Supplementary Material

# Sample collection

Aerial microbiome samplers (typically termed *bioaerosol samplers*) can be categorised into several main functional types (Figure S1, see Ghosh et al., 2015; Haig et al., 2016; and Lindsley et al., 2017 for comprehensive overviews). Within each functional type, samplers tend to have a set of common advantages and limitations (see Table S1). For example, filters tend to have high collection efficiencies, but poor potential for the maintenance of biological viability. However, even within categories, the available samplers are highly diverse and can have variable sampling capacities and characteristics (such as flow rate, collection efficiency, and collection medium, e.g. see Haig et al., 2016; Kesavan and Sagripanti, 2015; Wang et al., 2015 for a summary). A comprehensive list of bioaerosol samplers, together with their particle size range and application suitability is provided in Lindsley et al. 2017.

A picture containing indoor, table, different, man

Description automatically generated

**Figure 1.** Schematic illustrating the key types of bioaerosol samplers: (a) Filter (IOM sampler); (b) Cascade impactor (Sioutas) (c) Cyclone (aluminium cyclone); (d) Impinger (glass midget impinger mounted on pump). Images courtesy of SKC Inc.

The key implication of the diversity and differences between samplers is that sampler choice strongly affects the outcomes of aerial microbiome studies. Results from studies using different samplers are not easily comparable, and in some cases inappropriate sampler choice may make a study’s conclusions invalid. For example, Kesavan and Sagripanti (2015) show that inadequate sampler selection can result in a serious underestimate of infectious disease risk, the same principles would apply when sampling UAMs and could lead to an underestimation of ecosystem service potential. Although sampling technologies are continuing to advance and evolve, standardisation remains unlikely given that sampler choice will remain guided by study design and questions. However, the obstacle of different sample collection techniques for understanding UAM’s for ecosystem service provision will be minimized if techniques for downstream genetic and statistical analysis are unified and data sharing implemented. Here we describe some of the benefits and drawbacks of the various sampling methods.

# Table S1. Core categories of microbiome (bioaerosol) samplers and their key advantages and limitations. Based on comprehensive reviews in Ghosh et al., 2015; Haig et al., 2016; Kesavan and Sagripanti, 2015; Lindsley et al., 2017. Note that within each category there are numerous individual sampler types, which may have widely varying specific sampling characteristics and will be of varying suitable for different bioaerosol types. For a comprehensive list of specific samplers, their particle size range and application suitability (e.g. culture/microscope/immunoassay/genomic studies), see Lindsley et al., 2017.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sampler type | Advantages | Disadvantages | Key sub-types | Common examples |
| FiltersPFB | Flexible application - many types available  Cheap and simple to deploy  Many samplers are lightweight/portable → suitable for personal monitoring  Some sample inhalable fraction (e.g. Button) | Subject to collection/viability loss via desiccation, deposition on sampler walls, incomplete elution from filter, filter overloading  Requirement for pumps & power → limitations on field deployment  Must be preceded by a size selective inlet (e.g. cyclone/ impactor) for size classification | Cellulose filter  Gelatin filter  Glass fibre filter  PTFE filter | IOM  Button  PAS-6 |
| ImpactorsPFB | Flexible application - many types, varied flow rates & collection media (agar, glass slides, liquid)  Direct-collection onto growth/microscopy media→ reduced post-processing  Some offer size classification, inhalable fraction sampling and/or long-term sampling capacity | Collection media (plates/slides) can become overloaded making enumeration difficult  Subject to collection/viability losses via shear forces, desiccation, particle bounce, re-entrainment, inlet losses, deposition build up | Slit impactor  Cascade impactor  Virtual impactor | Hirst-type  Rotorod  BioStage Impactor  Anderson multi-stage |
| CyclonesFBV | Minimises desiccation and shear/impaction stress → suitable where viability is important  Less prone to particle bounce than impactors → good collection efficiency  Multi-stage versions → size classification | Collection efficiency curves less sharp than most impactors  Subject to collection/viability losses via shear forces, liquid carry-over, evaporation, adherence to cyclone walls | Wet cyclone  Dry cyclone | NIOSH one stage  NIOSH two -stage  Coriolis  PAS-5 |
| ImpingersFBV | Minimises desiccation → suitable where viability is important  Widely used → good info. on collection efficiency | Collection/viability losses due to shear forces, re-aerosolization, evaporation, wall adherence  Requires post-processing for analysis  Evaporation limits collection time  Relatively expensive and fragile | Single-stage  Multi-stage | Burkard Multi-stage  AGI-30 Impinger  Midget Impinger |
| ElectrokineticPFBV | Cheap and simple to deploy  Much higher collection efficiency than passive samplers  Low desiccation/impaction stress  Lack of pump/low power requirement → flexible field deployment, can be unattended long-term | Lower collection efficiency than most pump-based samplers (e.g. filters)  Electrical charge may affect bacterial viability  Limited studies to date → relative lack of information on sampling performance | n/a | Rutgers Electrostatic Passive Sampler  Inspirotek Sampler |
| CondensationPFBV | Can collect ultrafine bioaerosol particles  Maintains microorganism viability | Complex, multi-component and expensive | n/a | LSS100 |
| Real-timePFB | Capable of real-time and large-scale surveillance  Strong potential for greater technological development | Lower precision than other methods, possible interference from non-biological material  ID affected by fragmentation & orientation  Limited studies to date → relative lack of information on sampling efficiency, precision | Fluorescence & light scattering  Flow cytometry | WIBS  Plair2000 |
| PassivePFB | Extremely cheap and simple to deploy  Efficient means of obtaining preliminary/qualitative information  Suitable for culturing without post-processing  Does not disturb airflow  Reproduces real conditions | Volume of air unknown → cannot quantify micro-organism concentrations, not comparable with active sampling methods  Reliance on settling → collection bias towards larger particles  Generally not suitable for long term continuous sampling (e.g. agar dries out after 4 hrs) | Agar settling plates  PTFE filter settling plates  Electret cloth |  |

* 1P=Pollen, F=Fungi, B=Bacteria/Archaea, V=Viruses

**Works Cited**

Ghosh, B., Lal, H., Srivastava, A., 2015. Review of bioaerosols in indoor environment with special reference to sampling, analysis and control mechanisms. Environ. Int. 85, 254–272. https://doi.org/10.1016/j.envint.2015.09.018

Haig, C.W., Mackay, W.G., Walker, J.T., Williams, C., 2016. Bioaerosol sampling: Sampling mechanisms, bioefficiency and field studies. J. Hosp. Infect. 93, 242–255. https://doi.org/10.1016/j.jhin.2016.03.017

Kesavan, J., Sagripanti, J.L., 2015. Evaluation criteria for bioaerosol samplers. Environ. Sci. Process. Impacts 17, 638–645. https://doi.org/10.1039/c4em00510d

Lindsley, W.G., Green, B.J., Blachere, F.M., Martin, S.B., Law, B.F., Jensen, P.A., Schafer, M.P., 2017. Sampling and Characterization of Bioaerosols, in: Ashley, K., O’Connor, P.F. (Eds.), NIOSH Manual of Analytical Methods. National Institute for Occupational Health and Safety, Washington DC, pp. 82–112. https://doi.org/10.1103/PhysRevB.71.165307

Wang, C.H., Chen, B.T., Han, B.C., Liu, A.C.Y., Hung, P.C., Chen, C.Y., Chao, H.J., 2015. Field evaluation of personal sampling methods for multiple bioaerosols. PLoS One 10, 1–19. https://doi.org/10.1371/journal.pone.0120308