Topic (B6): Prediction & measurement

A COMPARISON OF THE SAMPLING EFFICIENCY OF BIOAEROSOL SAMPLERS AND PARTICLE COUNTERS IN NATURAL AND CONTROLLED ENVIRONMENTS

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INTRODUCTION

The bioaerosol sampler chosen by researchers for an experiment is often based on familiarity and availability. However, amongst the most popular general purpose samplers, is one more appropriate than the others for different sampling conditions? This project aims to examine 6 common samplers, in terms of their efficiency for detecting the total concentration and size distribution of airborne bacterium.

METHODOLOGIES

The controlled environment experiments were carried out in a mechanically ventilated, class 2 aerobiological test chamber. The chamber has a volume of 32 m^3 (4.20 m x 3.36 m x 2.26 m) with a 7.6 m^3 ante-room between the chamber and the laboratory. The temperature, humidity, ventilation rate and ventilation regime within the chamber were externally controlled. Background samples were taken with each sampler. Then a known concentration of either *Staphylococcus aureus* or *Bacillus Subitilis* was continually introduced into the centre of the chamber via a six-jet Collision Nebuliser (CN 25, BGI Inc, USA) at a flow rate of 8 L m^{-1} and a pressure of 12 psi. Once steady state conditions were achieved within the chamber, a second set of samples were taken with each sampler. The particle counters used included an Aerodymanic Particle Sizer (APS) Spectrometer and a Geo-α Handheld Laser Particle Counter. The biosamplers used include: a single- and a six-stage Andersen Cascade Impactor, an SKC BioSampler® Impinger and an All Glass Impinger (AGI 30).

The particle counters were located within the chamber near the ventilation extract and connected to a laptop in the ante-room to facilitate continuous monitoring of the chamber air. They were continuously counting and sizing the airborne particles within the chamber before, during and after the nebulisation of the bacterium. The bioaerosol samplers were located in the ante-room and sequentially sampled the chamber air through a tube located at the ventilation extract. Each piece of equipment was operated according the manufacturer's instructions.

The natural environment experiments were carried out in a naturally ventilated 4th floor single person office. The room has a volume of 37 m^3 (3.4 m x 3.6 m x 3.0 m). Temperature, relative humidity and CO_2 levels were continuously monitored at various locations within the

room. The four bioaerosol samplers and two particle counters sampled at the centre of the room. The room occupancy was varied from 1 to 5 people and the window was either open or closed to alter the ventilation.

The impingers sampled into 20ml of ¼ strength Ringers solution with 0.01% Tween 80 and 0.005% antifoam, for 30 mins at 12.5 L/min. The samples were either concentrated (using Amicon Ultra-15 Centrifugal Filter Devices) or serially diluted, and then plated onto TSA for incubation at 37 °C for 24 hrs and the resulting colonies were counted. The Andersen samplers were filled with agar plates containing of 37 ml of TSA (necessary to ensure the correct distance between the plates and stages), which were subsequently incubated at 37 °C for 24 hrs and counted. The sample time for the Andersen samplers varied from 30 s to 10 mins, depending on the sampling environment.

RESULTS AND DISCUSSION

The manufacturer specifications for the various samplers used, are summarised in Table 1. As can be seen from Table 1; particle size resolution is one of the key variables for differentiating the various samplers.

Table 1. Summary of sampler specifications

	Aerodynamic Particle Sizer Spectrometer (Model 3321)	**Geo-α Handheld Laser Particle Counter (Model 3886)**	**Single Stage Viable (Microbial) Impactor**	**Six Stage Viable Cascade Impactor**	**BioSampler® Swirling Aerosol Collector (SKC Impinger)**	**All Glass Impinger (AGI 30)**
Manufacturer	TSI Inc.	Kanomax Japan Inc.	Various	Various	SKC Inc.	Ace Glass Co.
Operating Principle	Particle spectrometer	Particle spectrometer	Inertial impaction	Inertial impaction	Liquid impingement	Liquid impingement
Size Range	0.5 - 20 µm	0.3- 5.0 µm	0.65 – 1 µm	0.65 - 7.0+ µm	D_{50}: 0.30 µm	D_{50}: 0.30 µm
Size Resolution	52 channels	5 channels	1 stage	6 stages	n/a	n/a
Time Resolution	1 s - 18 hrs	1 s - 99 mins	Typically 1 - 30 mins	Typically 1 - 30 mins	Typically 0.5 – 4 hrs	Typically 10 – 30 mins
Flow Rate	1.0 ± 0.2 L/min	2.83 L/min	28.3 L/min	28.3 L/min	12.5 L/min	12.5 L/min

The particle spectrometers, in particular the APS, can provide excellent size resolution however they are not chemically specific and therefore will sample all airborne particles regardless of composition. This is a particular problem when counting bioaerosols in real environments. Of the bioaerosol samplers investigated in this study, the six-stage Andersen Impactor, is the only one which provides useful information on the size resolution of the bioaerosols in the environment sampled. Particle size is a critical factor for determining the potential risks to the occupants of that environment.

