ATMOSPHERIC ABUNDANCE AND VARIABILITY OF BIOAEROSOLS FROM AN URBAN LOCATION AT KANPUR IN CENTRAL IGP

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Abstract : It has been widely realized that bioaerosols play a very important role in climate change through participation in the carbon cycle of the ecosystem and holding potential cloud condensation nuclei (CCN) as well as ice-nucleation (IN) activity. Also, they are responsible for causing many allergenic effects. Human exposure to bioaerosols through physical contact or inhalation may lead to adverse health effects like asthma, COPD (chronic obstructive pulmonary disease), whooping cough and sick-building syndrome, etc. Thus, it is of utmost importance to study their occurrence and effects in indoor and outdoor environments. However, despite being a very important area of research, bioaerosols have been studied little less over Indian region. Towards this, we have conducted a year-long campaign to study and document bioaerosols variability from central IGP. We observed large seasonal variability in the concentration of bioaerosols. Gram-negative bacteria (GNB), a source of endotoxin in ambient air, averaged at 180 ± 90 CFU/m^3 during post-monsoon (October–November); 200 ± 75 CFU/m^3 during winter (December–February); 75 ± 25 CFU/m^3 during pre-monsoon (March-May) and 110 ± 60 CFU/m^3 during SW-monsoon (June–September).A parallel enhancement in GNB abundance was observed with the biomass burning emissions intensification period ($t = 4.0$, $p < 0.05$).

***Index Terms*- Bioaerosols, Northern India, Seasonal variability.**

I. INTRODUCTION

Bioaerosols represent the air suspended particles that are living (Fungi, bacteria, and viruses) or have been originated from living organisms (e.g., pollens from plants). Their presence in the atmosphere is plausibly a function of dispersal from a site of colonization, survival, and/or growth. The health effects of bioaerosols include allergies, infectious diseases, and acute toxic effects. Furthermore, cancer, in conjunction with the threat of bioterrorism and SARS (severe acute respiratory syndrome), has increased public awareness on the importance of the study on bioaerosols. There are numerous technical methods for sampling bioaerosols and can be employed depending on the method sensitivity or concentration of microorganisms. There have been difficulties and challenges in the standardization of sampling methods. The major problems include the establishment of a causal relationship arising due to the complex composition of bioaerosols and variation in human response as a function of exposure. It has been a widely followed activity to monitor bioaerosols in various microenvironments for epidemiological investigations about infectious diseases. The research on airborne microorganism's abundance, spread, and control represents as a quality control measure on monitoring bio-hazardous and relevance to their impact on climate (as CCN: cloud-condensation nuclei and IN: ice-nuclei). In many developing countries, including India, there is a very little awareness on the indoor air quality, contamination of mould and potential factors for transmission of infections (ranging from mild influenza to deadly tuberculosis).

II. METHODOLOGY

Study site at Kanpur (Urban location: 26.30 °N; 80.14 °E) is situated in the central part of IGP.The IGP is stretched from north-west to the north-east region in India (Chakraborty et al., 2017, Rajput et al., 2019, Sorathia et al., 2018). This region holds ~ 40% of the south Asia's population and produces over 85% of the rice-wheat. Nearly 20 million hectares of agricultural-land area is located in NW-part of IGP (states of Punjab, Haryana and western part of Uttar Pradesh). Due to crop rotation activity, a conspicuous seasonal and annual feature, poor farmers burn 100s of million tons of paddy-residues (during October–November) and wheat-residues (during April–May)(Rajput et al., 2014). Under prevailing NW-winds, our sampling site is strategically located downwind of the major agricultural-fields in IGP(Choudhary et al., 2018). Thus, the sampling location is influenced by massive biomass burning activities(Kumar et al., 2018). The region experiences usually ~ 1000 mm annual precipitation with harsh summers and cold winters associated with fog events(Rajput et al., 2018). However, year 2015 (annual rainfall of 375 mm) was influenced due to El Niño(Rajeev et al., 2018).

Fig. 1: Sampling setup of bioaerosols sampler(Chauhan, 2016).

