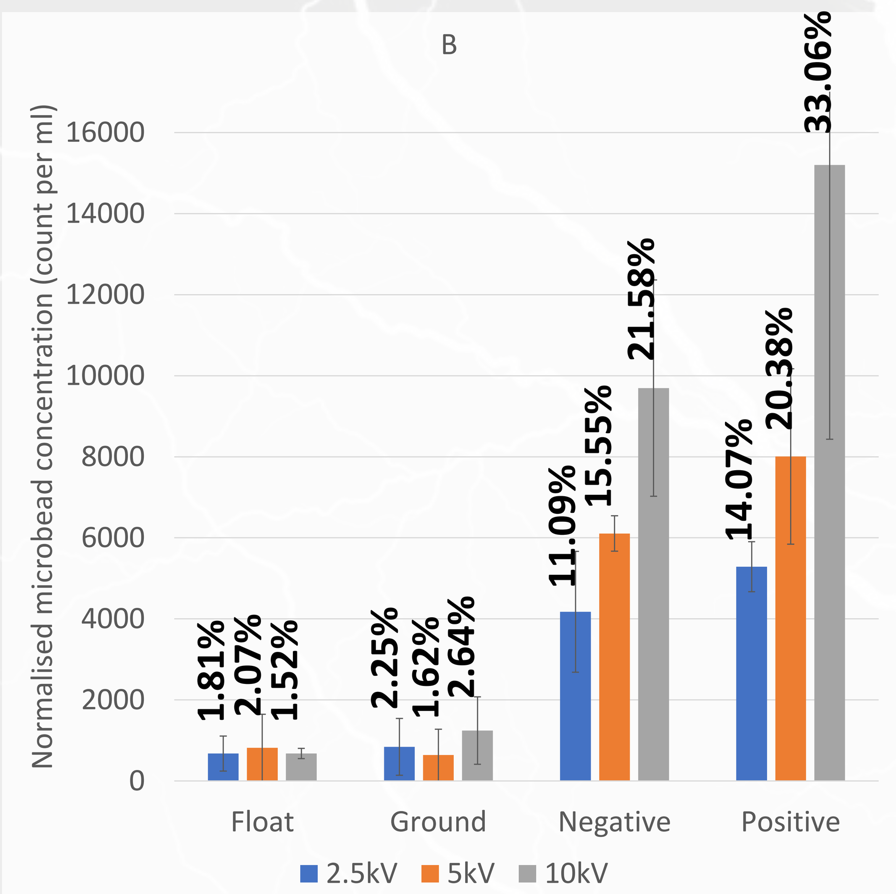


Figure 2: Average dielectrophoretic actuation of aerosolised microbeads normalised against chamber concentration using set up A. Error bars denote the standard deviation of triplicates.



Potentials kept microbeads attracted during air impaction

Direct airflow to collection surface allowed for a boost of the collection efficiency

Up to 33% collection efficiency

Figure 3: Average dielectrophoretic actuation of aerosolised microbeads normalised against chamber concentration using set up B. Collection efficiency displayed as percentages (%). Error bars denote the standard deviation of triplicates.

Positive voltage had the highest collection performance

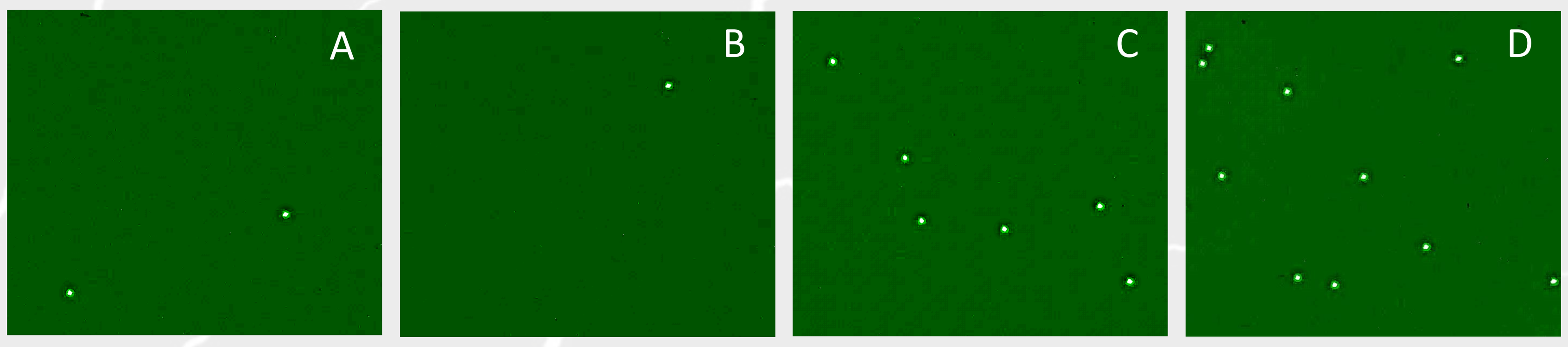


Figure 4: Fluorescent microscope images of collected microbeads on ITO slide with forced potential. A) Float, B) Ground, C) Negative and D) Positive.

Future work

- Explore the air flow impact on the dielectrophoretic collection efficiency
- Investigation on dielectrophoretic collection efficiency on bioaerosols
- Investigate the viability of bioaerosols when collected using dielectrophoresis
- Dielectrophoretic enhanced collection directly into liquid

Conclusion

This research demonstrates that dielectrophoretic collection can be used to enhance the collection of airborne particles and can potentially be applied as an alternative to existing aerosol sampling methods.

References

1. Piri A, Kim HR, Hwang J. Prevention of damage caused by corona discharge-generated reactive oxygen species under electrostatic aerosol-to-hydrosol sampling. J Hazard Mater. 2020 Feb 15;384:121477. doi: 10.1016/j.jhazmat.2019.121477. Epub 2019 Oct 18. PMID: 31704122. **2.** Mainelis G. Bioaerosol Sampling: Classical Approaches, Advances, and Perspectives. Aerosol Sci Technol. 2020;54(5):496-519. doi: 10.1080/02786826.2019.1671950. Epub 2019 Oct 4. PMID: 35923417; PMCID: PMC9344602. **3.** Li, X., Chen, H., Qi, X., Peng, Y., Zhou, L., Ma, J., Yao, M. (2021). A Robot Assisted High-flow Portable Cyclone Sampler for Bacterial and SARS-CoV-2 Aerosols. Aerosol Air Qual. Res. 21, 210130. https://doi.org/10.4209/aaqr.210130. **4.** Hong S, Kim MW, Jang J. Physical collection and viability of airborne bacteria collected under electrostatic field with different sampling media and protocols towards rapid detection. Sci Rep. 2021 Jul 16;11(1):14598. doi: 10.1038/s41598-021-94033-7. PMID: 34272448; PMCID: PMC8285527.