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Experimental Investigation on Bio Aerosols to Determine Its Impacts

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ABSTRACT

Bioaerosols consist of aerosols originated biologically such as metabolites, toxins, or fragments of microorganisms that are present ubiquitously in the environment. International interests in bioaerosols have increased rapidly to broaden the pool of knowledge on their identification, quantification, distribution, and health impacts (e.g., infectious and respiratory diseases, allergies, and cancer). However, risk assessment of bioaerosols based on conventional culture methods has been hampered further by several factors such as: (1) the complexity of microorganisms or derivatives to be investigated; (2) the purpose, techniques, and locations of sampling; and (3) the lack of valid quantitative criteria (e.g., exposure standards and dose/effect relationships). Although exposure to some microbes is considered to be beneficial for health, more research is needed to properly assess their potential health hazards including inter-individual susceptibility, interactions with non-biological agents, and many proven unproven health effects (e.g., atopy and atopic diseases).

Keywords: Bioaerosols, Health, Environment, Sampling, Standards, Risk

I. INTRODUCTION

Bioaerosols are very small airborne particles (ranging from 0.001 to 100 μm) that originate biologically from plants/animals and can contain living organisms. Therefore, pathogenic and/or non-pathogenic dead or alive microorganisms (e.g., viruses, bacteria, and fungi) may exist in bioaerosols. Bioaerosols are easily shifted from one environment to another because of their small size and light weight. In recent years, exposure to bioaerosols in both occupational and residential environments has drawn much attention in light of their probable impacts on human health.

Sources of bioaerosol exposure in occupational activities are diverse enough to include waste sorting and composting, agricultural and food processing activities, the livestock industry, etc. Indeed, the prevalence of diverse respiratory diseases or symptoms (allergic asthma, rhinitis, airway inflammation, etc.) has been reported from workers susceptible to such exposure. Bioaerosols were estimated to be responsible for approximately 5 to 34% of indoor particulate matter air pollution. The sources of indoor bioaerosol pollution include outdoor sources (passing through windows, doors, and ventilation); building materials; furnishings; occupants; pets; house plants; and organic wastes (Nazaroff, 2016). Regular or ordinary human activities (e.g., coughing, washing, toilet flushing, talking, walking, sneezing, and sweeping floors) are also capable of generating bioaerosols (Chen and Hildemann, 2009). However, basic environmental conditions, such as temperature and moisture content, can considerably influence the extent of their formation and dispersion due to their controlling effect on the formation of microorganisms. Consequently, the prevalence of bioaerosols can be associated with certain human diseases, such as pneumonia, influenza, measles, asthma, allergies, and gastrointestinal illness. However, under certain circumstances, exposure to some microbes is beneficial for health in terms of developing a healthy immune system and protect children from developing allergies and asthma. Although the importance of bioaerosols and their impact on human health has been recognized, it is yet difficult to accurately describe their role in the initiation or worsening of diverse symptoms and diseases.

Table 1 Microorganisms and some of the major resulting diseases

Species	Approximate size	Resulting disease	Infection/transmission
Legionella pneumophila	Length: 2 μm Width: 0.3–0.9 μm	Legionnaires' disease	Inhalation of a water aerosol containing the bacteria
Mycobacterium tuberculosis	Length: 2–4 μm Width: 0.2–0.5 um	Tuberculosis	Person to person through the air
Bordetella pertussis	Length:40–100 nm Diameter: 2 nm	Whooping cough	Direct contact or inhalation of airborne droplets
Yersinia pestis	Length: 1–3 μm Width:0.5–0.8 μm	Pneumonic plague	Being bitten by infected rodent flea or by handling infected animals
Bacillus anthracis spore	Length: 3–5 μm Width: 1.0–1.2 μm	Anthrax	Contact with infected animals, flies, and the breathing of air containing anthrax spores
Variola vera	Length: 220–450 nm Width:140–260 nm	Smallpox	Inhalation of airborne variola virus, prolonged face-to-face contact with an infected person, direct contact with infected bodily fluids or contaminated objects
Herpesvirida, HHV-3	Diameter: 150–200 nm	Chickenpox and shingles	Direct contact with fluid from the rash blisters caused by shingles
Morbillivirus measles	Length: 125–250 nm Diameter: 21 nm)	Measles, mumps, and rubella	Bodily fluids: drops of saliva, mucus from the nose, coughing or sneezing, tears from the eyes, etc.

