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Microorganisms associated particulate matter: A preliminary study

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HIGHLIGHTS

- We determined the microbiological quality of particulate matter in an urban area.
- We found fungi and actinobacteria in low counts.
- $1/PM_{2.5}$ concentration was the main determinant of microbial concentrations.
- Negative correlation was found between O_3 and $PM_{2.5}$.
- Temperature had negative effect on microorganisms associated $PM_{2.5}$.

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ABSTRACT

This study aims to determine the microbiological quality of particulate matter (PM) in an urban area in Jeddah, Saudi Arabia, during December 2012 to April 2013. This was achieved by the determination of airborne bacteria, fungi, and actinobacteria associated PM_{10} and $PM_{2.5}$, as well as their relationships with gaseous pollutants, O_3, SO_2 and NO_2, and meteorological factors (T°C, RH% and Ws). High volume samplers with PM_{10} and $PM_{2.5}$ selective sizes, and glass fiber filters were used to collect PM_{10} and $PM_{2.5}$, respectively. The filters were suspended in buffer phosphate and aliquots were spread plated onto the surfaces of trypticase soy agar, malt extract agar, and starch casein agar media for counting of bacteria, fungi and actinobacteria-associated PM, respectively. PM_{10} and $PM_{2.5}$ concentrations averaged 159.9 μg/m^3 and 60 μg/m^3, respectively, with the ratio of $PM_{2.5}/PM_{10}$ averaged ~0.4. The concentrations of O_3, SO_2 and NO_2 averaged 35.73 μg/m^3, 38.1 μg/m^3 and 52.5 μg/m^3, respectively. Fungi and actinobacteria associated PM were found in lower concentrations than bacteria. The sum of microbial loads was higher in PM_{10} than $PM_{2.5}$, however a significant correlation ($r = 0.57$, $P \leq 0.05$) was found between the sum of microbial loads associated PM_{10} and $PM_{2.5}$. *Aspergillus fumigatus* and *Aspergillus niger* were the common fungal types associated PM. Temperature significantly correlated with both PM_{10} ($r = 0.44$), and $PM_{2.5}$ ($r = 0.5$). Significant negative correlations were found between O_3 and $PM_{2.5}$ ($r = -0.47$), and between SO_2 with PM_{10} ($r = -0.48$). Wind speed positively correlated with airborne microorganisms associated PM. The regression model showed that the inverse $PM_{2.5}$ concentration ($1/PM_{2.5}$) was a significant determinant of fungal count associated PM. Chemical processes and environmental factors could affect properties of PM and in turn its biological quality.

1. Introduction

Particles with both biological and non-biological origins are transported together with air currents in the atmosphere. Particles originate from various natural and anthropogenic sources, and affect visibility, climate, air quality, and human health (Fuzzi et al., 2006). Particle concentrations are influenced by meteorological conditions, long-range transport of pollutants, and new particle formation in the air (Sippula et al., 2013). Particles are removed from the air either by sedimentation or precipitation (Despres et al., 2012).

Biological particles/bioaerosols are particles of biological origin suspended in the air such as: bacteria, fungi, viruses, microbial toxins, proteins and enzymes (ACGIH, 1999). Such particles may be suspended in the air either as individual organisms or attached to dust particles or tiny droplets of water (Lighthart, 1997). Bioaerosols tend to attach in

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coarser PM fraction, however fungal spores, fragmented pollen, and non-agglomerated bacteria are found in the fine fraction as well (Meklin et al., 2002), due to the mechanism of reaction between biological agents and PM (Oikonen et al., 2003).

Biological particles have received less attention in the atmosphere than other aerosol particles such as: sulfates, mineral dust and ash (Friedlander, 2000), because its average concentrations have been assumed to be insignificant compared to non-biological particles (Penner et al., 2001; Kuhn and Ghannoum, 2003). Fungi accounted for up to ~10% of organic carbon, and ~5% of PM_{10} at urban and suburban locations (Bauer et al., 2008). In pristine tropical rainforest airborne fungal spores accounted for up to ~45% of a coarse PM (Despres et al., 2012). Biological materials above land constituted ~25% of the total particulate matter (Jones and Harrison, 2004).

Bioaerosols undergo daily and seasonal changes depending on environmental factors, and human activities (Rossi et al., 2005). The survival of airborne microorganisms may be affected by hydrocarbons, NO_2 and SO_2 (Ho et al., 2005), and trace elements (Jackson et al., 1978). PM bound with airborne pollen and fungal spores (Glikson et al., 1995) could alter their biological and morphological characteristics. Physical, chemical and biological compositions of suspended dust may be changed depending on dust source, whether it originated from desert or dried wetland (Soleimani et al., 2013). Smoke contains deleterious compounds that may either kill microorganisms or modify their antigenic properties (Abdel Hameed, 2003). PM may change microbial dispersal pattern, and alter their aerodynamic diameters (Monn, 2001).

T°C, RH% and wind speed affect concentrations and viability of airborne microorganisms (Jones and Harrison, 2004). Climate change could alter the timing and abundance of aeroallergens and the growth and distribution of organisms that produce them (Burge and Rogers, 2000).

