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Comparison of lab-made electrostatic rod-type sampler with single stage viable impactor for identification of indoor airborne bacteria

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ABSTRACT

Impactor is a widely used air sampling device because of it is relatively inexpensive and easy to use for sampling bioaerosols. However, sensitive microorganisms may have significant mechanical stress by inertia impaction. Therefore, this sampling method can underestimate the concentration of airborne bioaerosols. Electrostatic sampling can be a good alternative method for bioaerosol sampling because of a less stressful collection technique and has been frequently used. However, it is well known that ions and ozone generated by corona discharge can also inactivate the bioaerosols. In this study, the performance of our lab-made electrostatic rod-type sampler was compared with that of a single stage viable impactor (TE-10–880, Tisch Environmental, USA). The flow rate of our electrostatic sampler was determined so that the number of aerosols collected using the electrostatic sampler would be same as that of aerosols collected using the impactor of which flow rate was 28.3 lpm. After counting the colony numbers of bacteria captured using two different samplers, each cultured colony was identified with Matrix-Assisted Laser Desorption Ionization-Time of Flight Mass Spectrometry (MALDI-TOF MS) at indoor environment. The total number of identified bacterial genus was 17. Among 17 bacterial genuses, 15 genuses were identified when the electrostatic sampler was used while 9 genuses were identified when the impactor was used. In common, 7 genuses were detected from both samplers. 5.2 folds concentration of bacteria were cultured when the lab-made electrostatic rod-type sampler was used.

1. Introduction

About 90% of modern people spend their time indoors (Klepeis et al., 2001). Human exposure to airborne microorganisms may result in a variety of adverse health effects, therefore, monitoring of indoor bioaerosols is an important issue. Aerosol sampling is a prerequisite to the monitoring of bioaerosols.

Inertial impactors have been widely used for aerosol sampling. Araujo, Cabral, and Rodrigues (2008) investigated bioaerosols in rooms and wards equipped with different air filter systems using an Andersen-type one-stage impactor (BioStage single-stage bioaerosol impactor; SKC Inc., USA) to evaluate the effect of different filters and access conditions on airborne fungi in hospital facilities. Byeon, Park, Yoon, Park, and Hwang (2008) measured size distributions of total airborne particles and bioaerosols in a full-scale composting facility, using an optical particle counter and an agar-inserted six-stage impactor (TE-10–800, Tisch Environmental, USA), respectively. Kim et al. (2007) performed an on-site survey study to determine the concentrations and emissions of aerial

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contaminants in different types of swine houses in Korea using a one-stage viable particulate impactor (Model 10–800, Andersen Inc., USA). As illustrated, impactor is a widely used air sampling device because it is relatively inexpensive and easy to use for sampling bioaerosols. However, sensitive microorganisms may have significant mechanical stress by the inertia impaction sampling method. Therefore this sampling method can underestimate the concentration of airborne bioaerosols (Stewart et al., 1995).

Electrostatic sampling can be a good alternative method for bioaerosol sampling because of a less stressful collection technique and has been frequently used (Han, Fennell, & Mainelis, 2015; Ma et al., 2016; Park, Kim, & Hwang, 2016; Park, Park, Lee, & Hwang, 2015). Mainelis (1999) estimated that the velocity of particles perpendicular to the collection medium is about two to four orders of magnitude lower than that in bioaerosol impactors operated at comparable sampling flow rates. Yao and Mainelis (2006) developed the Electrosampler without charger and compared culturable fractions of collected bacteria in indoor and outdoor environments against a traditional microbial impactor operated in parallel. They found that their Electrosampler recovered more airborne bacteria microorganisms than the impactor with a difference as large as 1.5–9.3 times under certain conditions. In Xu and Yao (2011), biological collection efficiencies and culturable bacterial aerosol diversities were investigated when different bioaerosol sampling tools were applied. Different samplers resulted in different cultured concentration of sampled bacteria. The differences in cultured concentration of sampled bacteria could be due to many factors including the sampling mechanism and sampling time. However, it is well known that ions and ozone generated by corona discharge can also inactivate the bioaerosols (Fletcher et al., 2007; Korachi, Turan, Şentürk, Şahin, & Aslan, 2009; Kowalski, Bahnfleth, & Whittam, 1998; Timoshkin et al., 2012). In Yao and Mainelis (2006) and Xu and Yao (2011), bacteria particles were not identified after the bacteria particles were sampled with different sampling methods, therefore, the effect of sampling method on bacteria genus was not studied.

In this study, the performance of our lab-made electrostatic rod-type sampler was compared with that of a single stage viable impactor (TE-10–880, Tisch Environmental, USA). The flow rate of our electrostatic sampler was determined so that the number of aerosols collected using the electrostatic sampler would be the same as that of aerosols collected using the impactor of which flow rate was 28.3 lpm. After counting the colony numbers of bacteria captured with two different samplers, each cultured colony was identified with Matrix-Assisted Laser Desorption Ionization-Time of Flight Mass Spectrometry (MALDI-TOF MS). Experiments were carried out first with *Staphylococcus aureus* and then indoor airborne bacteria.

2. Materials and methods

2.1. Aerosol samplers

A single stage viable impactor (113 mm in diameter, 88.9 mm in height) of which cut-off size is 0.65 μm is used for aerosols sampling with flow rate of 28.3 lpm. The aerosols pass through 400 holes (each diameter is 0.25 mm) and are collected on an agar plate. The distance between each hole and the agar surface is 1 mm. A hand-held electrostatic rod-type sampler (110 mm in width, 115 mm in length, and 200 mm in height) developed by Park et al. (2015) is also used. The sampler is battery-operated. After a fan is turned on, airborne particles pass through a wire-to-rod charger (consisting of four wires and five rods; wire: 40 μm rod: 4 mm in diameter) and become positively charged. Next, charged particles are collected on a collecting rod (5 mm in diameter), which is made of stainless-steel and located downstream the charger, by an electric field.

The number of aerosols deposited on the agar plate of the impactor during the sampling time τ (n_I) is expressed as follows;

$$n_I = C_{up} Q_I \eta_I \tau \tag{1}$$

where C_{up} is the number concentration of aerosols at the inlet of the impactor and Q_I is the sampling flow rate of the impactor (28.3 lpm). The collection efficiency of the impactor (η_I) is defined as follows;

$$\eta_I = 1 - \frac{C_{down}}{C_{up}} \tag{2}$$

where C_{down} is the aerosol number concentration at the exit of the impactor. Similarly, the number of aerosols spread on another agar plate after recovering the bacteria sampled on the collecting rod of the electrostatic sampler during the sampling time τ (n_E) is as follows;

$$n_E = C_{off} Q_E \eta_E R \tau \tag{3}$$

where C_{off} is the aerosol number concentration measured downstream of the electrostatic sampler when the electrostatic sampler is off, and Q_E is the sampling flow rate of the electrostatic sampler. The collection efficiency of the electrostatic sampler can be written as follows;

$$\eta_E = 1 - \frac{C_{on}}{C_{off}} \tag{4}$$

where C_{on} is the aerosol number concentration measured downstream of the electrostatic sampler when the electrostatic sampler is on. The particle recovery efficiency of the electrostatic sampler (R) is defined as follows;

$$R = 1 - \frac{N_{After\ washing}}{N_{Before\ washing}} \tag{5}$$

where $N_{After\ washing}$ is the number of particles on the collecting rod after washing with 2 mL of deionized water in a tube by hand