

# Metal Concentration in PM<sub>2.5</sub> and PM<sub>10</sub> and their Microbial Nature in Ambient Air of Agra, Region During Winter Season

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## ABSTRACT

**Background and Objective:** Rapid industrialization and urbanization have contaminated air in many areas of the world, either directly or indirectly. In this study particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), microbial and metal concentration in the ambient environment of the city of Taj, i.e., Agra is explored.

**Materials and Methods:** Two sites were selected based on roadside and semi-urban. Sampling was conducted in the winter season. The PM<sub>2.5</sub> and PM<sub>10</sub> were measured by dichotomous sampler and their metals were obtained by acid extraction. Serial dilution method was used to identify the microbial activity in PM<sub>2.5</sub> and PM<sub>10</sub>. **Results:** The average mass concentration of PM<sub>10</sub> at Khandari and Trans Yamuna was found to be 232.81 and 231.85 µg/m<sup>3</sup> and the concentration of PM<sub>2.5</sub> was found to be 147.24 and 121.91 µg/m<sup>3</sup>, respectively during the study period. Microbial concentration revealed a high frequency of fungal contaminants in comparison to bacterial contaminants, further, *Aspergillus niger* and *Aspergillus flavus* were the most prominent fungal contaminants observed at a higher frequency, while in a few samples, gram-positive bacteria were isolated at a lower frequency. **Conclusion:** Heavy metal concentration for PM<sub>10</sub> and PM<sub>2.5</sub> was found higher at the Khandari site than Trans Yamuna site. *Aspergillus flavus* was the most abundant contaminant found in the highest frequency followed by *Aspergillus niger*, *Mucor*, *Aspergillus fumigatus*, *Penicillium* and *Rhizopus*.

## KEYWORDS

Dichotomous PM<sub>2.5</sub> and PM<sub>10</sub>, ambient particulate concentration, elemental concentration, microbial concentration, Agra

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## INTRODUCTION

Both developed and developing country citizens' health conditions have gotten worse due to air pollution<sup>1</sup>. Studies conducted in the last few decades have demonstrated that ambient air pollution raises the risk of illness and death.

A class of aerosols ranging in size from 10 nm to 100 µm known as biotic components, or bioaerosol, are substances that are either alive, carry living creatures, or are expelled from living organisms (such as viruses, pollen, bacteria, fungus, cells and biofilms). Aerosol's biotic and abiotic components contribute significantly to health issues. Modern epidemiological research has consistently and logically linked air



pollution to many health outcomes, even if the biological mechanisms underlying these relationships are still poorly understood. As implied by their name, bioaerosols are derived from biological sources<sup>2</sup>. Airborne bacterial and fungal spores are mostly found on the surfaces of both living and dead plants. Microorganisms from naturally occurring water accumulations may be aerosolized by wind, waves or even rain<sup>3</sup>.

From the middle of the ocean to the middle of the Arctic, bioaerosols are found in nature everywhere. They are made up of particles like skin scales, pollen, bacterial spores, cells, viruses, protozoa and insect pieces. They consist of both coarse and fine particles. Among the tiniest bioaerosol particles are viruses, with certain species measuring only a few tens of nanometers. Pollen grains can reach diameters of more than 100µm, which is the other extreme of the size spectrum. The concentrations of bioaerosols differ greatly from place to place, just as other types of aerosols<sup>4</sup>. The biological component of ambient particulate matter might potentially have a considerable negative impact on one's health, even though it only makes up 20% of the aerosol load<sup>5,6</sup>. These effects are compounded when chemical constituents are present. Numerous diseases are brought on by biological components, such as various microbes and fungal spores; therefore, biological characterization of the aerosol, in addition to its chemical contents, is required and is carried out in this work.