Table 2 lists the total concentration of aerosols and bioaerosols as detected by an APS and a 6-Stage Andersen sampler respectively, in both the real and controlled environments. The APS data has been grouped into the same size ranges as are measured by the 6-Stage

Andersen sampler. As expected, the concentration of aerosols detected by the APS is far greater than the concentration bioaerosols detected by the 6-Stage Andersen. In the real environment, the percentage of viable bioaerosols detected by the Andersen in relation to the total aerosols detected by the APS is 0.01%, and 0.25% in the controlled environment. While both these values are very low, there is a significant difference between the two. This is expected, as the air supply (at 6ACH) to the controlled environment is HEPA filtered and there are no occupants in the room. Therefore the majority of aerosols present in the controlled environment, should be as a direct result of the bacteria nebulisation process, which will generate aerosols of a range of sizes and composition. By contrast, there were 2-5 people present in the real room and their physical activity was not restricted, therefore the size and composition of the airborne particles is expected to be much more diverse.

Table 2. Aerosol and bioaerosol concentrations in real and controlled environments.

Size range	**Real Environment**		**Controlled Environment**	
	APS (#/m³)	6-Stage Andersen (cfu/m³)	APS (#/m³)	6-Stage Andersen (cfu/m³)
S6: 0.65-1.1	4,725,535	115	6,111,348	7441
S5: 1.1-2.1	2,006,832	299	607,368	9132
S4: 2.1-3.3	656,176	211	43,511	75
S3: 3.3-4.7	261,577	80	2,409	10
S2: 4.7-7.0	161,014	111	733	15
S1: 7.0+	13,682	130	13	0
Total	**7,824,815**	**946**	**6,765,381**	**16673**

The trend in the size distribution of bioaerosols does not correlate with the size distribution of aerosols, regardless of environment. This is demonstrated in Figure 1, which illustrates the percentage of the total aerosols/bioaerosols detected per instrument, with increasing size ranges. The APS data (green lines) follows an exponential decay in concentration with increasing particle size, with the highest concentrations occurring for the smallest sized particles (0.65-1.1µm). However the bioaerosol data (red lines) shows a peak concentration in the second size range of 1.1-2.1 µm, after which, it drops to almost zero per cent concentration for all subsequent size ranges (in the controlled environment). Although in the controlled environment, the data from both instruments determined that 99-100% of all particles detected were between 0.65 and 2.1 µm, no similar correlations are seen in the real environment data. This lack of correlation between the size distribution of aerosols detected by the APS and bioaerosols detected by the 6-stage Andersen indicates that no specific predictions can be made regarding the size distribution of bioaerosols based on the data from an aerosol sampling instrument.

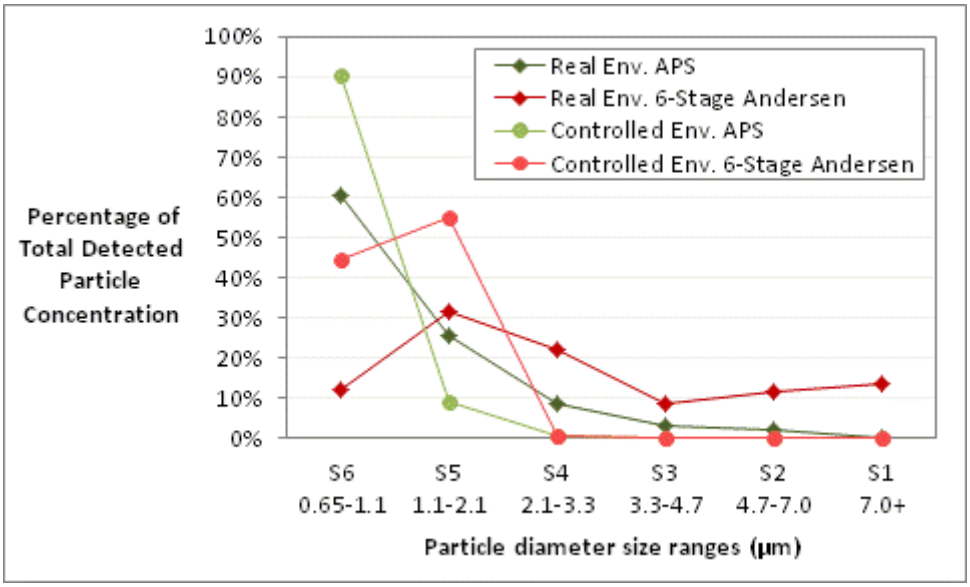

Figure 1. Percentage of total concentration in each size range.

