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Electrostatic precipitation of airborne bio-aerosols

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ABSTRACT

In this study, we report electrostatic precipitation of *Escherichia Coli*- and *Yeast*-aerosols in air. The aerosol size distribution and their electrostatic precipitation efficiency are monitored by using an Electrical Low Pressure Impactor. The results indicate that the *E. Coil*-aerosols are mainly around 0.8 μm in aerodynamic diameter and the *Yeast*-aerosols are in the range of 1.3–3.1 μm, respectively. At an average electric field of 1 kV/cm, the precipitation efficiencies of *E. Coli*- and *Yeast*-aerosols are about 31% and 5%, respectively. They rise to 79% and 71% when the field strength rises to 7.5 kV/cm. For H_2O-aerosols, the diameter is about 0.02 μm and the efficiency is almost 100% under the same condition.

1. Introduction

Bio-aerosols in air usually consist of viral particles of viruses, cells and metabolites of bacteria, spores and hyphae of fungal, pollen, mites and their fragments and excreta. Exposure to bio-aerosols can cause infections, hypersensitivity, respiratory and lung disease [1–4]. Microorganisms in air, such as *Escherichia coli*, can carry up to 10^4 elementary charges [5], which can benefit their collection by using electrostatic force. Yao and Mainelis reported that for bio-aerosols with sufficient charges and at 5 kV/cm their collection efficiencies are 70% and 90% for indoor and outdoor, respectively [6]. Lee et al. presented the possibility to individually collect positive and negative charged bacteria and fungi [7]. In this work, we investigate bio-aerosols grade collection efficiency by using a home-made electrostatic precipitator (ESP).

2. Experimental setup and experimental bio-aerosols

Fig. 1 shows a schematic diagram of the experimental setup. A TK-3 Collision nebulizer (Midwest Inc., Beijing, China) is used as the bio-aerosols generator to produce bio-aerosols in air. A suspension of washed microorganisms is atomized at a flow rate of $Q_{neb} = 0.3$ mL/min. The Collision nebulizer breaks up the bacterial liquid into polydisperse bio- and H_2O-aerosols. Then they are diluted by dry air with a flow rate of $Q_{dil} = 10$ L/min. The precipitator consists of two parallel electrodes with a width of 15 cm, a length of 20 cm and a gap distance from 2 cm to 10 cm, respectively. The real-time aerosol number densities are measured with the Electrical Low Pressure Impactor (ELPI) (Dekati Inc., Finland) [8]. A negative DC voltage V_{esp} of up to 25 kV is applied to the precipitator. The temperature and relative humidity are around 26 °C and 80%, respectively.

The ELPI is a 12-stage impactor. It is used to collect bio-aerosols in terms of their size from 30 nm to 10 μm. *E. coli* ATCC 25922 is used as the model bacterium and *Candida albicans* ATCC 10231 as the fungi. The *E. Coli* is cultivated for 8 h at 37 °C in a standard LB medium. The *Yeast* is cultivated for 48 h at 32 °C with extra glucose. Fig. 2 shows typical collected bio-aerosols on the ELPI's stage for 1 min. And their number density is obtained by means of heterotrophic plate count (HPC) method. Fig. 3 shows two microscope images of the collected *E. Coli*- and the *Yeast*-aerosols, respectively. The *E. Coli* is in a rod-shape with a diameter of 0.3–4 μm. The *Yeast* is spherical with a diameter of 2–5 μm.

3. Results and discussion

3.1. Size distribution of bio-aerosols

Fig. 4 illustrates the size distribution of the *E. Coli*- and the *Yeast*-aerosols for the present system, where N_{single} represents the number of microorganisms collected on a single ELPI's stage, and $N_{all\ stage}$ represents the number of 12 stages in total. The *E. Coli*-aerosol is mainly concentrated around the 8th stage at an aerodynamic diameter of 0.8 μm. The *Yeast*-aerosols are mainly in the range of 1.3–3.1 μm with a peak value at 2.0 μm.

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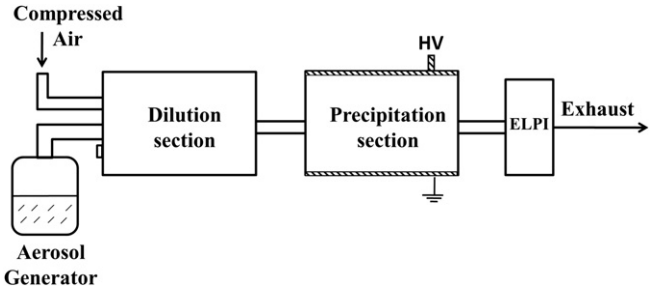

Fig. 1. Schematic diagram of the experimental setup.

