



Concentrations and size distributions of viable bioaerosols under various weather conditions in a typical semi-arid city of Northwest China



Yanpeng Li^{a,b,*}, Rui Lu^a, Wanxin Li^a, Zhengsheng Xie^a, Ying Song^a

^a School of Environmental Science and Engineering, Chang'an University, Xi'an 710054, PR China

^b Key Laboratory of Subsurface Hydrology and Ecology in Arid Areas, Ministry of Education, Xi'an 710054, PR China

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ABSTRACT

In recent years, atmospheric particulate matter (PM) has become one of the top pollutants affecting the air quality and human health in Xi'an, the largest city in semi-arid inland of China. Few studies have been carried out on the microbial fraction of PM (defined as bioaerosols) in this region, especially under specific weather conditions. In this study, airborne microbial samples in Xi'an city were collected from Aug. 2014 to Jul. 2015. The concentrations and size distributions of airborne viable bacteria and fungi were characterized under different weather conditions (e.g. sunny, cloudy, rainy and hazy days). The results showed that the concentrations of airborne viable microbes in Xi'an were lower than those in most cities worldwide due to the semi-arid climate feature. The concentrations of airborne viable microbes varied by weather conditions, with the highest value observed on hazy days and the lowest observed on rainy days. In particular, the mean concentrations of viable bacteria and fungi on the hazy days (1311 ± 371 and 896 ± 559 CFU/m³) exceeded the recommended permissible limit values in China. Moreover, the size distribution of airborne viable bacteria presented a similar unimodal pattern under four weather conditions, while no clear distribution pattern for airborne viable fungi was found in the non-haze weathers. Another important finding was that more than 60% viable bioaerosols were in respirable size range under all weather conditions. The present results can improve our understanding on the influence of viable bioaerosols on human health and air quality in semi-arid regions under various weather conditions.

1. Introduction

With rapid urbanization and industrialization over the past 20 years, the increasing energy consumption and traffic vehicles have caused serious air pollution in Xi'an, the largest city in northwestern China. Atmospheric particulate matter (PM), especially fine fraction, has become one of the main pollutants affecting air quality in Xi'an (Niu et al., 2016). In addition to chemical components of PM, the microbial fraction of PM, generally named as bioaerosols, has substantial effects on atmospheric environment and human health. Bioaerosols are defined as airborne particles or large molecules carrying living organisms or released from living organisms (e.g., bacteria, fungi, viruses, pollen) (Ariyap and Amyot, 2004). It has been reported that bioaerosols may contribute as much as 25% to atmospheric aerosols (Jaenicke, 2005). Exposure to bioaerosols may lead to adverse health effects including infectious diseases, acute toxic effects, allergies and cancers (Douwes et al., 2003; Goldman and Huffnagle, 2009; Walser, Gerstnera, Brennera, Büngeberg,

* Corresponding author at: School of Environmental Science and Engineering, Chang'an University, Xi'an 710054, PR China.

E-mail address: liyanp01@chd.edu.cn (Y. Li).

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Eikmann, Janssen and Herra, 2015). Therefore, bioaerosols have attracted more and more attention in recent years.

Extensive studies have been conducted to quantify characteristics of airborne bacteria and fungi for indoor and outdoor environments in different regions of the world: residence or public buildings (Pastuszka et al., 2000; Kim and Chi, 2007; Karbowska-Berent et al., 2011; Frankel, Bekö, Timm, Gustavsen, Hansen and Madsen, 2012; Nasir and Colbeck, 2010; Li, Wang, Guo, Wang, Fu, Zhao and Wang, 2015a), agricultural or food processing settings (Zorman et al., 2008; Kim et al., 2009; Martin et al., 2010; Rajasekar and Balasubramanian, 2011), waste solid or waste water treatment factories (Huang et al., 2002; Fracchia et al., 2006; Grisoli, Rodolfi, Villani, Grignani, Cottica and Berri, 2009; Li, Qiu, Li, Ma, Niu, Wang and Feng, 2012; Li et al., 2013), urban traffic area or educational area (Wu, Chan, Rao, Lee, Hsu, Chiu and Chao, 2007; Fang et al., 2008; Gao et al., 2015; Li, Fu, Wang, Liu, Meng and Wang 2015b), and rural or coastal region (Li, Qi, Zhang, Huang, Li and Gao, 2011; Hurtado, Rodríguez, López, Castillo, Molina, Zavala and Quintana, 2014; Dong, Qi, Shao, Zhong, Gao, Cao and Chu, 2016). These studies have indicated that the concentrations and size distributions of bioaerosols have great regional and seasonal variations, depending on such biotic and abiotic factors as the type of microorganism species, environmental conditions, and human activities. For example, the concentration of total microorganisms ranged from 4800 CFU/m³ to 24,000 CFU/m³ in Beijing, China (Fang et al., 2008), and the concentration range of total airborne microbes was 8.49×10^4 – 2.11×10^6 Cells/m³ in Qingdao, China (Dong et al., 2016) while the total airborne fungi concentration was in the range of 184–16,979 spores/m³ in Cincinnati, Ohio, USA (Adhikari et al., 2006).