Measurements of viable bioaerosols (n ≈ 125) have been performed for one year from June 2015–May 2016 at CESE (Center for Environmental Sciences and Engineering) building in the campus of Indian Institute of Technology Kanpur. Using a single-stage impactor (aerodynamic diameter > 0.6 µm) sampler (flow rate: 12 LPM) (Gupta and Chauhan, 2014), viable bioaerosols were collected at ~ 1.5 m from ground level and cultured in Petri dishes equipped with specific nutrient agar mediums. Sampling setup of bioaerosols sampler is shown in figure 1. We have collected (three days a week) and cultured GPB in Mannitol Salt Agar Broth (MSAB), GNB in MacConkey and Fungi in Sabrouraud Dextrose Agar medium. Briefly, petri dishes (n = 3 for each day sampling) equipped with specific nutrient agar mediums were placed in the air-sampler, and the collection was subjected to 4 min for every three types of mediums sequentially. Soon after the collection, these bioaerosols in separate petri dishes were incubated at 35 °C for microbial culture in our lab (Atmospheric Particle Technology Lab, in CESE). Subsequently, their enumeration (counted) through a magnifying lens was performed into a bio-safety cabinet. The well-established protocol has been followed to proper sterilize the sampler as well as nutrient media every time before sampling. The images of specific agar mediums and post to bioaerosols sampling and incubation are shown in figure 2.

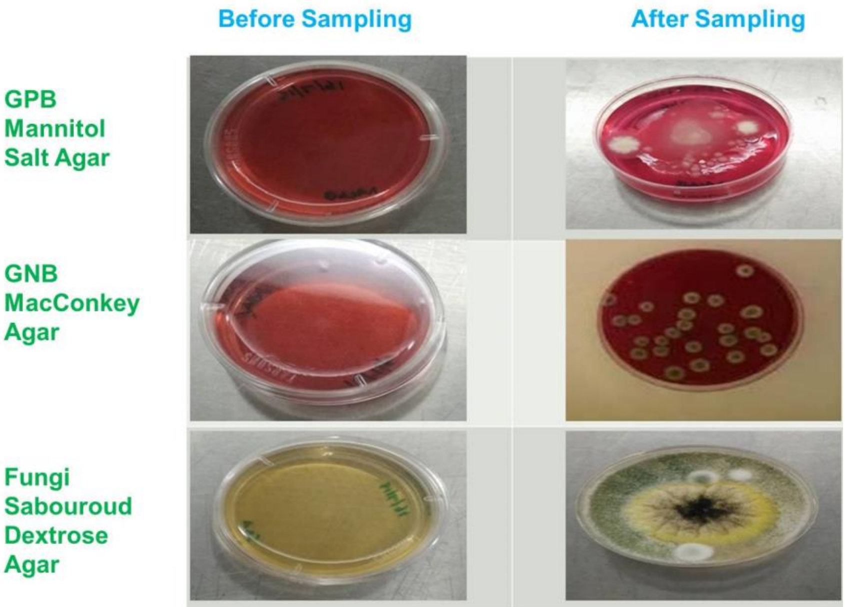

Fig. 2: Images of specific nutrient agar mediums before and after bioaerosols sampling.

III. RESULTS & DISCUSSION

3.1 Brief overview

Biologically produced (from plants/animals) aerosols are widely referred to as bioaerosols (also referred to as primary biological aerosol particles: PBAPs). Improper sanitation, waste-disposal practices, and biomass burning may also result in the generation of huge amounts of microbes in the air. In the atmosphere, they are ubiquitous as bacteria, viruses, fungal spores, bio-debris, and pollens. The size of different types of bioaerosols varies over a large range: viruses can be of less than 300 nm, bacteria in the range of 0.3–8 µm, fungal spores in the range of 1–30 µm and size of pollens are greater than 17 µm. The size of bio-debris (fragments from plants/animals) may vary from sub-micron to coarser fraction. It is important to mention here that bioaerosols can adsorb onto existing particles in the ambient atmosphere, and thus, their aerodynamic diameter and residence time can be influenced by the physical characteristics of the suspended particulates. The contribution of bioaerosols in the total particulate matter have been assessed previously from different environmental conditions reporting 28% over remote continental, 22% in populated continental and 10% in remote maritime environments (Matthias-Maser et al., 2000). A recent study (Zhu et al., 2016), has studied quantitatively the contribution of PBAP during daylight and nighttime in a temperate coniferous forest in Japan (at Wakayama). They have measured biomarkers of PBAP (fungal spores tracers: arabitol, mannitol, and trehalose) through solvent extraction followed by derivatization approach. The contribution of fungal spores in organic carbon (OC) was found to be relatively high in their study during nighttime (45%) as compared to that in daytime (22%) and they have attributed this observation to nocturnal sporulation under near saturated RH condition. Thus, the contribution of bioaerosols to OC can be quite significant over/near the forest/polluted region. Recent estimate of various major botanical species spread over ~ 1000 acres of lush-green campus of IIT Kanpur is provided in figure 3.