Fig. 2. Typical collected bio-aerosols.

3.2. Electrostatic precipitation of bio-aerosols

The generated aerosols usually consist of bio- and H_2O-aerosols. The neutral H_2O-aerosols are mainly distributed from the 1st to the 6th stages or within 0.03–0.5 μm. The chemical composition of bacterial surfaces, such as ionizable amino (NH_2) and carboxyl (COOH) groups of proteins, contribute to the natural charge of the bio-aerosols [5]. We observe the aerosols become positive and

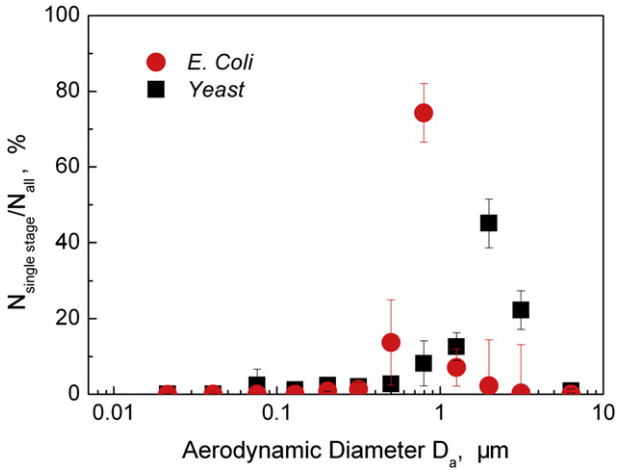

Fig. 4. Size distribution of *E. Coli* and *Yeast-aerosols*.

negative charged when atomizing the *E. Coli* and the *Yeast*, respectively. Their charging mechanism is, however, not clear yet.

Figs. 5 and 6 present typical real-time number density and the precipitation efficiency of the *E. Coli*- ($D_a = 0.8$ μm) and the *Yeast*-aerosols ($D_a = 2.0$ μm), respectively. The gap distance between the two electrodes is 5 cm. When $V_{esp} = 5$ kV, about 40% and 31% of the H_2O-aerosols (E) ($D_a = 0.02$ μm) and *E. Coli*-aerosols are collected. When the applied voltage rises to $V_{esp} = 25$ kV or the electrical field of 5 kV/cm, the precipitation efficiencies are 80% and 72% as shown in Fig. 5b, respectively.

For the *Yeast*-aerosol, when V_{esp} increases from 5 to 25 kV, the efficiency rises up to 49% as shown in Fig. 6b. In comparison with the *E. Coli*-aerosols, it is smaller because of their size and charges. The grade collection efficiencies for each of them are, however, mainly dependent on the applied electric fields but not significantly on their sizes as illustrated in Figs. 5b and 6b. With regard to effects of the electrode gap distance or the applied electric field, Fig. 7 shows typical grade precipitation efficiency via the electrode gap distance under the applied voltage of 15 kV.

Considering the relationship between the ESP index and the collection efficiency [9], Fig. 8 summarize all grade collection efficiencies in terms of the $E{\cdot}S$ value, where E is the averaged electric field strength in the unit of kV/cm, and S is the ESP specific collection area in the unit of $m^2/m^3/s$. The collection efficiency can be approximately estimated by the following equation:

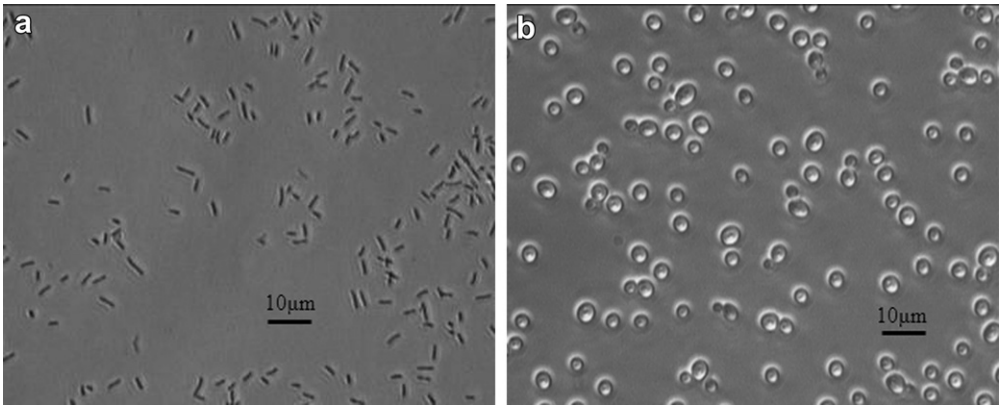

Fig. 3. (a) *E. Coli*- and (b) *Yeast*-aerosols.