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SAMPLING OF AIRBORNE VIABLE PARTICLES - A COMPARATIVE STUDY OF COMMON INSTRUMENTS

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ABSTRACT

Microbial monitoring of the indoor environment can be performed in several ways and with the aid of different techniques. Knowing the limitations of the chosen system is of vital importance for the correct evaluation and interpretation of the results. The number of Colony Forming Units (CFU) detected by one method can not be directly compared with results from another method.

The paper presents an evaluation of commonly used instruments for the collection and counting of airborne viable particles. Physical properties are discussed, such as impaction velocity and efficiency of particle collection. Microbiological tests have been performed in a controlled environment in order to achieve comparative results of commercially available instruments.

KEYWORDS

Air quality, Bioaerosol sampling, Measuring instruments, Measuring techniques.

INTRODUCTION

Impaction is the most commonly used technique for collection of airborne viable particles. It is based on blowing or drawing a stream of air towards a surface at high velocity. Because of inertia, the particles cannot follow the deflection of the air at the surface without being thrown against the surface and being caught on it. The surface may consist of different sticky, solid materials. Direct impact of viable particles on nutrient media is considered suitable. The impaction principle has been employed in different ways in available sampling devices and the subject is described in the literature, see e.g., Benbough et al (1993), Buttner and Stetzenbach (1993), Jensen et al (1992), Marple et al (1993), Mehta et al (1996) and Nevalainen et al (1993).

The impaction process depends on the physical parameters of the impactor and on the inertial properties of the particle. The physical parameters are the inlet nozzle dimensions and the airflow pathway. The particle properties are size, density and velocity. The lower-inertia particles remain airborne with the airflow while particles with sufficient inertia impact/deposit onto the collection surface.

Collection efficiency is the ability of the sampler to remove particles from the airstream and transfer them to the collection medium. A characteristic diameter (d_{50}), the cut size, is generally considered to be the particle diameter above which all particles are collected (Marple et al 1993). For efficient collection it is important to chose an impactor whose d_{50} is below the mean size of the particles being sampled (Jensen et al 1992).

The length of collection time also plays a major role in the efficacy of air sampling for the retrieval of culturable microorganisms. Guidelines for the selection of optimal sampling times for various air samplers have been published

(Nevalainen et al 1993). Parameters which must be considered are the expected concentration of viable particles and the effect of sampling stress. The stress of impaction may injure the collected microorganisms, depending on either physiological characteristics (type of microorganism). Higher impaction velocities give greater impact stress, but also on the degree to which the microorganisms may be embedded in the collection medium plays a role (Steward et al 1995).

There are a wide variety of commercially available air samplers for collection of airborne microorganisms used for assessment of the indoor environment. Data between different studies are often difficult to compare because of differences in exposure levels, sampling and analysis methods. The purpose with this paper is to present results from a comparative study of different impaction air samplers under real conditions.

METHODS

Seven different impaction type air samplers of have been evaluated. These can be divided into three groups according to their impaction principle: slit-to-agar samplers (brand names BIAP, ES2, FH3), sieve samplers (brand names Andersen 6-stage, MAS, SMA) and centrifugal sampler (brand name RCS Plus).

Slit-to-agar samplers have an air intake through a slit (usually 0.2 -1.0 mm wide below which a revolving agar Petri dish is placed. In the slit, a linear velocity of 10-50 m/s is imparted to the air. At this velocity, particles with a minimum diameter of 0.5 to 1 um (the smallest at higher velocity) do not follow the deflecting stream of air but impact against the collection surface. The dish slowly revolves at set speeds. Remote air intake is usually available.

Sieve impactors have the air intake through a plate with perforations of a predetermined size; air is drawn towards a collecting surface that usually consists of agar in a Petri dish. A vacuum pump draws air through the cover and particles in the air impact on the agar medium. By placing a number of perforated plates with progressively smaller holes in series an increased air velocity is obtained through the holes for each stage. A size distribution of airborne particles containing CFUs is obtained. The impaction velocity depends on the size of orifices, the distance to the impaction surface and the performance of the vacuum pump.

Centrifugal samplers have a propeller that pulls air into the sampling unit and pushes the air outward to impact on a tangentially placed strip of nutrient agar set on a flexible plastic base. Particles in the incoming air can than be thrown out of the air current stream by the centrifugal force against the peripheral surface and remain there. The samplers demonstrate a selectivity for larger particles. Larger particles are more likely to include viable particles. This type of sampler may result in higher counts than other types of air samplers because of the inherent selectivity for larger particles. On the other hand the sensitivity for collecting large particles might be an advantage in some cases. The impact velocity depends on the rotational velocity of the turbine, the number and shape of the blades, the weight and shape of the particles and the distance between the blade tip and the peripheral surface.

