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Variation of correlations between factors and culturable airborne bacteria and fungi

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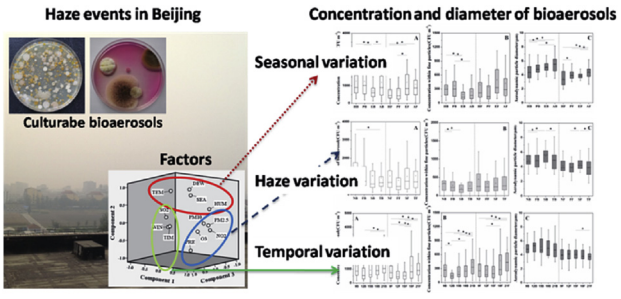
HIGHLIGHTS

- Bioaerosol characteristics vary with haze-level, season, and time of day.
- The influences of PM10 and temperature on bioaerosols vary with haze level.
- PM2.5 has a seasonal influence on concentrations but not on diameters of bioaerosols.
- A temporal influence of PM10 on bioaerosol concentration appears during rush hour.
- SO_2/NO_2 shows a temporal influence on bioaerosol in the morning/evening and mid-day.

GRAPHICAL ABSTRACT



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ABSTRACT

Bioaerosols, including their characteristics and overall changes correlated with environmental factors, have the potential to impact human health and influence atmospheric dynamics. In this study, the varying interrelationship between the concentration and diameter of culturable bioaerosols and twelve factors including PM2.5 (AQI), PM10 (AQI), sampling time, sampling season, temperature, relative humidity, dew, pressure, wind, O_3, NO_2, and SO_2 is determined for twelve months during non-haze and haze days in Beijing. Results of principal component analysis (PCA) indicated that the influence of factors on culturable bioaerosols is mainly associated with haze levels, sampling time, and season. Multiple linear regressions showed that the correlation between PM10 (AQI) or temperature and culturable bioaerosols varied at different haze levels. The seasonal influence of PM2.5 (AQI) was observed in culturable bioaerosol concentrations, but not their diameters. A temporal relationship between PM10 (AQI) and culturable bioaerosol concentration was detected during rush hour. SO_2 and NO_2 show positive and negative correlations with culturable bioaerosol concentrations in the morning/evening and mid-day, respectively. These results are useful for accurately evaluating the health effects of exposure to bioaerosols.

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1. Introduction

Suspended particulate matter (PM), present in the atmosphere

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for extended periods of time can have profound adverse effects on ecosystems and human health (Tao et al., 2014). Recent accounts of increasing PM and haze event frequency and intensity have been reported globally including China (Li and Zhang, 2014), France (http://earthobservatory.nasa.gov/IOTD/view.php?id=83356) and India (Rastogi et al., 2014) and making this an international issue. As a significant portion of atmospheric PM, bioaerosols may cause or aggravate allergic and asthmatic reactions (Yamamoto et al., 2012) and are considered a strong risk factor for various health problems. It has become a growing public concern in recent years (Cao et al., 2014).

Because bioaerosols are usually bound to PM (Glikson et al., 1995), and it's biological and morphological characteristics may experience considerable changes during a haze event (Alghamdi et al., 2014). These changes in microbial dispersal patterns and aerodynamic diameters could lead to variations in deposition locations in human respiratory tracts (Monn, 2001). Under the high concentration of atmospheric chemicals on haze days, potential synergistic effects between biological and chemical pollutants may further intensify the hazards on human health (WHO, 2005).

To uncover the changes of bioaerosols during air pollution episodes, linear or multiple regressions have been used to explore the relationships between bioaerosol characteristics, various meteorological parameters, as well as non-biological pollutants (Adhikari et al., 2006; Sousa et al., 2008; Degobbi et al., 2011; Grinn-Gofroń et al., 2011; Abdel Hameed et al., 2012). However, during heavy haze days with PM2.5 concentrations greater than 500 $\mu g\ m^{-3}$ there are very few investigations on possible haze-associated variation of ambient bioaerosols (Cao et al., 2014; Gao et al., 2015). Moreover, the correlation between factors and bioaerosols vary in different conditions, such as time of day, season (Hasheminassab et al., 2014), year (Sousa et al., 2008), and air pollution levels. For example, the level of aeroallergens (Sousa et al., 2008) or correlations between air pollutants, meteorological parameters, and concentration of airborne fungi (Grinn-Gofroń et al., 2011) depend on the episodes analyzed. To better understand the accurate influence of bioaerosols on human health and atmospheric dynamics under different conditions, a particular investigation of the complicated interrelationships is needed between environmental factors and bioaerosols.

