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Reprint of bioaerosol: A bridge and opportunity for many scientific research fields

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ABSTRACT

Bioaerosol is a concept that is used to describe all biological materials suspended in the air, including bacteria, fungi, viruses, pollen, and their derivatives such as allergens, endotoxin, mycotoxins and etc. In some studies, primary biological aerosol particle (PBAP) is also coined to refer to intact microbes in the air. Bioaerosol is a multidisciplinary research subject, involving many different fields such as microbiology, mechanical engineering, air pollution, medical science, epidemiology, immunological science, biochemistry, physics, nanotechnologies and etc. The bioaerosol field has undergone about 200 years' research history since 1833 when mold spores were first detected in the air by Charles Darwin on the Cape Verde Islands. In recent decades, there has been a research boom in bioaerosol field, thus triggering many outstanding research opportunities. Visible progress has already been made in understanding bioaerosol roles in human health, atmospheric and ecological impacts as well as their respective technologies: bioaerosol capture, monitoring and also inactivation. Most recently, researchers from different fields start to bridge together for solving bioaerosol challenges and addressing key scientific problems, e.g., bioaerosol spread, real-time detection, indoor microbes, human bioaerosol emissions, and bio-defense. Toward this effort, a "Bioaerosol Xiangshan Science Conference-the 600th" has been successfully held in the summer in Beijing, China. A total of 47 scientists and funding agency officials including leading bioaerosol experts from overseas were invited and two-day long extensive discussions on bioaerosol progress and problems were carried out. Future bioaerosol directions have been outlined by the attendees during the conference. Some of the participants have also contributed to this bioaerosol special issue. This special issue consists of a total of 20 bioaerosol articles from eight countries including one review, and contributes to the advances in bioaerosol emission, transmission, health effects, ambient bioaerosols, method development and instrumentation, and control. Through this special issue, the bioaerosol community has obtained a better understanding of bioaerosol health risks and developed the corresponding strategies to confront the threats. This special issue might serve as a starting point to not only link bioaerosol scientists from different continents, but also bring together people from various fields yet with an interest in bioaerosol to collectively advance the field further.

1. Bioaerosol sources, transport and impacts

Bioaerosol collectively refers to all suspended particles of biological origins in the air. In theory, all biological materials can be released either directly or resuspension into the air upon various disturbances from the earth surfaces such as soils, oceans, animals, forests, humans and etc. Once airborne, as shown in Fig. 1 biaoerosol particles could undergo human inhalation, dry/wet depositions, aerial transport, ice nucleation, cloud condensation processes, atmospheric transformation and others. Accordingly, they have important impacts on infectious disease spread, allergic diseases, bio-security, atmospheric chemistry as well as climate (Douwes et al.,

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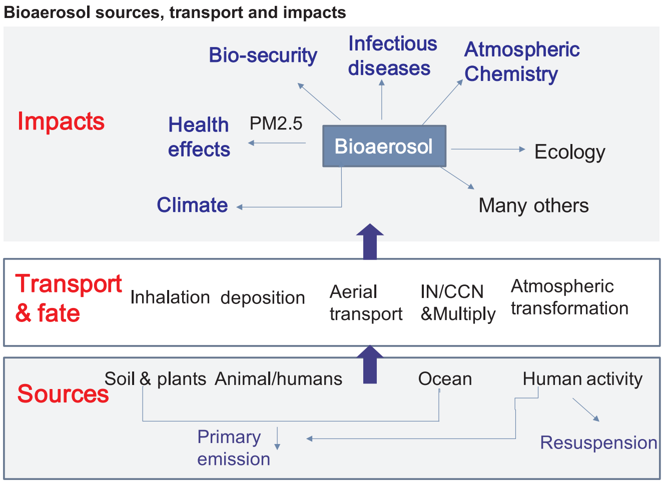

Fig. 1. Bioaerosol emission sources including primary and resuspension, transport & fate, IN/CCN, transformation and impacts.