According to Haywood and Ramaswamy<sup>7</sup> particulate matter (PM) in the atmosphere affects visibility, atmospheric chemistry, the balance of radiation on Earth and the health of all living things, including people. Globally, sulfate and carbonaceous PM are the main sources of direct radiative impacts from PM, such as PM<sub>2.5</sub> and PM<sub>10</sub>, which are directly induced by human activity (as opposed to dust entrainment brought on by desertification)<sup>8</sup>. The health of humans is greatly endangered by these particles. Breathing particles, particularly PM<sub>2.5</sub>, which is more dangerous because they enter the lungs more deeply than PM<sub>10</sub>, can cause very serious illnesses when they reach the lungs' alveoli. In addition to being dust, these PM particles also contain various microorganisms known as bioaerosols<sup>9</sup>.

The objective of the study was to determine ambient PM<sub>2.5</sub> and PM<sub>10</sub> mass concentration levels over Agra city during winter seasons. To characterize ambient PM<sub>2.5</sub> and PM<sub>10</sub> in terms of distinct metal content over Agra in winter seasons and to characterize and identify the bio-aerosol (microbial components) in PM<sub>2.5</sub> and PM<sub>10</sub> during winter seasons in ambient air of Agra region.

## **MATERIALS AND METHODS**

**Study location:** Agra is situated in the North-central part (27°10'N, 78°05'E, 169 m above the mean sea level) of India. Agra is one of the most famous tourist spots in North India due to the presence of the Taj Mahal. It is a semi-arid region bounded by the desert of Rajasthan on two-thirds of its peripheries. The study was carried out during the winter season from November, 2021 to January, 2022. Temperature ranges from 9-25°C during the daytime and at night sometimes drops below 5°C. The sampling sites industrial area (Trans Yamuna) and Roadside (Khandari) were selected for the study. The descriptions of sampling sites are as follows.

**Trans Yamuna (industrial area):** Trans Yamuna site 27°12'26"N, 78°2'42"E, an industrial region that is located on the city's Eastern edge. Here, industrial operations include the processing of rubber, the casting of both ferrous and non-ferrous metals, the oxidation and pulverization of lime and general engineering tasks. Coke, firewood and diesel are the fuel sources for these machines. The location is roughly 500 m from a major highway.

**Khandari roadside:** Semi-urban roadside areas (Khandari, Agra) 27°12'37.7"N, 77°59'24.3"E is a very busy crossing on NH-19 with residential colonies lying sideways while Kausalpur is a densely populated residential area adjacent to NH-19 with a high level of vehicular pollution, caused by the highway and localized traffic congestion.

