Selecting an Air Sampler for Bioaerosol Collection

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Summary: Indoor Air Quality (IAQ) investigators should select cost effective, efficient and the highest quality sampling equipment for evaluation of indoor environments. Particle impaction onto an adhesive surface (non-viable) or into culture media (viable) are the most widely used techniques to evaluate the presence and levels of airborne bioaerosols, particularly in non-industrial indoor environments. These processes depend on the inertial properties of the particles, such as size, density and velocity, and on the physical parameters of the impactor, such as inlet-nozzle dimensions, jet-to-plate distances and airflow velocities and paths. Because of differences in physical characteristics, samplers differ in collection efficiency, often referred to as "cut-off" size (d_{50}) (e.g., the particle size above which 50% or more of the particles are collected). As most impactors have very sharp cut-off characteristics, most particles larger than the d_{50} are collected.[1,2] No sampler collects all particles with equal efficiency, and it is therefore not surprising that different quantitative and qualitative results are obtained using different sampling devices. IAQ investigators should select Air-O-Cell®, Allergenco-D®, Cyclex®, Cyclex-d® or Micro-5® spore trap cassettes based on their operational characteristics (summarized below). No corresponding studies have been published on Andersen Type viable impactors fabricated by different manufacturers, but as a class, these remain cost effective and efficient viable samplers for use in IAQ investigations.

Discussion: The selection of an air sampler for Indoor Air Quality investigations is based on many criteria. These criteria and some samplers have been reviewed in "Bioaerosols: Assessment and Control[3]", published by the American Congress of Governmental Industrial Hygienists and edited by Janet Macher. Since this volume was published in 1999, additional peer reviewed articles have appeared in the literature and more sampler options have entered the marketplace.

> "5.2.2 Choosing an Air Sampler
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> An investigator selects one or more sample collection methods and gathers samples based on (a) the agents of interest, (b) the analytical methods by which the laboratory will identify and perhaps quantify the biological agents or indicators of the active agents, and (c) the sites and times at which samples will be collected…
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> 5.2.3 Sample Volume and Sample Collection Times
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> Sample volume and collection time are related through the minimum air volume needed to detect a target material present at a given concentration. In turn, sample volume and collection time depend on the volumetric flow rate of a bioaerosol sampler. The lower detection limit(LDL) for a bioaerosol sampling method can be determined from (a) the minimum amount of material that an assay can detect, (b) the recovery efficiency for the assay method and any concentration steps that may apply, (c) an air samplers flow rate, and (d) the maximum sample collection time…
>
> Investigators aim for sampling times that are (a) sufficiently long to collect a detectable and representative numbers of particles…but short enough to avoid masking (i.e. the overlap of particles on microscope specimens…)"

Non-Viable Impactors – The choice of a non-viable impactor is based on factors including initial & recurring costs, efficiency, total volume of air, convenience, etc. Table 2 (attached) summarizes selected popular circular trace and slit trace impactors. The Micro-5® and Cyclex-d® are cassettes, which have circular traces and are very efficient at trapping smaller particles (d_{50}=0.8um). The Micro-5® offers the optional convenience of operation from low flow (5 liters per minute = 5 lpm) battery operated personal sampling pumps. The Cyclex-d® operates at 20 lpm using a high volume vacuum pump, collecting particles very consistently from a larger volume of sampled air. Impactors with slit traces include the Allergenco-D® (d_{50}=1.7um) and Air-O-Cell® (d_{50}=2.5um), both operate from high volume vacuum pumps at 15 lpm. From these data, smaller fungal spores (e.g. ~2 um Penicillium/Aspergillus spores) are most efficiently collected by the Micro-5® and Cyclex-d® and effectively collected by the Allergenco-D®, but would be under represented in e.g. Air-O-Cell® samples.

Evaluation of these impactors using duplicate samples under controlled field test conditions demonstrate variations both site-to-site and between impactor designs[2]. The Coefficient of Variation (CV), expressed as a %, measures the reproducibility of an impactor design and manufacturer {Lower CV's are Better}. The Micro-5®, Cyclex®, Cyclex-d® and Allergenco-D® have been shown to yield more reproducible results with lower coefficients of variation in side-by-side comparisons[2]. (see Table 1).

Table 1 Coefficient of Variation (CV %) for Several Non-Viable Impactors[2]

Field Test Site	Cyclex®	Cyclex-d®	Micro-5®	Allergenco-D®	Air-O-Cell®
Site 1	49.2	10.9	35.4	11.3	56.2

Viable Impactors – The choice of the collection (culture) medium as well as collection efficiency also affects the kinds and levels of fungi recovered[4]. No single collection medium will enable the entire range of viable fungi in the air to be isolated. Media which are generally accepted for aerobiological studies include malt extract agar (MEA), V8 juice agar and dichloran 18% glycerol agar (DG18)[7,8]. MEA and V8 agar are broad spectrum media, whereas DG18 is intended to be a selective medium for xerophilic fungi, but many of the common fungal species in air can also be isolated[4].

