Size-segregated Concentration of Bacterial Aerosols in Response to the Variation of Synoptic Weather at Japan Southwestern Coast

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Abstract

Bacterial aerosols, i.e., aerosol particles containing bacterial components and ranging from 0.1 μm to 100 μm, are an indispensable part of atmospheric aerosols and widely spreading in the global atmosphere. They play essential roles in the evolution and development of the Earth's environment, although they are also causing big concerns of public health. Quantification of their size-segregated concentration will largely benefit the understandings on their dynamics involved in aerosol variation and dispersion, as well as the roles they play in the complex atmospheric processes and the linking multiple ecosystems. However, the information of the number size distribution of bacterial aerosols is very limited, mainly because the traditional approaches using size-segregated samplers, i.e., Andersen samplers, have unquantified uncertainties, and new technologies rarely provide the accurate concentration of bioaerosols in a wide size range.

In order to establish a reliable method to measure the size-segregated characteristics of bacterial aerosols, laboratory suspension experiments were designed and conducted to assess the uncertainties in the measurements of size-segregated concentration of bacteria-containing bioaerosols with Andersen samplers. The uncertainties were caused by the prolonged impaction time from minutes to hours and even days. Microbes trapped in upper-stage filters in samplers may drop to subsequent-stage filters during the sample collection, leading to supposed uncertainties in the microbial size distribution. This study investigated the uncertainties in bacterial cell number size distribution measured with 8-stage Andersen samplers at a flow rate of 28.3 L min^{-1} (50% cutoff diameters: >11, 7.0, 4.7, 3.3, 2.1, 1.1, 0.65 and 0.43 μm). Results show that the concentration of bacterial cells in the size range of > 4.7 μm could be underestimated 40 - 50% as the concentration in the size range smaller than 3.3 μm was overestimated when the sample collection time was more than 6 hours. Sample collection time should be less than 20 minutes to suppress the uncertainty below10%, and 42 minutes below 20%. Based on identified exponential inverse relations between the dropping rates and the

sample collection time from each stage, a scheme was developed and validated to calibrate the counting results of Andersen sampler samples to obtain the number size distribution of airborne bacterial cells.

Using the calibration scheme, the number size distribution of bacterial aerosols was measured with the same type Andersen samples at AERU (32.324°N, 129.993°E, 23m a.s.l), a coastal site in Amakusa, Kumamoto, southwestern Japan. Results show that the distribution differed according to the source areas: terrestrial air, oceanic air, or a combination of the two. The distribution in the long-distance transported terrestrial air from the Asian continent was monomodal, with a peak of 3.3 - 4.7 μm. The distribution in local land breeze air was bimodal, with the peaks at 0.43 - 1.1 and 3.3 - 4.7 μm. A similar bimodal distribution was encountered when the local island air and long-distance transported terrestrial air mixed. In contrast, the size distribution did not show clear peaks in the air from either nearby or remote marine areas. According to the air mass backward trajectories, the longer the distance the air moved in the 72 h before arriving at the site, the lower the concentration of total bacterial aerosols. The estimation of dry deposition fluxes of bacterial cells showed that the deposition was dominated by cells larger than 1.1 μm with a relative contribution from 70.5% to 93.7%, except for the local land breeze cases, where the contributions in the size range larger and smaller than 1.1 μm were similar. These results show the distinctive number size distributions and removal processes of bacterial aerosols in different types of air.

Besides, the abundance and viability of particle-attached and free-floating bacteria in dusty air were also quantitatively investigated. We researched this subject based on the fact that airborne bacterial cells are approximately 1 μm or smaller in aerodynamic diameter; therefore, particle-attached bacteria should occur in aerosol samples of particles larger than 1 μm, and free-floating bacteria should occur among particles smaller than 1 μm. Our observations at the AERU, when the westerlies frequently transported dust from the Asian continent, revealed that particle-attached bacteria in dust episodes, at the concentration of $3.2 \pm 2.1 \times 10^5$ cells m^{-3} on average, occupied 72 ± 9 % of the total bacteria. In contrast, the fraction was 56 ± 17 % during

nondust periods and the concentration was 1.1 ± 0.7×10^5 cells m^{-3}. The viability, defined as the ratio of viable cells to total cells, of particle-attached bacteria was 69 ± 19 % in dust episodes and 60 ± 22 % during nondust periods on average, both of which were considerably lower than the viabilities of free-floating bacteria (about 87 %) under either dusty or nondust conditions. The present cases suggest that dust particles carried substantial amounts of bacteria on their surfaces, more than half of which were viable, and spread these bacteria through the atmosphere. This implies that dust and bacteria have important roles as internally mixed assemblages in cloud formation and in linking geographically isolated microbial communities, as well as possibly have synergistic impact on human health.

In summary, we developed a calibration scheme for the use of Andersen samplers in studies of bacterial aerosols and proposed a guideline, reported the size-segregated concentrations of bacterial aerosols under various weather conditions at Japan southwestern coast, and quantified the particle-attached and free-floating bacteria in dust and nondusty air from the Asian continent.

Keywords: Bacterial aerosols; Anderson sampler; Size range; Distribution mode; Air flow; Bacterial deposition