2003; Nazaroff, 2016; Després et al., 2012; Xu et al., 2011; Dannemiller, Gent, Leaderer, & Peccia, 2016). According to World Health Organization (2016), lower respiratory infection is ranked as the 4rd killer of humans, among which children under the age of 5 is suffering significant loss of life. The evidence for bioaerosol related adverse health effects is accumulating and recognized by worldwide bioaerosol scientists, and this can be exemplified by the citations (> 800) of the review by Douwes, Thorne, Pearce, and Heederik (2003). In addition, the health threats from bioaerosol exposure can be also greatly enhanced by airborne transmission of infectious agents via breathing such as SARS in 2003 and H1N1 in 2009 and also the potential risks of biological agent attacks, e.g., the anthrax events in 2001 in the United States. In term with allergic diseases, a study by Shiraiwa et al. (2012) reports that allergenic potency of allergens can be significantly increased by the nitrification in polluted air, possibly explaining the increasing prevalence of allergy in urban cities. On another front, increasing number of studies show that bioaerosol particles could have played important roles in the atmospheric chemistry as oxidants/reducer and climate as ice nucleator (IN) and cloud condensation nuclei (CCN);and specific discussions can be found in the review by Després et al (2012) and Haddrell and Thomas (2017). In a recent work, it was shown that different geographic locations with varying climate conditions have distinctive fluorescent bioaerosol particle size distribution and concentration levels, which reflects or influences local ecological and microbial landscape (Wei et al., 2015) and such similar findings were also observed in the United States (Perring et al., 2015). In a recent review by Haddrell and Thomas (2017), it was pointed out that in next 10 years multidisciplinary approaches combining existing and novel techniques in atmospheric chemistry, aerobiology and molecular biology will merge to help understand the long-sought mechanisms of bioaerosol transport and decay. In addition to these impacts, some other studies are also emerging such as use of bioaerosols as forensic fingerprints (Castillo, Staton, Taylor, Herckes, & Hayes, 2012) and bioaerosol emissions from humans via breathing or skin (Hospodsky et al., 2012; Xu, Wu, & Yao, 2017; Yamamoto, Hospodsky, Dannemiller, Nazaroff, & Peccia, 2015). During the summer of 2017, the 600th "Xiangshan Science Conference (2017)" with a bioaerosol focus has been successfully held in Beijing, China. A total of 47 scientists and funding agency officials including leading bioaerosol experts from overseas were invited and two-day long extensive discussions on bioaerosol progress and problems were carried out. Future bioaerosol directions have been outlined by the attendees during the conference. In the 600th Xiangshan Science Conference, participants also discussed the potential beneficial roles of bioaerosol on human's health such as the hygiene hypothesis. Nonetheless, biological fraction of particulate matter is often neglected in many health related studies, which could be partially due to limited established dose-response relationship for bioaerosol (Eduard, Heederik, Duchaine, & Green, 2012).

2. Bioaerosol sampling, detection and inactivation

In general, bioaerosol sampling is the first step toward characterizing bioaerosol exposure risks. For human health, indoor bioaerosols are more relevant, which are largely originated from human emissions, floor resuspension and some direct emissions such as fungal spore emissions (Qian, Peccia, & Ferro, 2014; Yamamoto et al., 2015). During the 600th Xiangshan Science Conference, majority of the participants agreed that airborne transmission of infectious agents was responsible for the larger outbreaks of infectious disease spreads. During the conference, the participants also outlined several challenges for bioaerosol sampling as shown in Fig. 2, e.g., low quantity and small size and also loss of viability and identification property during the collection process. Among others, electrostatic sampling and wetted cyclones are attracting great attention (Yao and Mainelis, 2006; Han, Nazarenko, Lioy, & Mainelis, 2011; McFarland et al., 2010). Previously, it was discussed that high volume aerosol-to-hydrosol sampling is greatly needed in order to concentrate bioaerosol agents into small amount of liquids (Xu et al., 2011). It was concluded that specific sampler should be selected for a particular species of interest, and no standardized sampling protocol can be generalized in other studies (Haddrell & Thomas, 2017; Haig, Mackay, Walker, & Williams, 2016). Overall, the sampling has to be adjusted accordingly for different purposes of the studies. With the development of metagenomics, bioaerosol researchers are now able to analyze thousands of microorganisms