Airborne particle collection into single droplets to analyse and identify harmful aerosol constituents

Priya Chopra[1], Dr Ian Johnston[1], Dr Loic Coudron[1], Dr Daniel McCluskey[1], Dr Laura Urbano[1]
[1]University of Hertfordshire, Hatfield , Hertfordshire, AL10 9AB, United Kingdom

Aim and Background

Identification of potentially rare aerosol constituents relies on having a sufficient concentration of particles in liquid for analysis.

The aim of this project is to design an electrostatic precipitator (ESP) prototype which collects aerosol directly into single liquid droplets.

Aerosol collection and sampling using the ESP will increase awareness of the constituents of ambient air.

Improved collections of aerosols will provide more accurate results, better statistics and confidence to inhale ambient air.

Sampler	Sampling rate ($Lmin^{-1}$)	Liquid Collected (mL)	Theor. max. con. rate (min^{-1})
BioBadge® (3)	40	5	8.0×10^3
CIP-10-M (4)	10	2	5.0×10^3
IOM (5)	2	10	2.0×10^3
Button Sampler (6)	4	10	4.0×10^3
PES (7)	10	10	1.0×10^3
ILO Chip (8)	0.12-0.14	0.025	5.7×10^3
ESP-EWOD (University of Hertfordshire) (2)	**5** **20**	**0.0029** **00029**	$\mathbf{1.7 \times 10^6}$ $\mathbf{6.9 \times 10^6}$

commercially available collection devices v's ESP-EWOD.

Collector Design

The ESP uses a combination of airflow and electrostatics to collect aerosols on the collection plate which then is processed further to recover the collected particles.

- The current prototype (1) employs additional microfluidic Electro-Wetting on Dielectric (EWOD) techniques to recover aerosols.
- Limitations of the ESP include in-field use and logistical burden which hinder expected high concentration collections.
- Collection directly into a droplet to overcome inefficiencies of recovery of collected particles from surfaces.

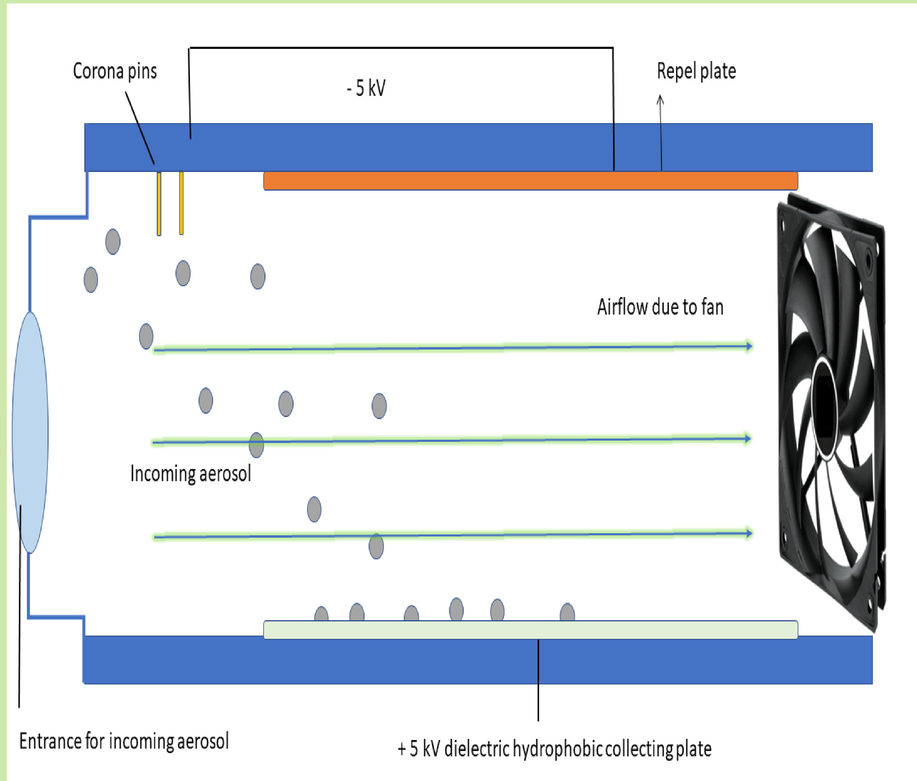

Figure 1: Systematic diagram of the ESP prototype.

