JOURNAL OF ENVIRONMENTAL SCIENCES XX (2016) XXX–XXX

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JES JOURNAL OF ENVIRONMENTAL SCIENCES

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Review

Approach of molecular methods for the detection and monitoring of microbial communities in bioaerosols: A review

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ARTICLE INFO

Article history:
Received 27 April 2016
Revised 4 July 2016
Accepted 8 July 2016
Available online xxxx

Keywords:
Bioaerosol
Airborne microbial community
Molecular methods
Metagenomics

ABSTRACT

Bioaerosols significantly affect atmospheric processes while they undergo long-range vertical and horizontal transport and influence atmospheric chemistry and physics and climate change. Accumulating evidence suggests that exposure to bioaerosols may cause adverse health effects, including severe disease. Studies of bioaerosols have primarily focused on their chemical composition and largely neglected their biological composition and the negative effects of biological composition on ecosystems and human health. Here, current molecular methods for the identification, quantification, and distribution of bioaerosol agents are reviewed. Modern developments in environmental microbiology technology would be favorable in elucidation of microbial temporal and spatial distribution in the atmosphere at high resolution. In addition, these provide additional supports for growing evidence that microbial diversity or composition in the bioaerosol is an indispensable environmental aspect linking with public health.

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http://dx.doi.org/10.1016/j.jes.2016.07.002

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Introduction

Microorganisms are ubiquitous in the environment and play key functional roles in nearly all ecosystems (Jaenicke, 2005). Bioaerosols originate from all types of environments, including the atmosphere, soil, freshwater, and oceans, and their dispersal into air is temporally and spatially variable. Airborne dissemination is likely a natural and necessary part of the life cycle of many microorganisms (Morris et al., 2008). Bioaerosols are generally defined as aerosols or particulate matter of microbial, plant or animal origin and includes a wide range of antigenic compounds, microbial toxins, and viruses; the term bioaerosol is often used synonymously with organic dust (Douwes et al., 2003; Peccia and Hernandez, 2006). Bioaerosols are emitted from terrestrial, soil, forest, and desert dust, agricultural and composting activities, urban areas, wetlands, coastal, and marine environments (Gandolfi et al., 2013; Jaenicke, 2005). Modern industrial activities (*e.g.*, waste sorting, organic waste collection, composting, agricultural production, food processing, livestock raising, and wastewater treatment systems) also emit large amounts of bioaerosols, resulting in abundant exposure to biological
Q6 agents (Brodie et al., 2007; Douwes et al., 2003). According to Matthias-Maser et al. (2000), the proportion by volume of biological material among total airborne particulates is 28%, 22%, and 10% in remote continental, populated continental and remote maritime environments, respectively. It has been estimated that 16% to 80% of the mass of primary atmospheric aerosols is from biological sources (Jaenicke, 2005).

The components of bioaerosols range in size. Pollens from anemophilous plants have typical diameters of 17–58 μm, fungal spores are typically 1–30 μm in diameter, bacteria are typically 0.25–8 μm in diameter, and viruses are typically less than 0.3 μm in diameter. Fragments of plants and animals may vary in size. Biological material does not necessarily occur in the air as independent particles. Shaffer and Lighthart (1997) determined that the majority of bacteria at inland sites are associated with particles of aerodynamic diameter greater than 3 μm. Bacteria may occur as agglomerations of cells or may be dispersed into the air on plants or animal fragments, on soil particles, on pollen, or on spores that have become airborne. Bioaerosols are a ubiquitous component of the atmosphere; a large number of these particles are small-sized microorganisms. Airborne bacterial and fungal cells can reach concentrations of ~10^3 and ~10^5 cells/m^3, respectively. Aerosolized bacteria and fungi are present in at altitudes of up to 10–20 km in the troposphere and even altitudes of 20 to 40 km above sea level in the stratosphere (Fahlgren et al., 2011).

Accumulating evidence indicates an important role of bioaerosols in the atmospheric environment (Brodie et al., 2007; Douwes et al., 2003; Georgakopoulos et al., 2009; Peccia et al., 2008). Bioaerosols contribute to atmospheric physical and chemical processes (Fig. 1) (Deguillaume et al., 2008; Jaenicke, 2005). Strong correlations between the variations in atmospheric bacterial community structures over time and the physical and chemical characteristics of air masses have been observed (Fierer et al., 2008; Maron et al., 2005). Ariya and Amyot (2004) suggested that bioaerosols play significant roles in atmospheric chemistry and physics by altering the chemistry of the atmosphere via microbiological degradation, thus modifying the chemical composition of other organic compounds upon collision or contact and driving chemistry at environmental interfaces, such as the air-particle interface. Recent studies have demonstrated that bioaerosols can become attached to ambient particles and have significant climatic effects, acting as cloud condensation nuclei and ice nuclei that can initiate precipitation (Amato et al., 2005; Bauer et al., 2002; Christner et al., 2008; Morris et al., 2008; Sattler et al., 2001). One study determined that approximately 33% of the ice-crystal residues in cloud-condensation nuclei and ice nuclei were biological particles (Pratt et al., 2009).

However, little is known about the composition of atmospheric bioaerosols and how it varies by location or meteorological conditions. Airborne microorganisms are very difficult to assess accurately under field conditions due to factors such as the collection efficiency of the selected sampler (Henningson and Ahlberg, 1994), variations in the robustness of different species of microorganisms, and the difficulty of differentiating strains of the same species (Griffin et al., 2001). The relationship between environmental conditions and bacterial aerial dispersal indicates that microbial compositions could increase the health risk due to pathogens or allergenic components of unclassified environmental bacteria. Bioaerosols may also cause climate change (Brodie et al., 2007). Bioaerosols likely do not survive for long durations due to atmospheric conditions, including wind, moisture, and UV exposure. However, concerns about bioaerosol exposures have increased in recent years because exposure to biological agents in both indoor and outdoor environments has been associated with a wide range of adverse health effects, including respiratory diseases, allergies and even cancer (Douwes et al., 2003; Shelton et al., 2002).

Although modern developments in the fields of microbiology, meteorology, and environmental science have opened up new possibilities for the study of bioaerosols, the field is dominated by a remarkable lack of knowledge and an abundance of speculation. Very few observations have been published comparing the aerial environment with other environments, such as water and soil, and the lack of standard methods, environmental guidelines, and databases complicates the interpretation and comparison of results.

Please cite this article as: Yoo, K., et al., Approach of molecular methods for the detection and monitoring of microbial communities in bioaerosols: A review, J. Environ. Sci. (2016), http://dx.doi.org/10.1016/j.jes.2016.07.002