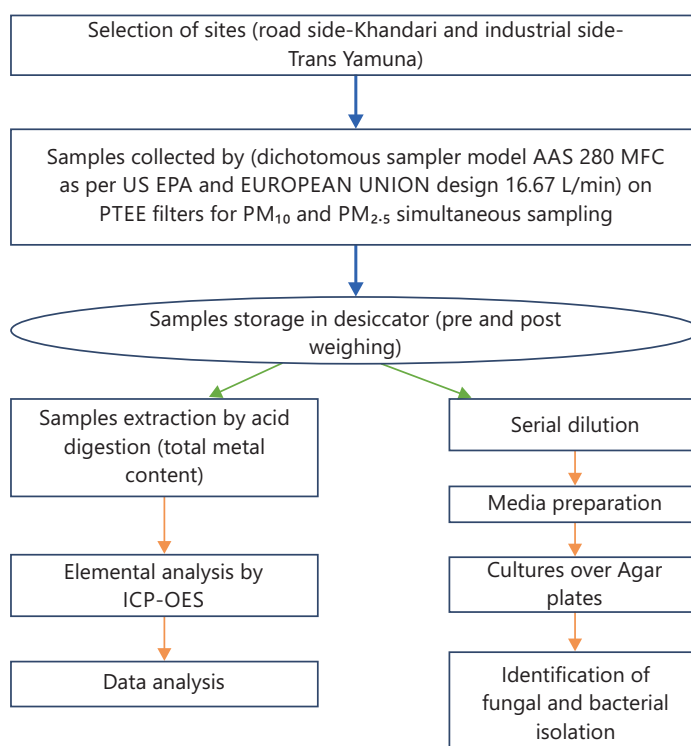


Fig. 1: Flow chart of sampling and analysis of PM and bioaerosols

**Sampling and analysis:** Sampling was carried out in the winter season in Agra city at two different locations Industrial Area Trans Yamuna and Khandari roadside<sup>10</sup>. Twenty-four Particulate matter samples were collected by a Dichotomous Sampler for PM<sub>10</sub> and PM<sub>2.5</sub> Simultaneous Sampler using high-volume ambient air samplers operating at a flow rate of 16.67 L/min. the duration of sampling was 6-8 hrs in a day. Sampling was started at 10 in the morning till 5 in the evening. The mass of the PM<sub>10</sub> and PM<sub>2.5</sub> were determined by the difference in weights before and after sampling. For the analysis of metals, acid extraction was carried out<sup>11</sup>. In the acid extraction method, metals will be extracted from filter paper, which was used in an air sampler for the collection of particulate matter. The filter paper was digested in a 5-10 mL analytical grade HNO<sub>3</sub> and HCl (1:3) in a 50 mL Erlenmeyer flask and kept on a hot plate at 40-60°C for 90 min till a clear solution was obtained. Now this clear solution is diluted up to 20 mL with distilled water and stored in the refrigerator (4°C) until analysis. The metal analysis was done by Inductive Coupled Plasma-Optical Emission Spectroscopy (ICP-OES).

For isolation and identification of microbial contamination, the filter papers were placed on nutrient agar for isolation of bacterial contaminants, while for fungal contaminants filter paper was placed on SDA broth for 24 hrs, after broth samples were streaked on nutrient agar for bacteria and on SDA agar for fungi<sup>12</sup>. Later colonies were counted to determine the microbial load and pure cultures were obtained by doing subculturing. Further pure cultures obtained were identified with lactophenol cotton blue staining for identification of fungi under a microscope (OLYMPUS, Model No. (BHS 217856) made by Japan). While gram staining was done for the identification of bacterial pure culture. The concentration of fungal and bacterial spores in the air is expressed as several colonies forming a unit per cubic meter of air (CFU/m<sup>3</sup>)<sup>13</sup>.

The concentration of fungal and bacterial spores in the air is expressed as a number of colonies forming units per cubic meter of air (CFU/m<sup>3</sup>). The sampling and analysis procedure has been presented as a flow chart in Fig. 1.

## RESULTS AND DISCUSSION

**Mass concentration of PM<sub>2.5</sub> and PM<sub>10</sub>:** The threshold limit of NAAQS (24 hrs average 100 and 60 µg/m<sup>3</sup> for PM<sub>10</sub> and PM<sub>2.5</sub>, respectively) set by the Central Pollution Control Board of India and WHO air quality guideline (annual average 50 and 25 µg/m<sup>3</sup> for PM<sub>10</sub> and PM<sub>2.5</sub>, respectively)<sup>21</sup>.

The results of the present study have been compared with the results obtained at the national level with studies done earlier which is shown in Table 1 at the national level for PM<sub>10</sub> and PM<sub>2.5</sub>. The results found that in Chennai (292 µg/m<sup>3</sup>), Delhi (245 µg/m<sup>3</sup>), Ahmedabad (327 µg/m<sup>3</sup>), Ghaziabad (260 µg/m<sup>3</sup>) concentrations were higher for PM<sub>10</sub>, while Chandigarh (151 µg/m<sup>3</sup>), Haryana (174 µg/m<sup>3</sup>), Mumbai (61 µg/m<sup>3</sup>) and Sonipat (213 µg/m<sup>3</sup>) was lower than present study in Agra (233.15 µg/m<sup>3</sup>). Also, on comparing the mass concentrations for PM<sub>2.5</sub>, result revealed that in Amritsar (178 µg/m<sup>3</sup>), Sonipat (156 µg/m<sup>3</sup>), Delhi (145 µg/m<sup>3</sup>), Ghaziabad (140 µg/m<sup>3</sup>) concentrations were higher for PM<sub>10</sub>, while Chandigarh (112 µg/m<sup>3</sup>), Haryana (71 µg/m<sup>3</sup>), Mumbai (43 µg/m<sup>3</sup>), Ahmedabad (106 µg/m<sup>3</sup>) and Chennai (81 µg/m<sup>3</sup>) was lower than present study in Agra (146.91 µg/m<sup>3</sup>).