Varibrio Cholerae	Length: 1.4–2.6 µm Width: 0.5–0.8 µm	Cholera	Bite of contaminated food or a sip of contaminated water
Salmonella Typhi	Length: 0.7–1.5 µm Thickness: 28 µm	Typhoid	Through contaminated food or water and occasionally through direct contact with someone who is infected
Microsporum Trichophyton	Length:5–100 mm Width: 3–8 mm	Ringworm	Direct or indirect contact with skin or scalp lesions of infected people, animals or fomites

Sources of Bioaerosol

In ambient air, bio-aerosols can exist as particular entities or in aggregates with organic matter, particulate matter, water droplets and chemical constituents of aerosols, which provide an amiable condition for maintaining the metabolism of these organic components that can reproduce even under stressful conditions. Hence, for this reason, it is crucial to know the sources of bio-aerosols, their metamorphosis during the course of movement to atmosphere and recycling to biosphere, their impact on public health, agriculture as well as ecosystem including their role in global climate change. The initial step towards becoming airborne is to be aerosolized first from contaminated sites. Bio-aerosols are ubiquitous in nature and present in troposphere at an altitude of 10–20 km and even 20–40 km above sea level within the stratosphere.

Major sources of airborne microorganisms are municipal dumping areas, waste streams and discharge points, shabby water-soaked buildings, soil, degenerated and fermented plant and animal parts, sewage sludge dumping sites, animal husbandry, fermentation process, agriculturally active areas, animal houses, breeding farms, feedstuff-factory outlets and various other anthropogenic activities. Some bio-aerosols are released to the environment by naturally active processes such as through fungal spores, which are emitted through osmotic stress or floor pressure impact whereas some via passive process, equivalent to thallus debris and dried fungal spores mainly due to wind

Health Problems Caused by Bioaerosol

Potential health problems caused by bioaerosols depend on the pathogenicity or immunogenic potential of specific microorganisms and their compounds as well as other factors, such as environmental conditions that influence the survival of the microorganisms in the air and the behavior of the bioaerosol particles. There are two main groups of diseases associated with bioaerosol exposure: noninfectious diseases and infectious diseases.

Objectives of the Research

The overall aim of this research was to increase the knowledge about sources and the airborne transport of infectious bioaerosols in order to prevent diseases from spreading via air. This was achieved by field measurements in different environments.

The specific objectives of this research were to:

- Identify possible sources of infectious bioaerosols through field measurements in different environments.
- Investigate the effect of aerosolization processes and relative humidity during airborne transport.
- Evaluate ventilation techniques and rapid bioaerosol detection techniques as prevention strategies to avoid nosocomial infections.

II. LITERATURE REVIEW

Swati Tyagi and Arun Srivastava (2023) author evaluated the size segregated fungal bioaerosol concentrations and associated health risks among the workers of the sugar mill in the Muzaffarnagar district of Western Uttar Pradesh. The mean fungal bioaerosol concentration varied significantly across the different months, highest was in January and lowest in the month of March. In addition to the sugar mill activities (unloading, cutter, processing, packing and storage), inhabitants and meteorological parameters (such as relative humidity, wind speed and temperature), influenced the bioaerosol emissions. The presence of significantly high bioaerosol concentration was observed at the cutter site throughout the sampling period. Furthermore, maximum and minimum bioaerosol concentrations were observed in January and March month at the sugar mill site, respectively.

