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Microbial and size characterization of airborne particulate matter collected on sticky tapes along US–Mexico border

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ABSTRACT

Particulate matter (PM) emissions from various sources can affect significantly human health and environmental quality especially in the Chihuahuan Desert region along US–Mexico border. The objective of this study was to use the low-cost sticky tape method to collect airborne PM for size characterization and identification of fungal spores. Sticky tape samplers were placed at 1.0 and 2.0 m above the ground surface at experimental sites in Ciudad Juárez, Mexico and at 0.6, 1.2 and 1.8 m at New Mexico sites, USA. Soil samples were collected in both countries to determine fungal diversity, texture and moisture content. Dust particles collected from all of the experimental sites had a dominant texture of clay (<0.002 mm). The dominant textures identified from soil samples collected from the US and Mexican sites were loam and sandy clay loam, respectively. *Alternaria*, *Penicillium* and *Fusarium* were frequently found funguses in the US sites while *Alternaria* and *Aspergillus* were commonly observed in the Mexican sites. The sticky tapes also showed a similar diversity of fungal microorganisms present in the airborne PM at both Mexico and US sites. *Alternaria*, *Penicillium* and *Aspergillus* were the three groups of airborne fungal microorganisms consistently present in the US and Mexican sites. The low-cost sticky tape method has the potential to be used for characterizing different airborne microorganisms and dust particles.

Introduction

The components of particulate matter (PM) emitted during dust storms and wind erosion events are inorganic particles consisting of the mineral fraction of the soil, chemicals present in the soil, and organic materials. The organic components of the PM may include microorganisms such as bacteria, viruses and fungi that can be transported over long distances (Després et al., 2012; Waisel et al., 2008). Previous studies have reported the transport of bacteria and fungi from the eastern hemisphere to the western hemisphere (Kellogg et al., 2004; Prospero et al., 2005; Smith et al., 2012). The atmospheric transport over long distances of some microorganisms is attributed to their capacity of forming spores and resisting desiccation (Kellogg et al., 2004; Al-Subai, 2002).

Large masses of fungal spores released into the air represent an important component of bio-aerosols and are considered elements of atmospheric contamination around

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the world. They constitute a significant fraction of bioparticles in air and can have implications for human health by causing allergies and a variety of diseases (Li and Kendrick, 1994; Abu-Dieyeh et al., 2010). However, not much is known on the relationship between fungal spores and their effects on health. Also, the knowledge of types of fungal species and their relative frequencies under different scenarios is important for understanding the exposure to the population (Shelton et al., 2002).

Human exposure to fine dust particles and airborne microorganisms is not uncommon in arid regions where fine soil particles are suspended in the air as result of strong winds over soils with low moisture content (Al-Dabbas et al., 2011; Griffin and Kellogg, 2004). Cornelis and Gabriels (2003) and Madden et al. (2010) reported that the emission of PM is negatively correlated with soil moisture content after conducting experiments under laboratory conditions using a closed blowing-type wind tunnel and mechanical laboratory dust generator, respectively. Similar results were reported by Funk et al. (2008) after conducting laboratory and field experiments. Vehicular movement through unpaved roads contributes to PM emissions in arid regions (Flores-Márgez et al., 2011; Gillies et al., 2005; Pinnick et al., 1985; Williams et al., 2008). PM emissions are produced from agricultural fields as a result of particles $\leq$32 μm in diameter that are transported primarily by suspension (Sharratt, 2011; Shukla and Flores-Márgez, 2014).