Less information is available on microbial community associated PM in arid regions. However few studies have been directed to investigate the factors affecting microorganisms associated non-biological particles and their health effects. A number of studies provide interesting information pertinent to evaluate bioaerosols in contributing to health effects associated with exposures to ambient PM (Stevanovic and Nikic, 2006). Health responses may be enhanced when chemical and biological constituents of particulate matter are combined together (USEPA, 2004).

The purposes of the present study were to 1) gain information on the microbial community associated PM_{10} and $PM_{2.5}$, with particular focus on fungi, and 2) determine relationships between microbial community associated PM with air pollutants (PM, O_3, NO_2, and SO_2), and meteorological parameters in an urban–arid region.

2. Materials and methods

2.1. The sampling site

Jeddah, 21.4869°N; 39.39.2517°E, is a costal city located in the western region of the Kingdom of Saudi Arabia on the Red Sea (Fig. 1). Jeddah's climate is warm and moderate in winter, and high temperature and humidity in summer (Khodier et al., 2012), with spare or no rainfall. Traffic, power stations, oil refinery and desalination plants are the main sources of air pollution.

The sampling site was located at the King Abdulaziz University campus (a sensitive place). It is an urban area characterized by high traffic density and barren with no vegetation or farmland. The air samplers were positioned at a height of ~8 m above the ground on a rooftop of the Faculty of Meteorology, Environment and Arid Land Agriculture Building, during the period between December 2012 and April 2013.

2.2. Particulate matter sample collection

$PM_{2.5}$ and PM_{10} samplers (Staplex Air Sampler Division, USA) operated at flow rate of 1.13 m^3/min were used to collect $PM_{2.5}$ and PM_{10}. The daily (10 AM–10 AM) $PM_{2.5}$ and PM_{10} samples were collected on

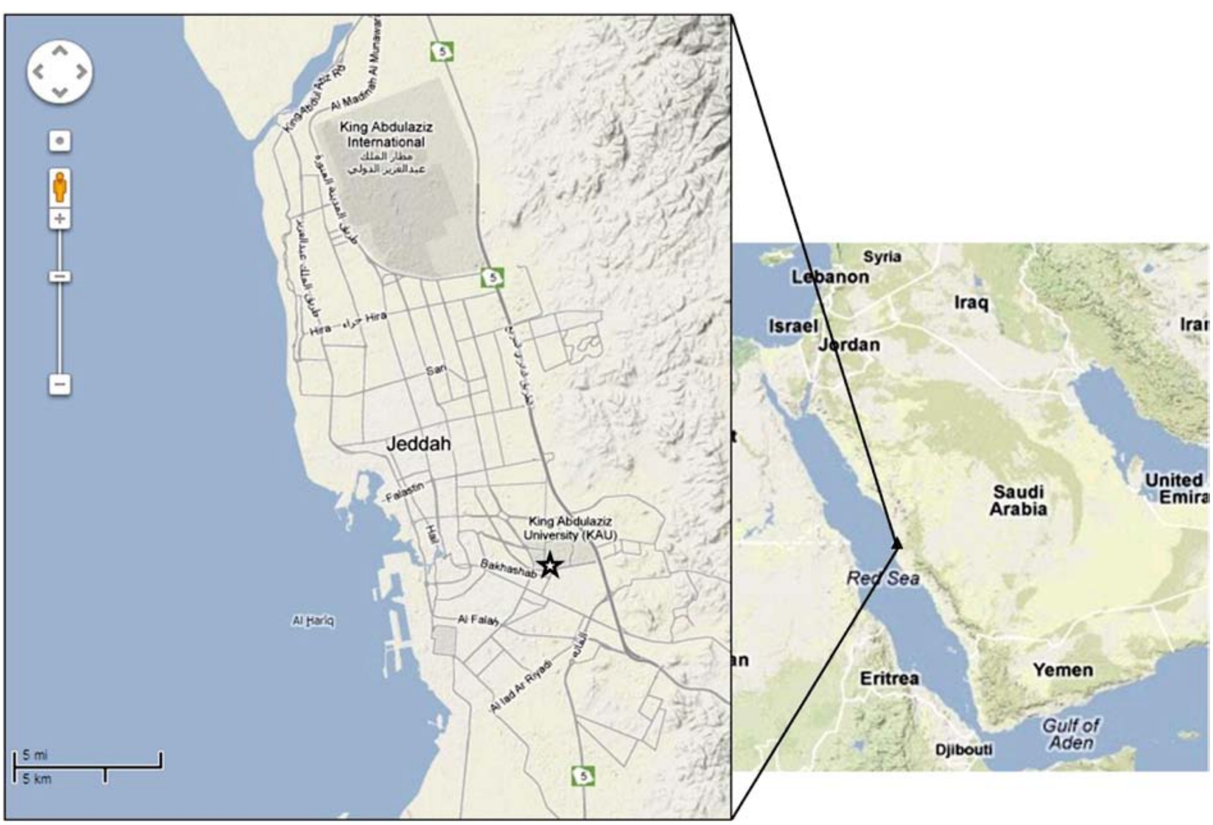

Fig. 1. Map of Jeddah with the sampling site marked with a star. Map data ©Google, 2013 Terra Metrics.