The dominant size range of fungal bioaerosol concentration was observed in stages 4 which is having the cut-off diameter of 2.1–3.3 μm, synonyms to the secondary bronchi of the human respiratory system. It indicates that the health of sugar mill workers who stayed inside the mill for a prolonged time might be at high risk. The HQ and HI were both observed to be less than 1, which indicates an acceptable hazard level. Nevertheless, the present study highlights the importance of reducing the fungal bioaerosol emission in the sugar mill by improving the ventilation system, usage of N95 masks, gloves, and other safety objects are advisable to reduce risk levels. Eight fungal genera were identified from the sugar mill site. Out of them, one was harmless, while three and five were immunotoxic and allergic, respectively. Penicillium, Aspergillus, Fusarium, Alternaria and Cladosporium were observed to be most abundant at all the sampling sites.

Pradeep Kumar et.al (2022) research paper aimed to isolate and characterize the seasonal (winter and spring) levels of culturable bio-aerosols from indoor air, implicating human health by using an epidemiological health survey. Microorganisms were identified by standard macro and microbiological methods, followed by biochemical testing and molecular techniques.

Sampling results revealed the bacterial and fungal aerosol concentrations ranging between (300–3650 CFU/m3) and (300–4150 CFU/m3) respectively, in different microenvironments during the winter season (December-February). However, in spring (March-May), bacterial and fungal aerosol concentrations were monitored, ranging between (450–5150 CFU/m3) and (350–5070 CFU/m3) respectively. Interestingly, Aspergillus and Cladosporium were the majorly recorded fungi whereas, Staphylococcus, Streptobacillus, and Micrococcus found predominant bacterial genera among all the sites. Taken together, the elevated levels of bioaerosols are the foremost risk factor that can lead to various respiratory and general health issues in additional analysis, the questionnaire survey indicated the headache (28%) and allergy (20%) were significant indoor health concerns.

Impact on Public Health

There are abundant living bacteria and residual biological particles in atmosphere, and these will act as a variety of carriers to influence human health and environment, exerting huge influence on social stability. According to one research, the exposure to some frequent microorganisms such as Streptococcus pneumoniae, Streptococcus pyogenes, Mycoplasma pneumoniae, Haemophilus influenzae, Klebsiella pneumoniae, Pseudomonas aeruginosa, and Mycobacterium tuberculosis can spell wide array of adverse effect: increasing probability of food pollution, deterioration of cosmetics and medicine as well as corrosion of metallic materials for infrastructure, leading to a huge economic losses. The potential hazard caused by bioaerosols depends on their specific pathogenicity and community structure. Sometimes even in the case of strains not identified as opportunistic pathogens can serve as a source of antibiotic resistance in the environment, thus posing a potential threat to public health. Moreover, the exposure to bioaerosols and chemical components attaching to particular matter lay hard upon the burden of health risk such as lower birth weight, frequent emergency room visit and hospital admission, more premature death and drastic infectious and chronic non-infectious diseases.

Respiratory Diseases

Why bioaerosol can invite severe respiratory diseases

From birth, microbes inside buildings seed, colonize, and transiently occupy our bodies, exerting influence on human health through aerosol deposition, surface contact, and human- animal interactions. In fact, bioaerosols can easily enter the respiratory tract, and a small part of them can exacerbate the occurrence and prevalence of infectious diseases which arise from exposure to biological agents by direct (i.e., licking, touching, biting) or/and indirect contact (i.e., cough, sneeze), vector-borne transmission and airborne transmission. Bioaerosols different in mass and structure are succumbed to source, aerosolization, and environmental condition prominent at the site. They can attach to particular matter, and have its aerodynamic as well as antigenic properties altered, strengthening their abilities to penetrating deeper regions of lung to trigger allergic, toxic and infectious responses in exposed individuals, including coughing runny nose, irritated eyes or throat, allergic rhinitis, aggravation of asthma and fatigue. The aerodynamic diameter of less than 2.5 μm may invites severe health risks, playing an important role in the prevalence of both non-infectious and infectious diseases, and a chronic exposure is linked to some deadly chronic disease, such as cancer.

