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Technical note

Concentration of environmental fungal and bacterial bioaerosols during the monsoon season

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ABSTRACT

Rain has been known to remove aerosol particles in air environments. The aerosol particles were captured and removed from the air by rain and the concentration of aerosol particles significantly decreased after rain events. Therefore, rain is regarded as having a good effect on air environments in terms of the respiratory health of the general public. However, humid environments produced by long-term rain events such a monsoon may be a sufficient condition for the growth of microorganisms and vibrations because of the splashing of droplets may facilitate the aerosolization of ground microorganisms. We therefore hypothesize that the rain may increase concentrations of bioaerosols in outdoor air environments, thereby possibly influencing respiratory diseases.

To verify this hypothesis, at the initial stepwise approach, we measured the concentration of airborne biological particles before, after, and during rain in a monsoon season. The measurement data of the concentration of fungal particles and bacterial particles show quantitatively that the bioaerosol concentrations during the rain event are several times higher than the concentration of the bioaerosols in the condition of no rain.

1. Introduction

An aerosol is defined in its simplest form as a collection of solid or liquid particles suspended in air. Aerosols are two-phase systems, consisting of the particles and the gas in which they are suspended. These aerosol particles suspended in the air that we breathe cause health problems (Hinds, 1999). A bioaerosol is an aerosol of biological origin. Bioaerosols include viruses, bacteria, fungi, and products of organisms (fungal spores and pollen) (Lee, 2011). The sources of bioaerosols are plants, animals (including humans), soil, and water. Bioaerosols are found in many types of indoors and outdoors. They vary greatly in the way they affect, not only our health and quality of life, but also visibility and the climate (Douwes et al., 2003; Hinds, 1999).

Bioaerosols have considerable influence on public health and may play an important role in the indoor air environment. Bioaerosols are suspected to be etiological agents for respiratory diseases such as allergic rhinitis, asthma (Bush & Portnoy, 2001; Cockcroft et al., 1977; Fiegel et al., 2006; Fung & Hughson, 2010; Zuskin et al., 1994), chronic obstructive pulmonary disease (COPD) (Lacey & Crook, 1988; Matheson et al., 2005; Olenchock et al., 1990), and for infectious diseases such as influenza and Severe Acute Respiratory Syndrome (SARS) (World Health Organization: WHO, 2009). In particular, bacterial

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bioaerosols are known to relate to pneumonia, tuberculosis, brucellosis, anthrax, and Q fever (Arancibia et al., 2002; LaForce, 1986). Allergic effects of bioaerosols come from chemical components of bioaerosols and infection effects of bioaerosols come from viability of bioaerosols (Robbins et al., 2000; Shelton et al., 2002). Bioaerosols also received special attention in 2001 during events of bioterrorism (Center for Disease Control and Prevention, 2001). Therefore, because of the importance of bioaerosol researches, in several previous studies, the concentration of bioaerosols has been measured in indoor environments. In those studies, bioaerosols have been measured in restrooms (Lee et al., 2012), hospitals (Li & Hou, 2003; Pastuszka et al., 2005), houses (Jeon et al., 2010; Jo & Seo, 2005; Lee & Jo, 2006; Ren et al., 1999; Roberts et al., 2006), and work places (Chang et al., 2001; Kalogerakis et al., 2005; Kim et al., 2007; Lacey & Crook, 1988; Law et al., 2001). Most previous studies show a wide range of the number concentrations of total culturable bioaerosols in indoor air environments and the results of those studies indicate the necessity of continuous monitoring and studying the indoor bioaerosol concentrations.

In addition, bioaerosols affect atmospheric chemistry (Pöhlker et al., 2012). Recently, increasing attention has been paid to the relationship between bioaerosols and the atmosphere. It is well known that the atmosphere is a conveyor of bioaerosols. However, it is also a site where significant microbial processes can take place during transport (Sattler et al., 2001). Bioaerosol particles in the atmosphere have been known to impact on the formation of clouds. Bioaerosol particles can act as ice or cloud nuclei in clouds (Huffman et al., 2013; Möhler et al., 2007; Pratt et al., 2009). Despite the importance of outdoor bioaerosol concentrations from the perspective of public health and atmospheric sciences, the current practical measurements of the concentration of bioaerosols are rare and it remains insufficient (Menetrez et al., 2007; Yeo & Kim, 2002). In particular, quantitatively measured data for special events are scarce.