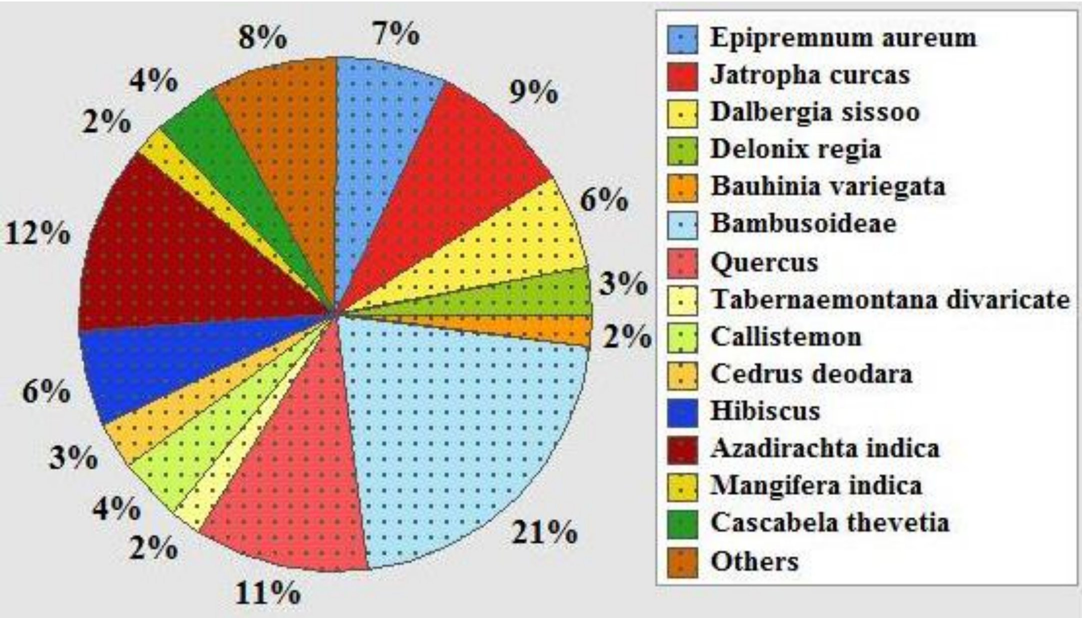

Fig. 3: Population density (in %) of major botanical species in ~ 1000 acres of the lush-green campus of IIT Kanpur.

3.2 Meteorological parameters

Meteorological parameters, including temp. (T), relatively humidity (RH), wind speed and rainfall during the study period have been monitored. It is important to mention here that air-mass back trajectories (AMBTs; Fig. 4) show a predominance of north-westerly and south-westerly wind system as a function of season.

3.3 Variability of viable bioaerosols colonies

The seasonal data set on bioaerosols variability is provided in Table 1. Total viable bioaerosols (Σviable bioaerosols = GPB + GNB + Fungi) concentration averaged at 310 ± 120 CFU/m^3 in monsoon, 420 ± 115 CFU/m^3 in post-monsoon, 490 ± 140 CFU/m^3 in winter and 220 ± 60 CFU/m^3 in pre-monsoon season, at Kanpur in IGP. Thus, the maximum concentration of Σviable bioaerosols was observed during wintertime, followed by post-monsoon >monsoon >pre-monsoon. We reiterate that in wintertime emissions from fossil-fuel combustion and bio-fuel burning in conjunction with low temperature and shallower boundary layer height are vital parameters co-governing the atmospheric concentrations of PM and viable bioaerosols.

Furthermore, we have also assessed the relative contribution of GPB, GNB, and Fungi of the Σviable bioaerosols (Fig. 5, Table 1). Accordingly, GPB has the highest fraction of 32% in wintertime. GNB has the highest fraction of 42% during the post-monsoon. This is also reflected in GPB/GNB ratio: 0.85 ± 0.55 in monsoon, 0.73 ± 0.44 in post-monsoon, 0.82 ± 0.17 in wintertime and 0.84 ± 0.37 in pre-monsoon. Summing up, GPB/GNB average ratio is > 0.80 in all seasons, the exception being the post-monsoon period wherein this ratio averaged at 0.7. Relatively lower ratio of GPB/GNB further revisits the observation that post-harvest paddy-residue burning (PRB) emissions are associated with elevated concentrations of GNB during post-monsoon. However, Fungi have higher fractions during monsoon (37%) and pre-monsoon (39%) with a maximum concentration of 290 CFU/m^3 during the monsoon (Fig. 5, Table 1). Bacteria/Fungi average ratio was ≥ 2.5 from monsoon through the wintertime, whereas it decreased to ~ 1.5 during the pre-monsoon (Table 2). Dry weather condition (low RH and high temperature) prevailing in pre-monsoon is attributable to a lower abundance of bacteria.