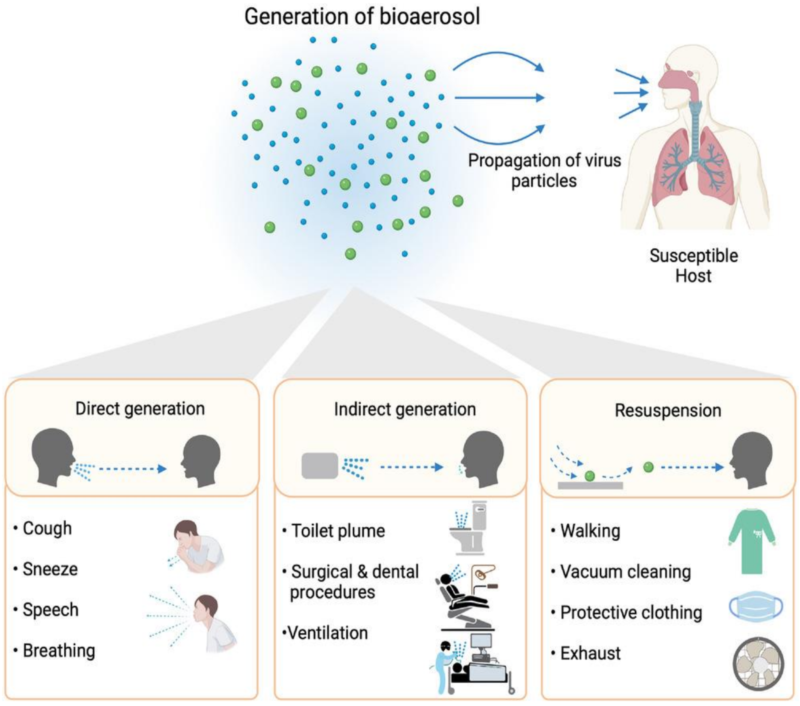


Fig 1 Medium of Bioaerosol Propagation.

III. METHODOLOGY

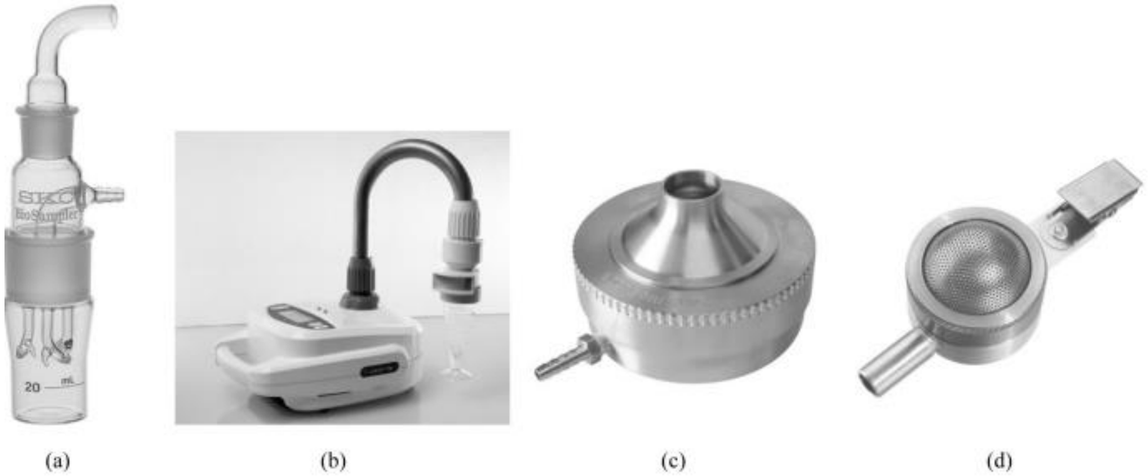


Fig 2 (a) SKC BioSampler (impinger); (b) Coriolis sampler (cyclone); (c) SKC BioStage Impactor; (d) SKC Button Sampler (filter).