Some studies have found that meteorological factors (e.g. relative humidity, temperature, wind direction and wind speed etc.) play major roles in bioaerosol concentrations and their transport (Jones and Harrison, 2004; Mouli et al., 2005; Burrows et al., 2009; Qi, Zhong, Shao, Gao, Wu, Huang and Ye, 2015; Zhong et al., 2016; Gao et al., 2016). High relative humidity can favour microbial growth, resulting in elevated bioaerosol concentrations. High temperature and intensive solar radiation may increase die-off rates and thus lead to the reduced microorganisms. However, most previous studies on bioaerosols in ambient air have been carried out on clean sunny days. More recently, several researchers begin to investigate the biological properties of PM during the haze episodes (Gao et al., 2015; Li et al., 2015b; Dong et al., 2016). It is worth noting that the haze day has been forecasted as a category of weathers (like sunny, cloudy and rainy) by China Meteorological Administration (CMA) in recent years. Different weather is well known to be characterized by different meteorological factors. However, available measurement data under other clean days and haze days are not yet sufficient although those existing studies have examined the correlation between airborne microbes and meteorological factors. In addition, in contrast to numerous studies in other geographic regions, the characteristics of bioaerosols in arid or semi-arid regions have been rarely investigated. Therefore, it is essential to determine the concentration and size distribution of bioaerosols in arid or semi-arid regions under various weather conditions, especially on hazy days, in order to provide a baseline understanding of their influence on human health when exposed to airborne microorganisms in various environments.

The present study was carried out in a typical semi-arid city with the aim of addressing these gaps in our knowledge. Therefore, bioaerosol samples in Xi'an, China were collected and analyzed to characterize the concentrations and size distributions of bioaerosols on sunny, cloudy, rainy and hazy days from Aug. 2014 to Jul. 2015. The objectives of this study are to acquire the knowledge of bioaerosol characteristics under various weather conditions, and further to provide basic data for hazard evaluation of bioaerosols on human health and for future determination of Chinese official standard of outdoor air quality.

2. Materials and methods

2.1. Sampling sites

Xi'an (34.22°N, 109.18°E, 424 m above sea level and 1100 km from the sea), located in the center of the Guanzhong Plain, has a population of over 8.468 million and an area of 39,064 km². It is surrounded by the Loess Plateau and Qinling Mountain. As a typical semi-arid inland city, Xi'an has four distinct seasons with long summer and winter and short spring and autumn. In general, the climate feature in Xi'an is rainy and humid in summer and cold and dry in winter with an annual average temperature of 13.0–13.4 °C and annual precipitation of 558–750 mm. The prevailing wind direction is North-East i.e., NE 12% and East–North–East i.e., ENE 8%.

The field sampling of ambient bioaerosols was carried out on the roof of School of Environmental Science and Engineering building of Chang'an University, which is located in the southern part of Xi'an city, as shown in Fig. 1. The building is approximately 20 m above the ground, which is situated between the 2nd and 3rd ring roads in Xi'an. The distance of the site from nearby major roads is about 400 m. The site is surrounded by the trees, greenbelts, residential and school buildings. There are no specific industrial pollution sources surrounding the site.

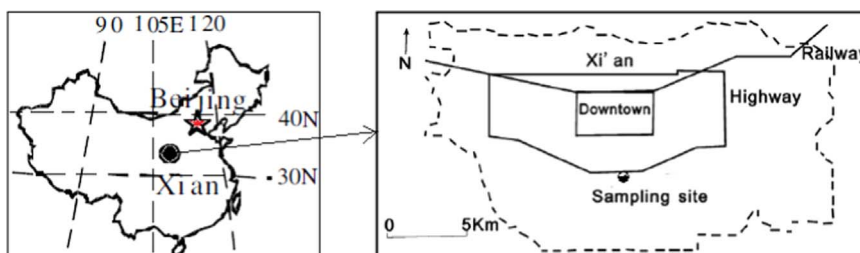


Fig. 1. Location of the sampling site at the south of downtown of Xi'an, China.

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