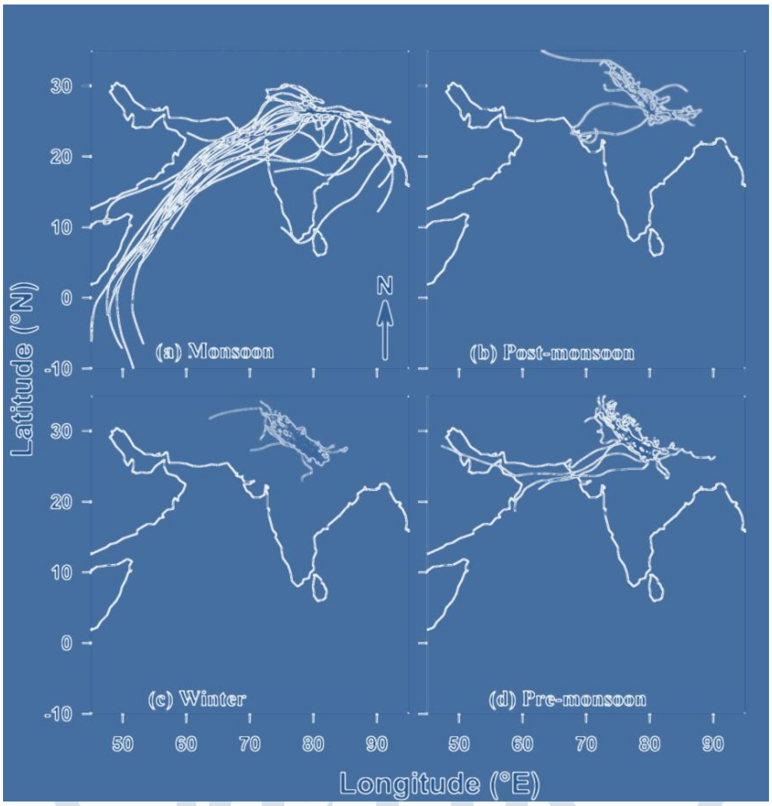

Fig. 4: Hysplit air-mass back trajectories (7 d; 100 m above ground level) during the study period.

Table 1.Seasonal abundance of bioaerosols in colony forming units (CFU/m^3) at Kanpur

Parameters	**Monsoon** (June–September)	**Post-monsoon** (October–November)	**Winter** (December–February)	**Pre-monsoon** (March–May)
GPB	21–188	28–166	63–272	21–125
GNB	21–292	25–352	63–325	42–146
Fungi	21–292	65–229	63–242	42–146

The other aspect we attempted to look into is percentage variability of these viable bioaerosols during different seasons of the studied year (Fig. 6). Briefly, we have transformed every data point by normalizing it concerning its percentage fraction. As we can see from figure 6 (also depicted from Fig. 5) that there is huge variability in percentage contribution of GPB, GNB, and Fungi during the entire study period. For example, overall GPB varied from ~ 10–60%, GNB varied from ~ 10–80% and Fungi varied from ~ 20–90%. Thus, based on 1-Y measurements coupled with meteorological data and relative abundance analysis of bioaerosols, it appears that bioaerosols are highly variable during each season and more studies are needed on bioaerosols characterization.