Research Methodology

Electrostatic modelling

Optimising the ESP and exploring relevant electrostatic parameters:

- Electric field strengths.
- Geometrical positioning of corona pins, repulsion and collection plates.
- Conductivity of droplet liquids.
- Particles size.
- Induced charge on particles.

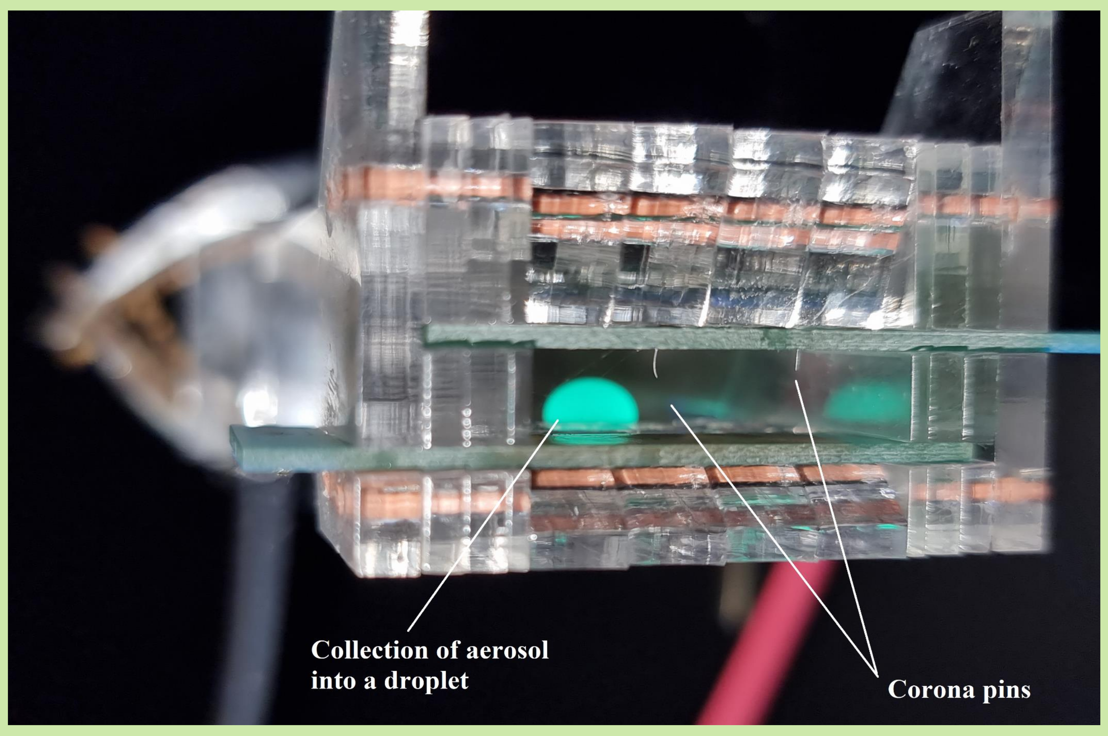

Figure 2: Concept prototype ESP collector With integral collection droplet.

Computational Fluid Dynamics

- Studying spatial mapping and temporal effects of the aerosols entering the ESP.
- Determining relevant boundary conditions and identifying parameters for investigation.
- Investigating the effects of introducing a droplet on air flow.
- Combining electrostatic and air flow models for improved deign.