Few published data are available on the validity (accuracy and precision) of the measurement of fungi in air as an estimate of exposure. All commonly used cultural air samplers use short sampling periods, typically 30 seconds to several minutes (See attached Table 2). The reproducibility in both the level (CFU/m[3)] in terms of species isolated[4] for viable samples is moderate at best. Repeated sampling within weeks at a given site has demonstrated that variation of viable spores within homes is much higher than the variation between homes[5]. Furthermore, the use of cultures for quantifying fungal particle concentrations in air samples will give an underestimate of the actual particle concentrations, and may cause significant fungal contamination to be missed altogether. The culturable fungal particles may comprise only a few percent of the total number of fungal particles[6].

Thus, in order to optimize the information available from air sampling, a comprehensive sampling plan using high quality samplers will include a sufficient number of both non-viable and viable samples for IAQ investigations. Micro-5®, Cyclex®, Cyclex-d® and Allergenco-D® impactors as well as E6 (Andersen type) viable samplers have been demonstrated as cost effective, efficient, and high quality scientific devises.

References

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Inspecting Residential Structures for Mold Contamination						**IESO 2210**
Non-Viable (non-culturable) Direct Examination Samples for Fungal Analysis						
Sample Type	Field Equipment(1)	Recommended (1) Sampling Rate	Media(1,3)	Efficiency Cut off d_{50}	Units(2)	Method Reference
Air Sample	All Pumps Calibrated					
Allergenco-D Cassette	High Volume Pump	Up to 10 min.@ 15 lpm	Allergenco-D Cassette	1.8 um	Spores/m^3	IESO 1210
Cyclex-d Cassette	High Volume Pump	Range 1-5 min. @ 20 lpm	Cyclex-d Cassette	0.8 um	Spores/m^3	IESO 1210
Micro-5 Cassette	Low Volume Pump	5 min. @ 5 lpm	Micro-5 Cassette	0.8 um	Spores/m^3	IESO 1210
Zefon: Air-O-Cell Cassette	High Volume Pump	Up to 10 min.@ 15 lpm	Air-O-Cell Cassette	2.6 um	Spores/m^3	IESO 1210
Integral Pump + Holder + Slide	Allergenco – Integral Pump	Programmable 10 min.@ 15 lpm	Multiple Samples - Adhesive Slide	2.0 um	Spores/m^3	IESO 1210
Holder + Slide	Burkhard – Integral Pump	Programable 1-9 min @ 10 lpm	Greased/Adhesive Slides	2.6 or 5.2 um	Spores/m^3	IESO 1210
Holder + Slide	Cyclex – Slide Holder – High Volume Pump	Cyclex 1-5 min. @ 20 lpm	Cyclex-Adhesive Slide	1.8 um	Spores/m^3	IESO 1210
Wall	High or Low Vol. Pump Drill, Wall-Kit	0.5-5 min. @ appropriate flow rate	Air-O-Cel, Allergenco-D, Cyclex-d, Micro-5 Cassettes & Cyclex		Spores/m^3	
Bulk/Vacuum/Tape						
Bulk	Sealed Container, e.g. Centrifuge Tube, Plastic Bag, etc.	~ 2 square inches	NA	ID		
Vacuum	High Volume Pump Highest Set Volume	Known Area ~(20 ft^2) or ~15 mg Total Dust	Filter, MCE or PVC Cassette	ID + ND, Light, Medium, Heavy, Excess		IESO 1310
Tape Lift	Tape Kit, Tape, Microscope Slide, Slide Holder, Plastic Bag	~1 cm^2	Microscope Slide	ID + ND, Light, Medium, Heavy, Excess		IESO 1110

Viable (Culturable), then Direct Examination Samples for Fungal Analysis						
Sample Type	Field Equipment	Sampling Rate/Area	Media	Units		Method Reference
Air Sample	All Pumps Calibrated			Efficiency Cut off d_{50}	Units(2)	
Air	High Volume Pump, Sampler, Agar Plates	Andersen Type e.g. N6 or E6 up to 10 min. @ 28.3 lpm	CEL, CMA, DG18, MEA Agar	0.65-0.70 µm	CFU/m^3	IESO 1220
Reuter Centrifugal sampler (RCS)	RCS - centrifugal impactors	20 sec-8 min. @ ca. 40 lpm		3.8 µm	CFU/m^3	
Bulk/Vacuum/Swab						
Bulk	Sterile Sealed Container, Plastic Bag, etc.	~ 2 square inches	NA	ID		
Vacuum	High Volume Pump Highest Set Volume	Known Area or ~15 mg Total Dust	MCE or PVC Cassette	CFU/in^2 or CFU/m^3		
Swab	Sterile Swab Kit	~1-4 square inches	Sterile Moist Swab	ID + ND, Light, Medium, Heavy, Excess		IESO 1120

1) Please research and use manufacturer's recommended procedures Limited or extended sampling times are often recommended for highly contaminated or very clean environments, respectively.
2) NA = Not Applicable; ID = Identity; ND = Non-Detected; Light, Medium, Heavy, Excess = Levels of Deposited Particles
3) CEL=Cellulose Agar – Molds on Sheetrock & Wood Substrates, CMA=Corn Meal Agar – Dermatophytes and Cellulosic Fungi (Not Common in IAQ), DG18 Agar – Dichloran 18% Glycerol Agar – Xerophilic (low water activity) Fungi in Carpets, etc., MEA Agar – Malt Extract Agar –Versatile All Purpose Media (medium to high water activity).