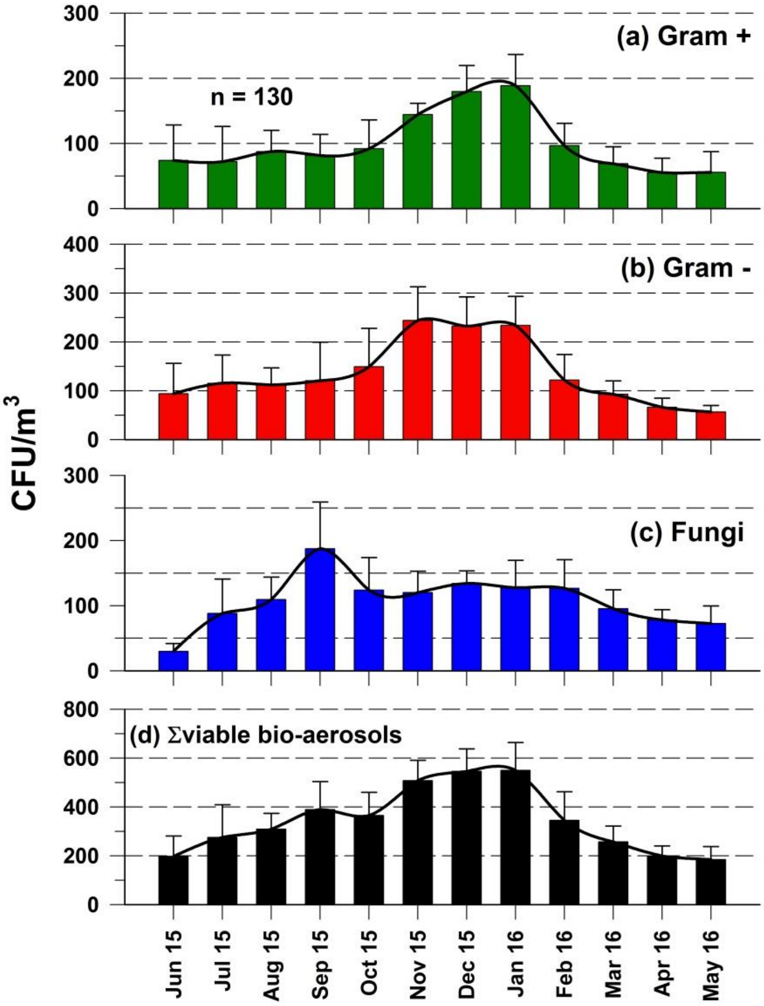

Fig. 5: Monthly averaged concentrations of bioaerosols in this study.

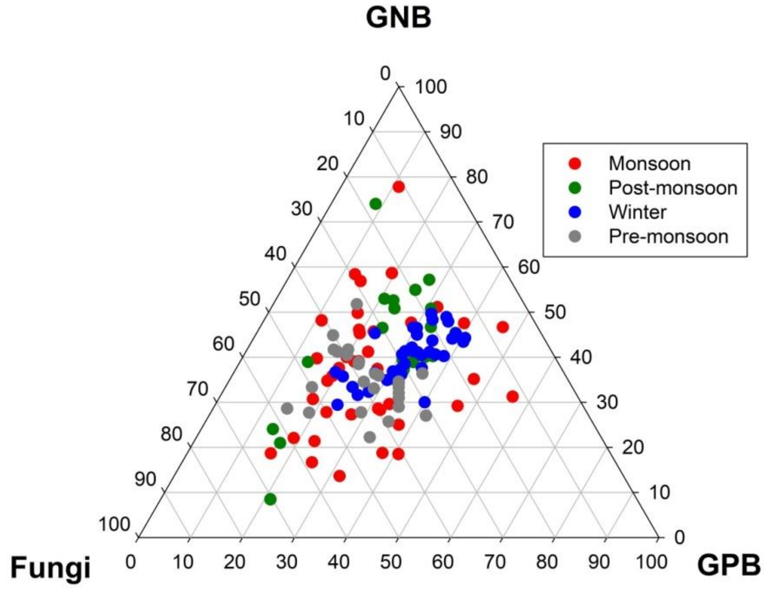

Fig. 6: Relative variability of bioaerosols (n = 130) in percentage during different seasons (GPB: gram-positive bacteria; GNB: gram-negative bacteria).

IV. CONCLUSIONS

Year-Long measurements of viable bioaerosols conducted from central IGP to assess their abundance and temporal/seasonal variability (Rajput et al., 2017). As far as viable bioaerosols are concerned, the highest concentration of GPB was recorded during December–January (Avg.: 190 CFU/m^3), GNB during November (Avg.: 240 CFU/m^3) and Fungi in September (Avg.: 190 CFU/m^3). We have attributed their major source of bioaerosols to be associated with anthropogenic emissions from PRB and bio-fuel burning in the IGP. Ambient temperature showed a negative impact on the abundance of GPB and GNB, whereas RH and wind-speed do not exhibit any pronounced effects. Low precipitation (<4 mm) relates to higher concentrations of bioaerosols, particularly the Fungi. Overall, GPB varied from ~ 10–60%, GNB varied from ~ 10–80% and Fungi varied from ~ 20–90%. This study provides field-based data on bioaerosols with a consideration of their potential role in influencing climate and human health.

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