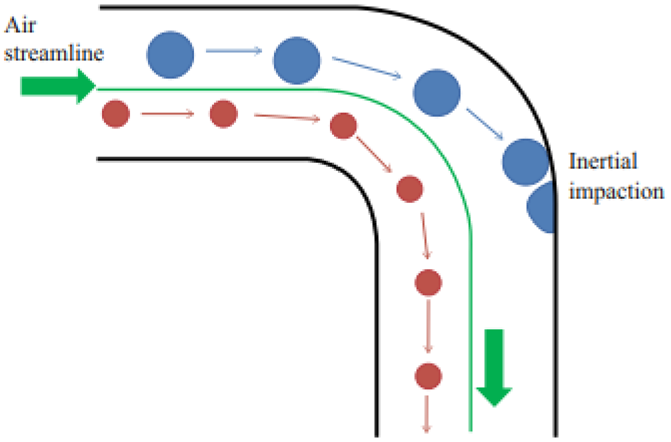


Fig 3 Inertial impaction in a pipe.

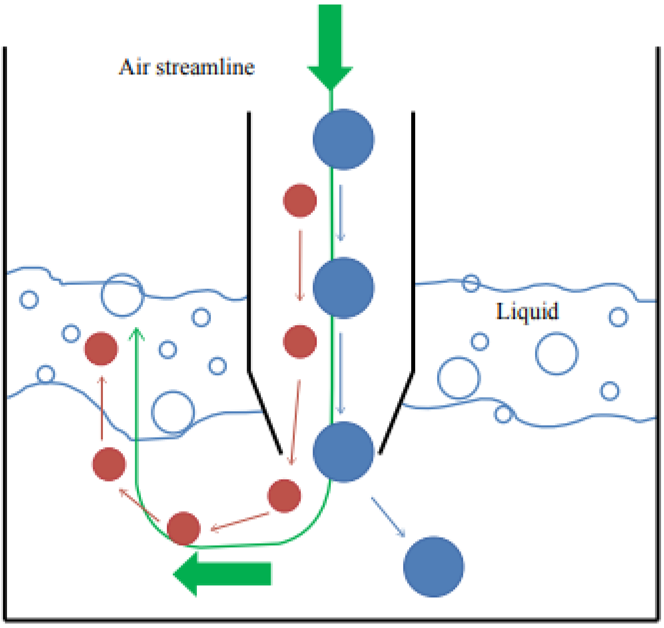


Fig 4 Particle-laden airflow in an impinger

IV. RESULTS AND DISCUSSION

Table 2. Variable distribution of bioaerosols, meteorological factors, ozone, particulate matter, trace elements, and organic carbon

Variables	n	Median	Media	SD	IQR
Total fungi (spores m3)	256	4229	3910	2458	3188
Aspergillus/ Penicillium	256	1771	1488	1218	1435
Alternaria	256	59	23	98	80
Ascospores	256	459	337	466	428
Basidiospores	256	417	335	369	456
Cladosporium	256	1171	630	1543	1085
Epicoccum	256	25	11	38	34
Rust spores	256	6	0	17	0
Smut spores	256	105	34	260	79
Total pollen (pollen m-3)	316	224	22	737	88
Ambrosia (Ragweed)	102	24	4	37	37
Acer (Maple)	122	35	0	133	6
Pinaceae (Pine, Fir, Spruce)	175	16	2	38	16
Poaceae (Grass)	232	6	2	12	5
Quercus (Oak)	127	211	2	793	65
Juniperus (Juniper, Cedar)	51	48	6	167	19
Ulmus (Elm)	87	52	5	165	31
Air pollutants					
Ozone (ppb)	306	28.31	28.37	11.74	16.02
PM10 (µg m-3)	181	23.99	22.03	10.73	14.22
PM2.5 (µg m-3)	303	17.2	15.07	8.87	11.46
Cadmium (µg m-3)	39	0.0029	0.0003	0.0061	0.0041
Copper (µg m-3)	39	0.0045	0.0035	0.0069	0.0058
Lead (µg m-3)	22	0.0125	0.005	0.0256	0.0101
Zinc (µg m-3)	39	0.026	0.0148	0.0362	0.3082
Organic Carbon (µg m-3)	35	5.26	4.81	2.14	2.72
Meteorological parameters					
Temperature (oC)	316	18.49	19.81	7.13	10.36
Relative humidity (%)	195	65.83	66.79	12.59	15.58