Figure 2 depicted the mass concentrations of PM<sub>10</sub> and PM<sub>2.5</sub> during the winter season (November-January) in Agra City at two locations, Khandari roadside and Trans Yamuna Industrial Area. The overall average mass concentration of PM<sub>2.5</sub> at Trans Yamuna and Khandari were 149.10 and 144.71 µg/m<sup>3</sup>, respectively. The overall average mass concentration of PM<sub>10</sub> at Trans Yamuna and Khandari were 241.94 and 224.36 µg/m<sup>3</sup>, respectively. The monthly variation in mass concentration of PM<sub>2.5</sub> in November, December and January at Trans Yamuna were 111.80, 132.025 and 203.48 µg/m<sup>3</sup>, respectively. The monthly variation in mass concentration of PM<sub>2.5</sub> in November, December and January at Khandari were 112.265, 182.215 and 139.67 µg/m<sup>3</sup>, respectively. The monthly variation in mass concentration of PM<sub>10</sub> in

Table 1: Comparison of PM<sub>10</sub> and PM<sub>2.5</sub> concentration with different studies in India

| Study area | PM <sub>10</sub> (µg/m <sup>3</sup> ) | PM <sub>2.5</sub> (µg/m <sup>3</sup> ) | References                                 |
|------------|---------------------------------------|--|--|
| Agra       | 233.15                                | 146.91                                 | Present study                              |
| Chennai    | 292                                   | 81                                     | Srimuruganandam and Nagendra <sup>14</sup> |
| Delhi      | 245                                   | 145                                    | Dumka <i>et al.</i> <sup>15</sup>          |
| Ahmedabad  | 327                                   | 106                                    | Rengarajan <i>et al.</i> <sup>16</sup>     |
| Amritsar   | 252                                   | 178                                    | Ravindra <i>et al.</i> <sup>17</sup>       |
| Chandigarh | 151                                   | 112                                    | Ravindra <i>et al.</i> <sup>17</sup>       |
| Sonipat    | 213                                   | 156                                    | Ravindra <i>et al.</i> <sup>17</sup>       |
| Ghaziabad  | 260                                   | 140                                    | Gupta <i>et al.</i> <sup>18</sup>          |
| Haryana    | 174                                   | 71                                     | Mor <i>et al.</i> <sup>19</sup>            |
| Mumbai     | 61                                    | 43                                     | Kumar and Joseph <sup>20</sup>             |

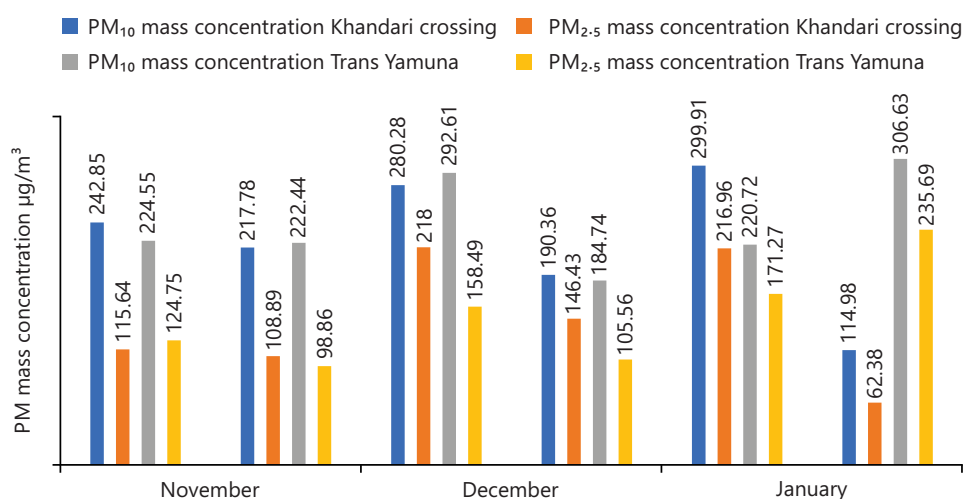


Fig. 2: PM<sub>2.5</sub> and PM<sub>10</sub> mass concentration at different site