Beijing, as an international megacity, has been exposed to haze for a long time (Cheng et al., 2013). In the present study, the concentration and diameter of culturable airborne bacteria and fungi and twelve factors is determined during non-haze and haze days in Beijing. PCA was used to determine the main components of the factors on the concentration and diameter of culturable bioaerosols based on one-year data. The particular variation of correlation between the culturable bioaerosols and factors were discussed further under three main components that included different haze, temporal, and seasonal conditions respectively using stepwise multiple regressions.

2. Materials and methods

2.1. Sampling site

Beijing (115.7°E–117.4°E, 39.4°N–41.6°N), China, is located on the North China Plain, with an area of 16,800 square kilometers (38% flat lands and 62% mountains). The area is surrounded by mountains to the north, south, and west with a northern temperate monsoon climate. Bioaerosols were collected atop the roof of the Beijing Academy of Agriculture and Forestry Sciences building (20 m high), on the Western 4th Ring Road of Beijing. There are no large industrial manufacturing facilities in that area.

2.2. Measurement of culturable bioaerosols

Samples were collected from January 14, 2013 to January 22, 2014, and data from 189 of the 218 sampling days were used in this study. To detect temporal differences, samples were collected at 9:00, 12:00, 15:00, 18:00, and 21:00 each day. Three consecutive replicates were taken for each single sampling time. Sampling of culturable bacteria and fungi was performed using an Andersen six-stage cascade impactor (Applied Technical Institute of Liaoyang, China). All inside surfaces were maintained in sterile condition until sampling and the six-stage impactor was sterilized between sampling using 75% ethanol. Bacteria samples were incubated on 20 ml nutrient agar medium (LB, Ao boxing Biotech, Co., China) at 37 °C for 48 h and fungi were cultivated on 20 ml Rose Bengal medium (BR, Ao boxing Biotech, Co., China) at 25 °C for 72 h (Li et al., 2011a, b). Colony forming units (CFU, from third to sixth stages) were counted using positive-hole correction (Andersen, 1958).

The total concentrations of airborne bacteria (BCON) and fungi (FCON) were sums of CFU from the first to sixth stages, while concentrations of airborne bacteria (BPM2.5) and fungi (FPM2.5) were sums of CFU from the fourth to sixth stages. Geometric mean diameters (d_g) were calculated (Hinds, 1999) to characterize the particle sizes of airborne bacteria (BD) and fungi (FD).

2.3. Meteorological meters and chemical air pollutants

The air quality index (AQI) value of PM2.5 was used to indicate the haze level (Wang et al., 2006) in this study. We defined PM2.5 (AQI) ranges of 0–100, 100–200, 200–300, and higher than 300, as non-haze, First, Second, and Third level haze days, respectively. Other factors recorded simultaneously, including temperature (TEM), relative humidity (HUM) and dew (DEW), pressure (PRE), wind (WIN), O_3, NO_2, and SO_2 were obtained from http://cdc.cma.gov.cn. One-year factors during the bioaerosol samplings are listed in Table 1.

2.4. Data analysis

PCA was chosen as the initial procedure to cluster a large number of factors into small groups called components to explain the observed variability (Degobbi et al., 2011). Stepwise multiple linear regressions were performed to indicate the statistically significant relationships between characteristics of bioaerosols (BCON, BPM2.5, FCON, FPM2.5, BD, and FD) and PM2.5, PM10, TEM, HUM, DEW, PRE, WIN, O_3, NO_2, and SO_2 during different haze levels, seasons, and sampling times. A T-

Table 1
One-year information for factors during bioaerosol sampling.

	N	Min	Max	Median	Mean	SD	SE
PM2.5(AQI)	189.00	14.00	493.00	174.00	196.31	118.94	8.65
PM10(AQI))	183.00	1.87	387.00	99.00	107.35	73.70	5.45
O3(AQI))	160.00	1.00	69.00	12.50	16.91	14.73	1.16
NO2(AQI))	160.00	4.00	84.00	30.00	32.78	19.85	1.57
SO2(AQI))	154.00	1.00	127.00	17.50	28.40	27.33	2.20
HUM(%)	181.00	2.90	88.00	43.00	45.08	22.62	1.68
DEW(°C)	158.00	−35.00	22.00	5.00	2.20	12.80	1.02
TEM(°C)	182.00	−8.00	40.70	19.00	17.00	11.56	0.86
WIN(m/s)	168.00	0.00	61.10	4.00	6.20	6.72	0.52
PRE(Pa)	158.00	992.00	1040.00	1019.00	1017.96	10.88	0.87

*N is sampling number.
SD is Standard deviation.
SE is Standard error of mean.

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