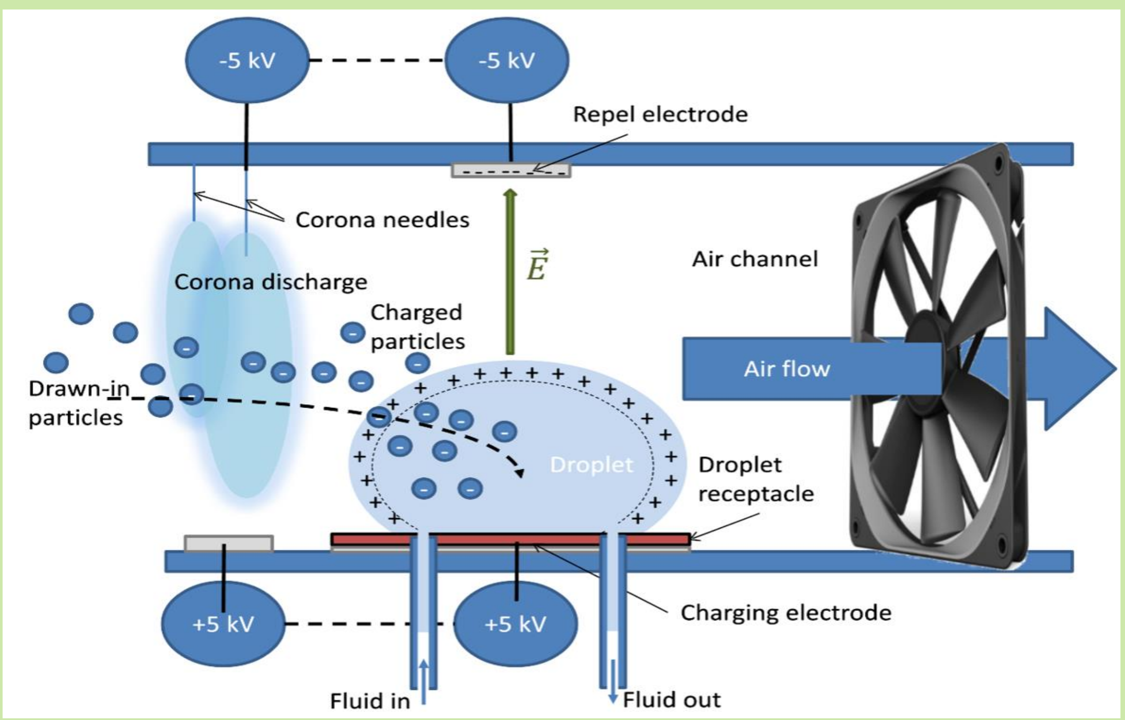

Figure 3: Schematic of proposed electrostatic particle collection from air flow into droplets (1).

Experimental Validation

Using Polystyrene Latex (PSL)

- Testing ESP efficiency with PSL microspheres.
- Improving the design of the ESP for increased collection.

Testing with biological simulants

- Experimental ESP validation by collecting ambient air and biological simulants.
- Iterative theoretical modelling and experimental testing of the ESP.

Validation of final prototype

- Experimental testing collection and recovery efficiency of the prototype ESP.
- Comparison with existing ESP-EWOD prototype and commercially available collectors.

References

1. Coudron, L., Foat, T., McCluskey, D., Munro, I., Tan, C., Baxter, R., Despeyroux, D. & Johnston, A novel bio-aerosol to droplet sampler for high concentration rate collection, I., 2 Sep 2021, p. 911
2. T.G. Foat, et al., A prototype personal aerosol sampler based on electrostatic precipitation and electrowetting-on-dielectric actuation of droplets, Journal of Aerosol Science Volume 95, May 2016, Pages 43-53
3. Eoin Ryan, et al., Measurement of airborne foot-and-mouth disease virus: Preliminary evaluation of two portable air sampling devices, The Veterinary Journal 179 (2009) 458–461
4. Peter G¨orner et al., Laboratory Study of Selected Personal Inhalable Aerosol Samplers, Journal of Virological Methods 177 (2011) 44–48
5. IOM Personal Samplers and IOM Samplers with MultiDust, SKC - specialists in air sampling since 1962, Accessed on 03/25/2022
6. Button aerosol sampler, SKC - specialists in air sampling since 1962, Accessed on 03/25/2022
7. Personal Environmental Monitor (PEM) SKC - specialists in air sampling since 1962, Accessed on 03/25/2022
8. L.S. Christensen et al., Detection of foot-and-mouth disease virus in the breath of infected cattle using a hand-held device to collect aerosols, The Annals of Occupational Hygiene, Volume 54, Issue 2, March 2010, Pages 165–187
9. https://health.clevelandclinic.org/can-face-masks-cause-health-problems/
10. https://www.shutterstock.com/image-vector/cartoon-lungs-vector-illustration-happy-characters-1628373859

Contact

Priya Chopra
Email: p.chopra@herts.ac.uk

UKRI Engineering and Physical Sciences Research Council

University of Hertfordshire UH