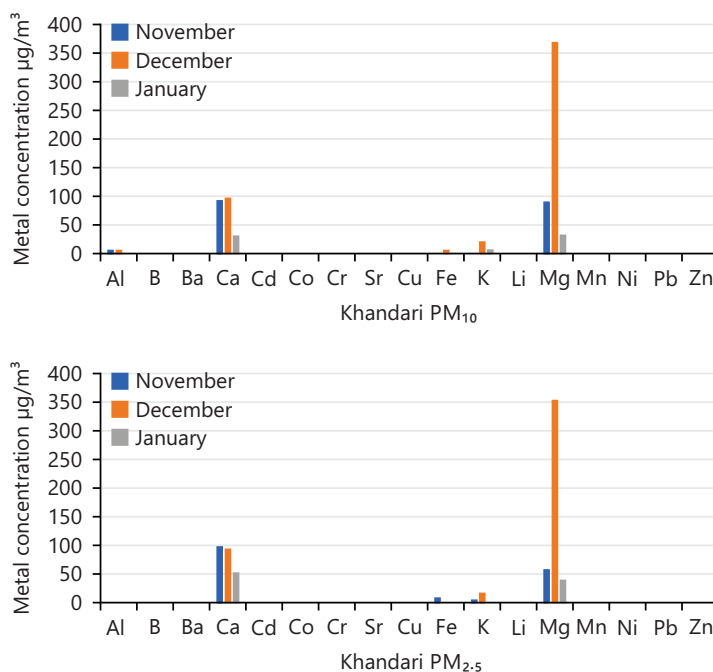


Fig. 3: Metal concentration of PM<sub>10</sub> and PM<sub>2.5</sub> at Khandari Roadside

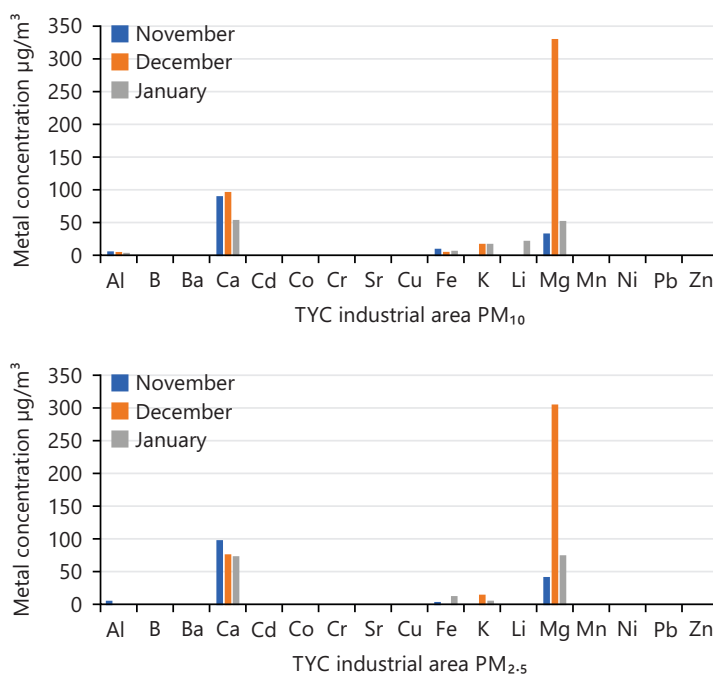


Fig. 4: Metal concentration of PM<sub>10</sub> and PM<sub>2.5</sub> at TYC industrial area

November, December and January at Trans Yamuna were 223.496, 238.675 and 263.675 µg/m<sup>3</sup>, respectively. The monthly variation in mass concentration of PM<sub>10</sub> in November, December and January at Khandari were 230.315, 235.32 and 207.445 µg/m<sup>3</sup>, respectively.

The mass concentration of PM<sub>10</sub> was found higher at both sites Trans Yamuna as well as Khandari roadside in January month while PM<sub>2.5</sub> was found higher at Khandari roadside in December.