Agricultural activities such as tillage and harvesting are sources of fungal spores that are transported from agricultural fields to adjacent rural and urban areas. Lee et al. (2006) evaluated the exposure to dust and bioaerosols collected on farms and reported that farmers were exposed to fungal spores during the harvest. Awad (2005) evaluated the role of vegetation as a source of airborne fungi and identified the common airborne fungal genera in rural and urban areas of Egypt. *Alternaria*, *Aspergillus*, *Penicillum* and *Cladosporium* were the dominant fungal genera found at all sampling sites, however *Alternaria* was dominant in cultivated areas while *Aspergillus*, *Penicillum* and *Cladosporium* were frequently detected in urban areas (Awad, 2005). *Cladosporium*, *Penicillum*, *Aspergillus* and *Alternaria* were the dominant airborne fungal genera in a study conducted by Medrela-Kuder (2003) which evaluated the seasonal variation in the occurrence of airborne fungi in outdoor and indoor environments in Poland. Medrela-Kuder (2003) reported that *Cladosporium* was the dominant fungus in air samples collected indoor and outdoor during summer, while *Penicillum* and *Aspergillus* were the dominant funguses in both test sites during winter. Shelton et al. (2002) reported that *Cladosporium*, *Penicillum* and *Aspergillus* were the most common culturable airborne fungi found both indoors and outdoors during all seasons and regions of the United States.

There is a vital need to quantify the inorganic, organic, chemical, and biological components of airborne PM because of their potential to adversely impact human health. Low-cost methods to measure organic, inorganic and microbial components of airborne PM are needed to monitor particle emissions. The combination of sticky tape samplers and rotorods is a low-cost method previously used to characterize only PM from unpaved roads (Williams et al., 2008). The objective of this study was to identify different types of fungi in the soil and in the PM collected on sticky tapes in the Chihuahuan Desert region along US–Mexico border. The data generated can be used to calibrate air quality models for forecasting the concentration of airborne fungal spores during dust storms.

1. Materials and methods

1.1. Experimental sites

Experimental sites are located in New Mexico, USA and Ciudad Juárez, Mexico along the USA–Mexico border. Experiments were conducted from January to September 2011 at four of the experimental sites, Anthony, Leyendecker Plant Science Research Center south of Las Cruces, Deming and Columbus, USA. Experiments were also conducted at three experimental sites, site 1 (Juárez 1), site 2 (Juárez 2) and site 3 (Juárez 3) in Ciudad Juárez, Mexico from October 2012 to April 2013. Juárez 1 and Juárez 2 are separated by 12 km while there is a distance of 4 km between Juárez 2 and Juárez 3 moving from north to southeast. Experimental sites in New Mexico were located in rural areas with unpaved roads, while experimental sites in Ciudad Juárez were located in urban areas with paved (Juárez 1) and unpaved (Juárez 2 and Juárez 3) roads. All the experimental sites were located in populated areas in the Chihuahuan Desert region along the US–Mexico border. Therefore, the microbial and size characterization of airborne PM from these sites is important for assessing impacts on the health of the people living in these areas in both countries.

1.2. PM and soil sampling

The low-cost sticky tape method (Williams et al., 2008) with rotorods was used to measure PM from unpaved roads at each experimental site. Double-sided sticky tapes (STR tape 0.076 mm thick; Shinto Paint Company Ltd.) and rotorods of a constant speed motor, U-rods (Sampling Technologies Inc., 1989) were combined to develop the sticky tape method. The sticky tape method consists of two rotorods installed on a steel tower of 1-inch in diameter. One of the rotorods was placed at 1.0 m and another at 2.0 m height above the ground surface in the experimental sites of Ciudad Juárez, while rotorods were placed above the ground surface at 0.6, 1.2 and 1.8 m in experimental sites of New Mexico. Each rotorod had two wings, and on each wing a transparent microscope glass slide (Microscopes Plus Ltd., Hertfordshire, UK) and a double-sided sticky tape were attached (Fig. 1).

Before conducting the dust monitoring, each glass slide was weighed using an analytical balance (OHAUS Adventure Pro, Parsippany, NJ, USA) with precision of four decimal points. The glass slides were stored in a box (HS15989RF, Fisher Durable slidebox) for microscope glass to avoid dust contamination before and after their use. A dry pre-labeled glass slide with sticky tape was placed at each wing of the rotorod. The rotorods were attached to a 9 V battery installed on the tower. Before turning on the rotorod, the adhesive tape was carefully peeled off and stored in a clean plastic Ziploc

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