In this study, we measured the number concentrations of total culturable bioaerosols in outdoor air environments rather than in indoor air environments. We focus on the effect of rain on bioaerosols among many specific events. Rain has been widely known to remove aerosol particles in air environments. The aerosol particles were captured and removed from the air by a rain event and the concentration of aerosol particles significantly decreased after rain events. Therefore, rain is considered to have a favorable effect on air environments in terms of the respiratory health of the public. However, rain events such as a long term monsoon, cause an increase in the humidity of the air environments. The humidity increase can affect the growth of the bioaerosols (Jones & Harrison, 2004). Therefore, a bioaerosol living environment may be created during this season. Furthermore, rain that may trigger bioaerosol emissions due to droplet splash vibrations can increase bioaerosol concentrations by the convective lifting of bioaerosols into the ambient air. To verify this hypothesis of the increase of bioaerosol concentrations in a monsoon season, the change in the concentrations of bioaerosols caused by rain events was evaluated in this study as an initial step for studying effects of rain on bioaerosols. We collected data before, during, and after rain events in a monsoon season in Seoul, Republic of Korea, where tens of millions people live currently. We measured the number of concentrations of total culturable fungal and bacterial bioaerosols in three outdoor air environments – in the forest, by the lake, and near a building – via a standard measurement method provided by the Ministry of Environment of the Republic of Korea. An indoor air environment – inside the lecture building of Konkuk University – was also chosen for measurements to compare with the data from the outdoor air.

The aim of this study is to provide an initial baseline understanding of the relationship between rain and bioaerosols in outdoor environments and to examine the quantitative level of concentrations of bioaerosols during rain events. This study presents the experimental results and discusses the findings.

2. Experimental methods

We used a sampler (Bio-culture sampler, Buck bio-culture, Model B30120, A.P. Buck, Inc., Orlando, Florida, US) for capturing fungal and bacterial bioaerosols. This sampler is an impactor type sampler with a flow rate of 100 l/min. The air containing fungal and bacterial particles was accelerated through 400 nozzles of the sampler and the potential fungal and bacterial particles were deposited onto the agar plate of the sampler. The potential fungal particles were deposited onto the agar which contained MEA (maltose 12.75%, dextrin 2.75%, glycerol 2.35% peptone 0.75% and agar 15%). The deposited fungal particles and normal particles were incubated at 25 °C for 48 h. The potential bacterial particles were deposited onto the agar which contained nutrient agar (beef extract 3%, peptone 5%, and agar 15%). The deposited bacterial particles and normal particles were incubated at 37 °C for 24 h. We enumerated the number of colonies and calculated the concentration of culturable fungal and bacterial bioaerosols in the air environment with the unit of CFU/m^3.

Figure 1 shows the locations where measurements were conducted. The measurement campaigns were conducted at Konkuk University which was located in the west side of Seoul, Republic of Korea. The measurement area around Konkuk University was a highly crowded area in Seoul (hundreds of thousands of pedestrians every day). We measured the number of concentrations of total culturable fungal and bacterial bioaerosols in three outdoor air environments – in a forest, by a lake, and near a building – and one indoor environment. One indoor measuring location was inside a six-story building that was not air-conditioned. We sampled bioaerosols at 40 cm above the ground surface with at least three replications.

We measured the outdoor fungal and bacterial bioaerosol concentrations for the summer season in Seoul, Republic of Korea. Especially, we measured the concentrations from July 1, 2013 to July 26, 2013, which was in the middle of the monsoon season of Korean peninsula. We chose this season because we wanted to compare fungal and bacterial bioaerosol concentrations on rainy days with the concentration on days without rain. We sampled bioaerosols during lunch time (around 12:30) when many people usually go outside for taking a walk.