Measurements have been performed in a controlled environment where different types of air samplers have been tested through parallel sampling. HEPA-filtered air has swept over the sampling devices at an air velocity of 0.4 m/s. The source of contamination has been a normally dressed person walking at intervals in the HEPA-filtered air in front of (upstream of) the measuring equipment. The principle arrangement is schematically shown in Figure 1.

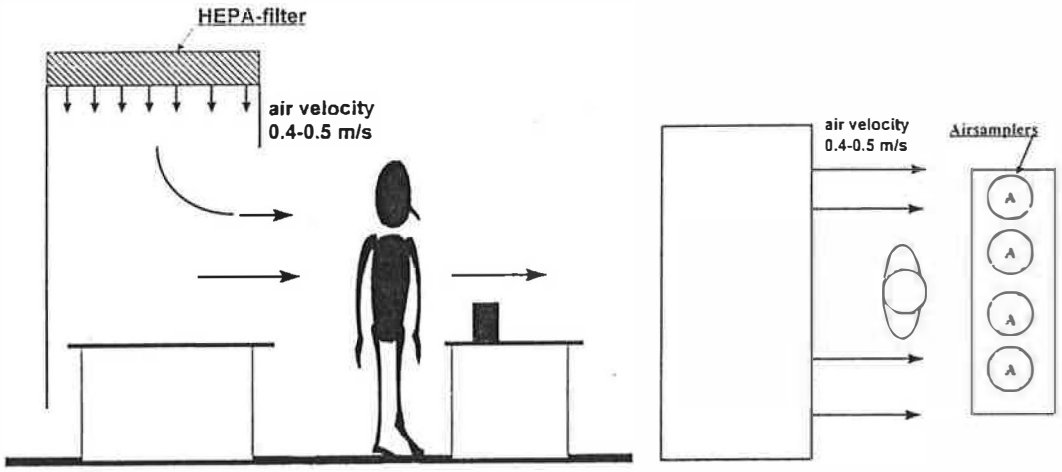

Figure 1 Principal arrangement of measurement environment

During the measuring periods of airborne viable particles the total number of airborne particles have also been registered with a particle counter (DPC, HiacRoyco 245 A). The particle sizes measured have been >0.5 µm, >5.0 µm and >10 µm.

RESULTS

The number of CFU detected at the comparative measurements are shown in Figures 2-5 and additional information for the four cases is given below.

Case 1 (Figure 2).

Particle levels

- >0.5 µm ca 1 000 000 per m³
- >5.0 µm ca 6 000 per m³
- >10 µm ca 600 per m³

Bacteria and Molds

- Cocci were found in all samples.
- Rods were found in 1 of 10 samples (with FH3).
- Spore forming rods were found in 4 of 10 samples (not detected with Andersen 6-stage).
- Molds were found in 7 of 10 samples (not detected with SMA).
- Sampling time was between 10 and 17 minutes and the sampling volume was ca 0.5 m³.

Case 2 (Figure 3).

Particle levels

Period 1

- >0.5 µm ca 120 000 per m³ per m³
- >5.0 µm ca 1 000 per m³
- >10 µm ca 200 per m³

Period 2

- >0.5 µm ca 350 000 per m³
- >5.0 µm ca 2 500 per m³
- >10 µm ca 350 per m³

Bacteria and Molds (16 single samples)

- Cocci were found in all samples.
- Rods were found in 7 of 16 samples (not with Andersen 6-stage).
- Spore forming rods were found in 3 of 16 samples (not detected with RCS Plus and Andersen 6-stage).
- Molds were found in 12 of 16 samples (detected with all instruments).
- Sampling time was between 10 and 17 minutes and the sampling volume was ca 0.5 m³.

Case 3 (Figure 4).

Particle levels

Period 1

- >0.5 µm ca 170 000 per m³
- >5.0 µm ca 600 per m³
- >10 µm ca 100 per m³

Period 2

- >0.5 µm ca 420 000 per m³
- >5.0 µm ca 800 per m³
- >10 µm <100 per m³

Bacteria and Molds

- Cocci were found in 9 of 10 samples (with all instruments).
- Rods were found in 8 of 10 samples (not detected with R2S).
- Spore forming rods were found in 8 of 10 samples (not detected with R2S).
- Molds were found in 2 of 10 samples (detected with FH3 and Andersen 6-stage).
- Sampling time was between 20 and 60 minutes and the sampling volume was between 1 and 3.3 m³.

Case 4 (Figure 5).