Abbreviations: n Z number of observations; SD Z standard deviation; IQR Z inter-quartile range.

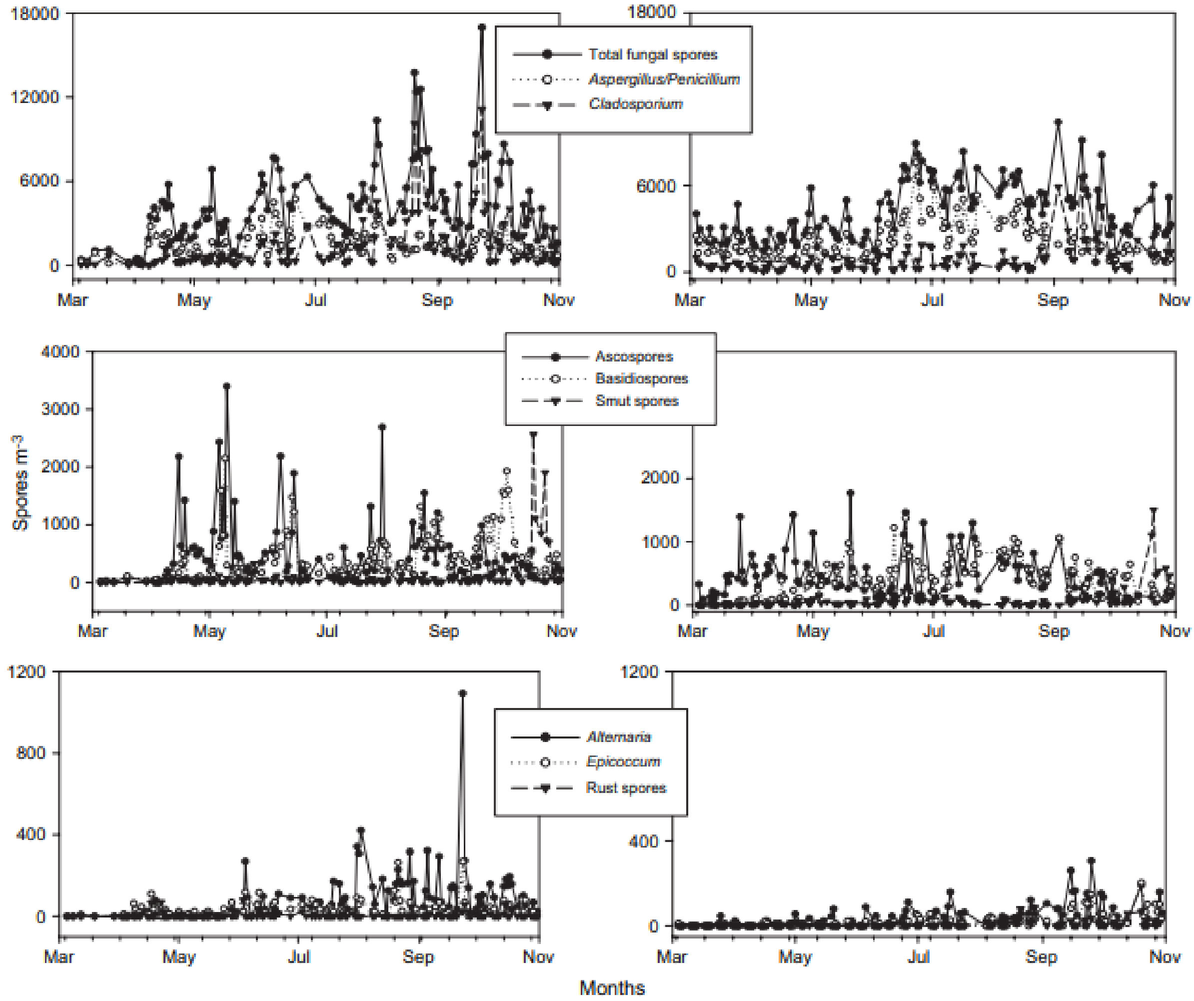
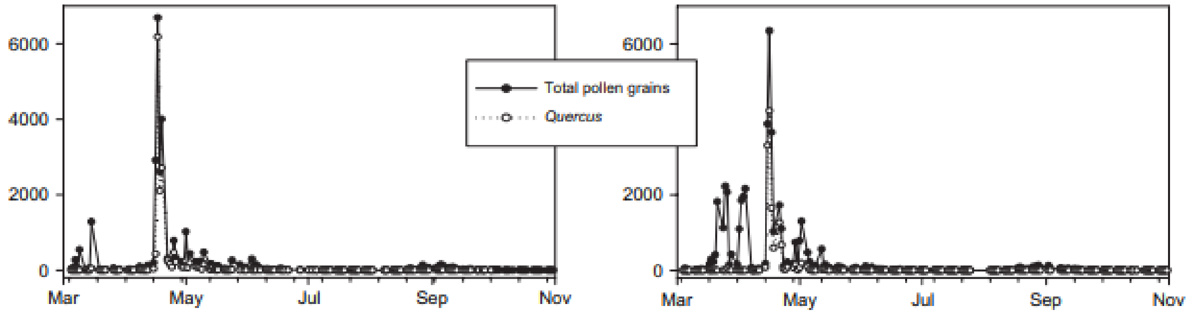


