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Factors affecting the performance of bioaerosol impactors

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While different principles are utilized for sampling biological aerosol particles, impaction appears to be the most common for collecting bacteria and fungi. This method is used for total and culture-based microbial enumeration. For instance, the total number of viable and non-viable airborne spores is conventionally counted under a microscope after collecting them on a slide of a single-stage impactor, e.g., Air-O-Cell sampling cassette (Zefon Analytical Instruments, Inc., USA), the Burkard Personal Volumetric Air Sampler (Burkard Manufacturing Co. Ltd., U.K.) and Allergenco-D (Environmental Monitoring Systems, Inc., USA) to mention a few. Available bioaerosol impactors are usually equipped with either circular or rectangular (slit) inlets. Some impactors have a single nozzle as an inlet, e.g., Air-O-Cell, while others have hundreds of nozzles, e.g., Millipore Air Tester (Millipore Corp., USA). More importantly, they differ from one another with respect to their ability to efficiently collect bio-particles of specific sizes as well as by the particle deposit uniformity on a substrate (the latter is often critical for applying certain microbial enumeration protocols). The collection efficiency is characterized by the cut-off size, d_{50} that depends on the flow velocity through the nozzle, nozzle size (W), nozzle shape, non-dimensional jet-to-plate distance (S/W), and other factors.

In this study, we have tested the physical performance of eleven bioaerosol impactors. The collection efficiency and the bio-particle deposit characteristics were determined in the laboratory using a real-time particle size selective aerosol spectrometer and different microscopic enumeration methods. The test impactors were challenged with non-biological polydisperse NaCl aerosol, monodisperse polystyrene latex (PSL) particles, and aerosolized bacterial and fungal spores (*Bacillus subtilis*, *Cladosporium cladosporioides*, *Aspergillus versicolor*, and *Penicillium melinii)*. The total number of spores, $N_{MICROSCOPE}$, collected on the slide deposition area, A_{DEP}, was counted and then related to the number of aerosol particles of a specific size range recorded by an aerosol spectrometer (Model 1.108, Grimm Technologies, Inc., Germany) upstream of the impactor over the time *t*. Thus, the actual collection efficiency of some of the tested impactors was calculated as

$$E_{ACTUAL} = \frac{N_{MICROSCOPE}}{C_{UP} Q t} \times 100\ \%$$

where C_{UP} is the upstream aerosol concentration and Q is the sampling flow rate. The overall physical collection efficiency was also determined for biological and non-biological particles from the ratio of the aerosol concentration up- and downstream of the impactor. Consequently, d_{50} was obtained for each tested impactor as presented in the table below.

Design and collection characteristics of the tested impactors.

Impactor	Jet shape	No of jets	Q, *l*/min	W, mm	S/W	d_{50}, µm
Air-O-Cell	slit	1	15	1.0	1.0	2.5
Allergenco -D	slit	1	15	1.0	0.89	1.7
Burkard	slit	1	10	1.0	1.0	2.4
CyClex	round	1	20	4.4	0.1	1.8
Micro-5	round	1	5	2.1	0.12	≤1
SMA	round	12	141.5	6.3	0.8	4.8
BioCulture	round	380	120	2.3	0.75	7
MAS-100	round	400	100	0.7	4	1.7
Microflow	round	378	120	2.5	0.84	8.8
SAS Super 180	round	401	180	0.8	2.7	2.1
Millipore Air Tester	round	1000	140	0.46	12.7	2.3

The data demonstrate how much the samplers differ by the cut-off size (d_{50} varies within a decade). Some impactors appear to significantly undersample airborne fungi, and almost all of the tested samplers have clear limitations to efficiently collect bacteria. Statistical modeling was applied to determine the role of different impactor design parameters in the bioaerosol collection and enumeration process. The study revealed that a relatively small change in the bioaerosol impactor design (e.g., Allergenco-D versus Air-O-Cell) may significantly improve its collection characteristics, decreasing the cut-off size so that practically all fungal species are collected on the substrate. The dimensionless jet-to-plate distance was confirmed to be influential for reducing the d_{50} of single-nozzle impactors. For some multi-nozzle impactors, we found that the collection efficiency is improved substantially if S is decreased by increasing the amount of agar on the collection plate. As to the microscopic enumeration of spores, the deposit uniformity and the count variability differ considerably from one sampler to the other. For several impactors, however, we found that the three methodologies – the entire impaction trace count, 40-field random partial count, and 20-traverses partial count – produced the same results ($p>0.05$).