Particle levels

- >0.5 µm ca 27 000 per m³
- >5.0 µm ca 300 per m³
- >10 µm ca 100 per m³

Bacteria and Molds

- Cocci were found in 8 of 12 samples (with all instruments).
- Rods were found in 4 of 12 samples (detected with BIAP and FH3)
- Molds were found in 5 of 12 samples (detected with all instruments).
- Sampling time was between 10 and 35 minutes and the sampling volume was between 0.5 and 1 m³.

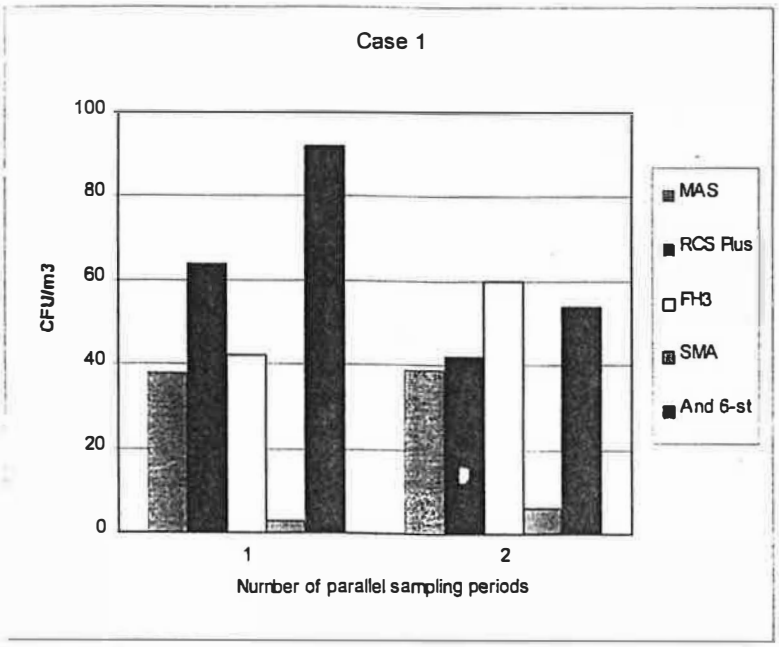

Figure 2. Observed number of airborne CFU from five air samplers (MAS, RCS Plus, FH3, SMA and Andersen 6-stage) during two parallel sampling periods. (Case 1).

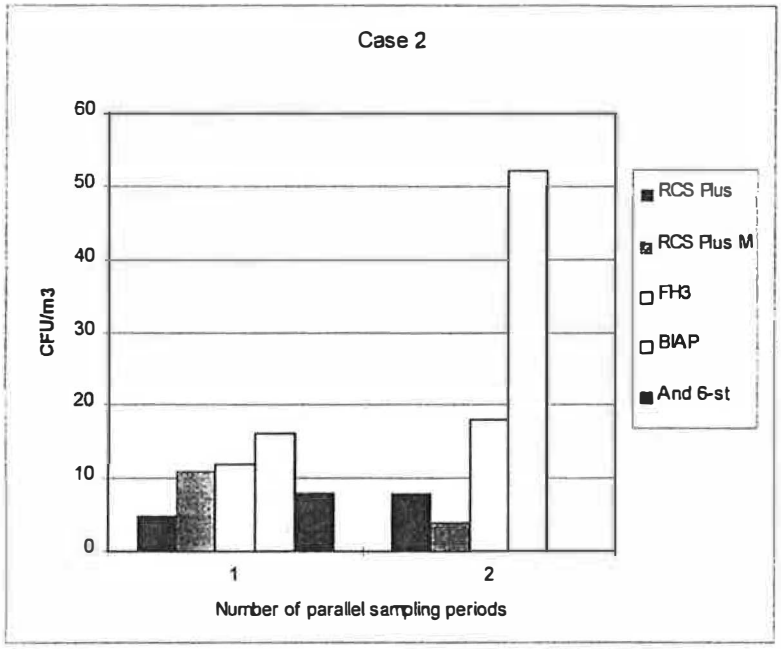

Figure 3. Observed number of airborne CFU from five air samplers (RCS Plus, RCS Plus M, FH3, BIAP and Andersen 6-stage) during two parallel sampling periods. (Case 2).