Fig 5 Monthly variation patterns of the airborne concentrations of prevalent airborne fungi

Airborne particulate matter

The 24-h average airborne mass concentration of PM10 and PM2.5 ranged from 6.70 to 65.38 µg m-3 (n = 181) and 5.04 to 45.02 µg m-3 (n = 303), respectively. Both mean PM10 (µg m-3) and PM2.5 (17.2 µg m-3) concentration levels. The concentration levels of both PM10 and PM2.5 were higher during summer and fall months, similar to fungi and unlike pollen. The significant correlations of the concentration patterns that the interaction between mold (fungal) aeroallergens and particulate matter was plausible.



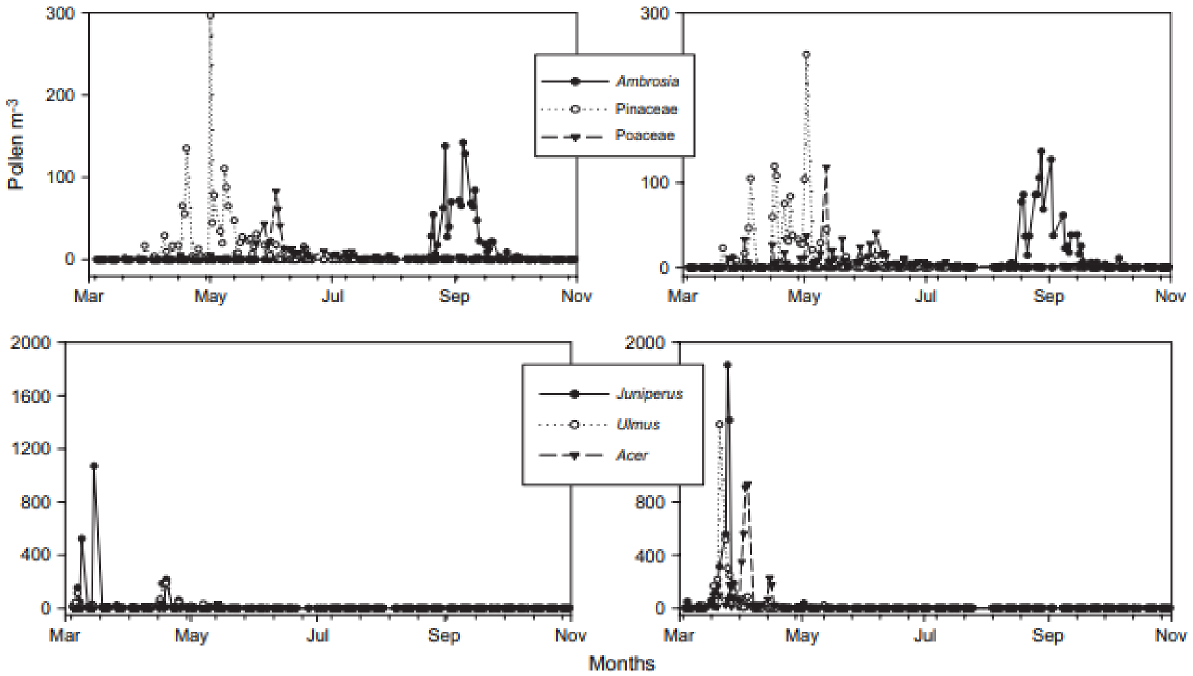


Fig 6 Monthly variation patterns of the airborne concentrations of prevalent airborne pollen grains

Atmospheric ozone

The daily average concentration of ozone ranged between 2.88 and 60.46 ppb (n=306). This seems reasonable because tropospheric ozone is produced by the reaction of solar radiation on nitrogen oxides.

Airborne trace metals and organic carbon in PM2.5

Concentration ranges of four selected trace metals were as follows: cadmium: 0-0.035 µg m-3 (n =39); copper: 0-0.041 µg m-3 (n=39); lead: 0-0.123 µg m-3 (n=22) and zinc:0.001- 0.187 µg m-3 (n=39). Zinc concentration was the highest among the four trace metals. Unlike the particulate matter and ozone, the trace metals did not show any consistent seasonal periodicity during the two years of monitoring. Although these trace metals are known to have adverse effects on leaf and soil mycoflora, their interactions with ambient airborne mycoflora and flowering of plants have not yet been adequately explored. Concentration of organic carbon ranged from 2.16 to 13.33 µg m-3 (n=35) No clear seasonal periodicity was observed for the organic carbon.