**Metals concentrations:** Figure 3 and 4 showed the total heavy metals concentration of PM<sub>2.5</sub> and PM<sub>10</sub> at Khandari and Trans Yamuna. The total metal concentration of heavy metal in this study for PM<sub>2.5</sub> at

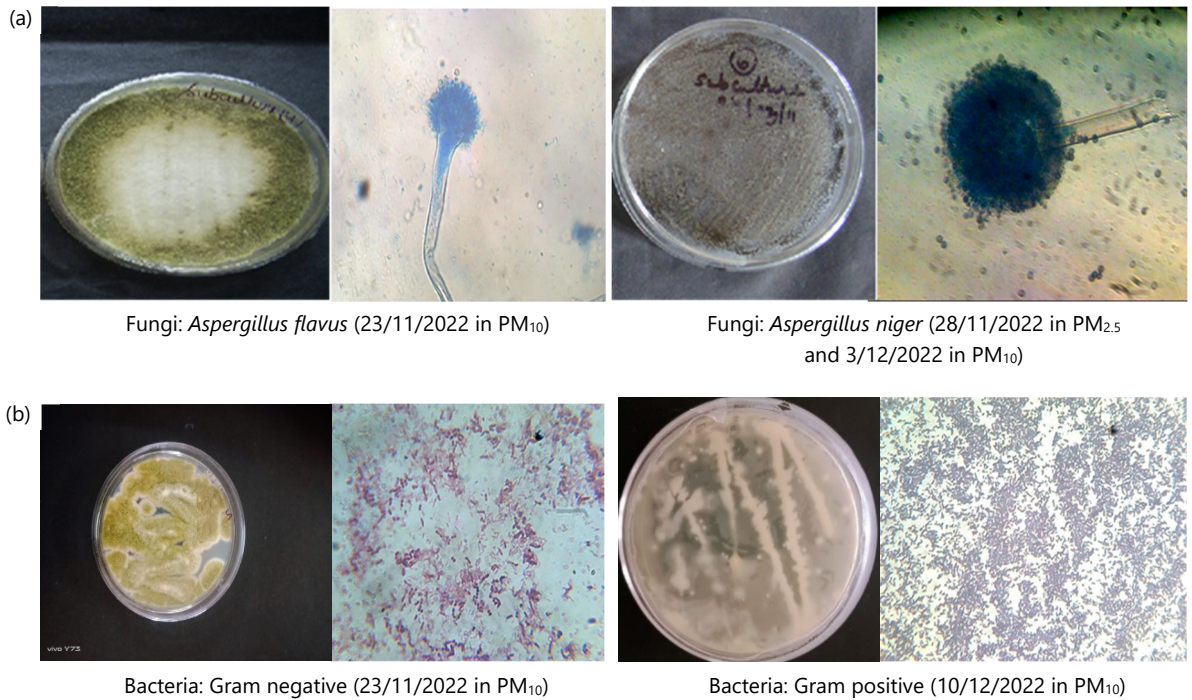


Fig. 5(a-b): Fungal and bacterial culture colony and microscopic identification  
Fungi and bacteria isolated from the air

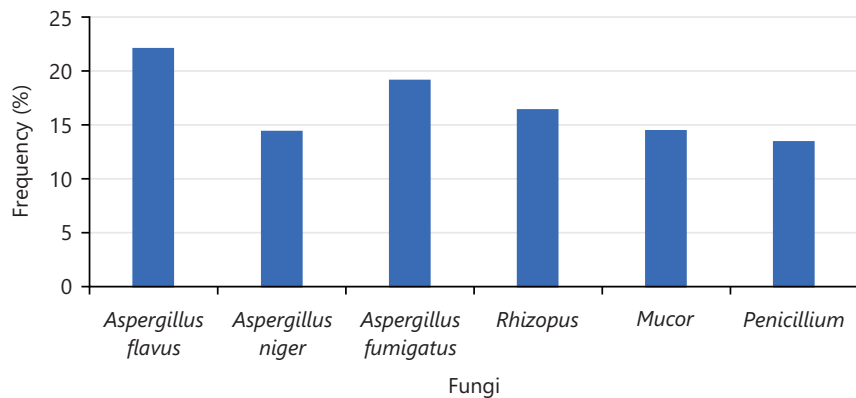


Fig. 6: Frequency of different fungal isolates in air samples collected from different places