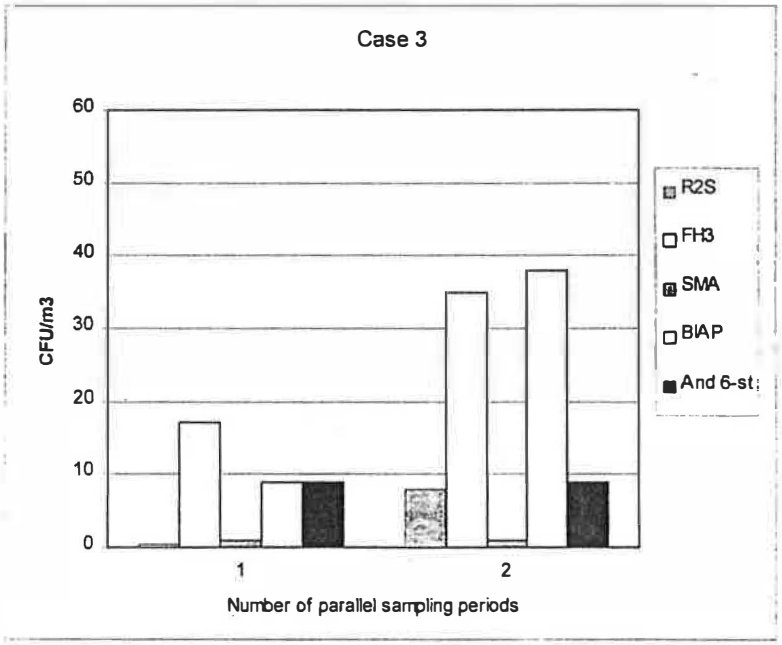

Figure 4. Observed number of airborne CFU from five air samplers (R2S, FH3, SMA, BIAP and Andersen 6-stage) during two parallel sampling periods. (Case 3).

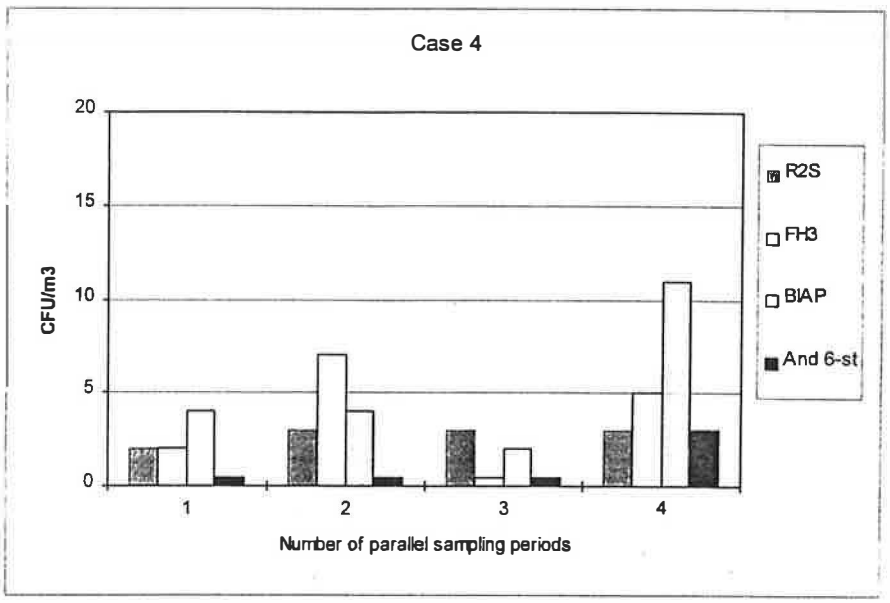

Figure 5. Observed number of airborne CFU from four air samplers (R2S, FH3, BIAP and Andersen 6-stage) during four parallel sampling periods. (Case 4).

DISCUSSION

Figure 2-5 show that the concentration level is less than 100 CFU/m³. These relatively low concentrations can be found in well-ventilated facilities without significant sources, such as offices, laboratories, clean rooms and operating rooms. The exposure situation with a human source in a controlled environment gives an approximate relation between total number of airborne particles and airborne viable particles. This relation between particles larger and equal to 0.5 um and of airborne CFU is estimated to be in the ratio of 10,000 to 1. This value has also been established from one type of clean room (aseptic production of sterile drugs) by Ljungqvist and Reinmüller (1995).

The low CFU values obtained by the SMA sampler is probably due to the low impaction velocity (around 1 m/s), which gives to high value of d_{50}. On the other hand the highest impaction velocity (around 50 m/s) has the R2S sampler, which of course will give a lower value of d_{50}, but might create higher impaction stress to the microorganisms. This should explain the relatively low CFU values seen in Figures 4 and 5 and the observed limited number of species.

CONCLUSIONS

The air samplers use different sampling times and have different collection efficiencies at different particle size ranges. During the microbial measuring periods it is advantageous to use a particle counter measuring the total number of airborne particles. The particle level indicates if correct measuring time has been chosen. The size ranges level indicates the suitability of the chosen air sampler. Recorded number of CFU from an air sampler should be seen as an indication and cannot be taken as a true absolute value. To improve the significance of the recorded CFU results the air sampler used should always be specified.

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