Temperature and relative humidity

The daily average temperature ranged from -2.7 to 30.2 C (n = 316) and the relative humidity range was 30.8-92.0% (n = 195). A clear temperature peak was found during summer months (June-August); however, the relative humidity levels did not show any seasonal peaks. Monthly variation patterns of temperature and ozone were found to be very similar.

V. CONCLUSION

The particulate matter, ozone, and several types of inhalable airborne fungi and pollen were positively correlated likely as a result of the atmospheric temperature influence. Temperature has a statistically significant effect on the concentrations of most airborne fungi.

For pollen, the effect is genera specific. Ambient bioaerosols might not be a significant contributor to PM10 and PM2.5 (by mass); however, temperature might act as a common influencing factor for both bioaerosols and PM. Inverse correlations were found between the toxic trace metals and inhalable bioaerosols, but in most cases the relationships were not statistically significant. Stepwise multiple regression analyses showed that although both temperature and ozone demonstrated statistically significant positive correlations with several bioaerosol types and particulate matter, the ambient temperature was the main influencing factor while ozone was a confounding factor.

Regression models from this study can be used in the future for predicting the levels and interrelationship between ambient inhalable bioaerosols, ozone, particulate matter, and ambient temperature. The synergistic effects of all these pollutants may cause increased incidence of respiratory health symptoms.

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