Trans Yamuna was found  $245.01 \mu\text{g}/\text{m}^3$  and follows the order  $\text{Mg} > \text{Ca} > \text{K} > \text{Fe} > \text{Al} > \text{Sr} > \text{Li} > \text{Pb} > \text{B} > \text{Cr} > \text{Ba} > \text{Zn} > \text{Mn} > \text{Cu} > \text{Ni} > \text{Cd} > \text{Co}$ . The total metal concentration of heavy metal for  $\text{PM}_{2.5}$  at Khandari was found  $250.37 \mu\text{g}/\text{m}^3$  and follows the order  $\text{Mg} > \text{Ca} > \text{K} > \text{Fe} > \text{Al} > \text{Sr} > \text{Pb} > \text{B} > \text{Cr} > \text{Li} > \text{Zn} > \text{Ba} > \text{Cu} > \text{Mn} > \text{Cd} > \text{Ni} > \text{Co}$ . In particular, for  $\text{PM}_{2.5}$ , the concentration of Mg and Ca was found highest and Co was the lowest on both sides of Trans Yamuna and Khandari.

The total metal concentration for  $\text{PM}_{10}$  at Khandari and Trans Yamuna was found 252.93 and  $250.70 \mu\text{g}/\text{m}^3$ , respectively. At the Khandari site, heavy metal concentration for  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  was found higher than at the Trans Yamuna site.

**Microbial activities of PM:** Collected air samples are subjected to fungal isolation, from all 24 samples collected a total of 6 fungal species were isolated and identified. They are *Aspergillus flavus*, *Aspergillus niger*, *Mucor*, *Aspergillus fumigatus*, *Penicillium* and *Rhizopus* sp. in the order of their percentage frequency as depicted in Fig. 5. The highest number of fungal colonies was reported in November and the



lowest was in December. This can also be explained by moderate rainfall, medium temperature and high humidity which provides an appropriate environment for microbial growth which results in a high concentration of fungal counts. Picture 1 and 2 show fungi and bacteria isolated from the air. A total of 6 species of fungi viz., *Aspergillus niger*, *Aspergillus flavus* and *A. fumigatus* species and gram positive and negative were isolated from a few samples and their frequencies were given in Fig. 6.

The maximum bacterial colonies were recorded during November and December and the lowest in January.

## CONCLUSION

The study concluded that the concentration of air spora was highest in October and lowest in January. Atmospheric conditions viz., temperature, relative humidity, rainfall, etc. plays a very important role. In the PM mass concentration of PM<sub>2.5</sub> and PM<sub>10</sub> was found higher at Trans Yamuna in January and the mass concentration of PM<sub>2.5</sub> and PM<sub>10</sub> was found higher at Khandari roadside in December. Heavy metal concentration for PM<sub>10</sub> and PM<sub>2.5</sub> was found higher at the Khandari site than Trans Yamuna site, by analyzing microbial count it can be concluded that *Aspergillus flavus* was most abundant contaminant found in highest frequency followed by *Aspergillus niger*, *Mucor*, *Aspergillus fumigatus*, *Penicillium* and *Rhizopus*. The overall air quality in the city in terms of (PM<sub>10</sub> and PM<sub>2.5</sub>) in the PM mass concentration, metal concentration and microbial count were found to be inferior and above the standard. This study concluded that there is a need to address the issue of PM monitoring with their chemical and microbial constituents, for all the seasons so that it can be beneficial for pollution amendment policy.

## SIGNIFICANCE STATEMENT

The ambient concentration of pollutants is a big problem these days worldwide. Scanty data is available in this region, particularly on bioaerosols and chemical constituents of particulate matter. The concentration of these pollutants affects human health, so it should be controlled by using low-cost interventions and environmental policies. This study will highlight the concentration of PM (PM<sub>10</sub> and PM<sub>2.5</sub>), metal and microbiota. So that policymakers can utilize this data for suggesting and executing the plan for the city to curb air pollution. This may be further extended to other cities of developing nations.

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