There is good agreement in the concentration and size distribution of aerosols detected by the two particle counters, as can be seen from Figure 2, where the error bars indicate one standard deviation above and below the mean. The APS data has been grouped into the same size ranges as are measured by the Geo- α. The table within Figure 2 indicates the percentage of the total concentration in each size range per instrument. There is statistically no significant difference in the size distribution of aerosols detected by the two counters. While the Geo-α counts a higher concentration of aerosols in each size range in comparison to the APS, further analysis is necessary to determine if this difference is significant.

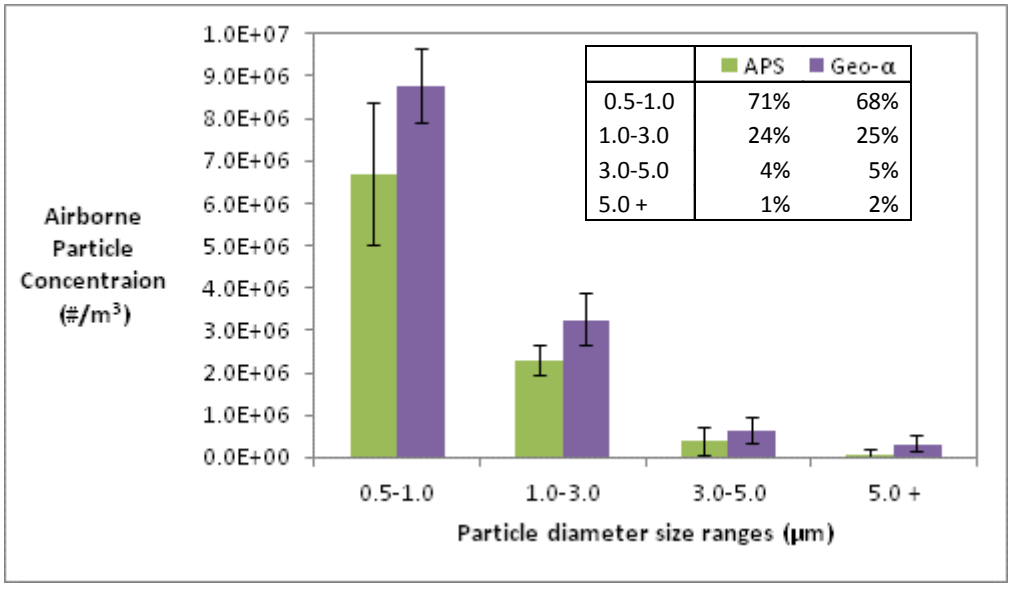

Figure 2. Airborne particle concentration for four size ranges, as identified by the APS and Geo-α in the real environment.

CONCLUSIONS

Initial results indicate that particle counters such as the APS and Geo-α, are not suitable substitutes for determining either the absolute values or trends, in the concentration or size distribution of bioaerosols. One possible exception is in predicting the cut off size of bioaerosols in a controlled environment. Here the APS and 6-Stage Andersen data both indicated that 99-100% of detectable aerosols and bioaerosols were between 0.65 and 2.1 µm in diameter.

Of the two particle counters tested, results of concentration and size distribution in both the real and controlled environments between the two counters compared favourably. This suggests that researchers on a tight budget could rely on data from the substantially less expensive Geo-α but must consider its size resolution, which is considerably inferior to the APS. The Geo- α is also a portable device which can be operated by battery. This is an important consideration when conducting field studies, where a power supply might not be easily accessible.

Further data analysis and statistical analysis is currently being applied to the collected data. It is expected that this analysis will yield additional clarification on the comparison between the collection efficiency of particle counters and bioaerosol samplers, as well as between samplers with the same operating principle (e.g. between the two bioaerosol impinger's). Sampler repeatability and reliability will be examined and the influence of ventilation rate on sampler efficiency will be discussed. When finalised, the results of this study will facilitate researchers in making informed decisions on their choice of biological sampler, hence generating more repeatable, reliable and accurate studies.

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