7.1 Preamble

Bioaerosols are aerosol particles associated with biological origins, consisting of bacteria, fungi, spores, and viruses. The significant portion of the bioaerosols in our environment comes from the soil, surface water, plants and animals (dead or alive) (Fröhlich-Nowoisky et. al., 2016; Gupta et. al., 2021; Jones & Harrison, 2004; Lin & Li, 2000; Mohr, 2007; Mouli et. al., 2005). It can be suspended in the atmosphere for a longer time and transported from one place to another (Després et. al., 2012). Biological nature affects the air quality, human health, climate and several atmospheric processes. (Bowers Robert et. al., 2009; Després et. al., 2012; Griffin Dale, 2007; Madhwal et. al., 2020; Pöschl et. al., 2010; Yadav et. al., 2020). Since the major fraction of bioaerosols comes in the respirable range (Fröhlich-Nowoisky et. al., 2016; Gupta et. al., 2021), it can add to the 50% of the infection-related disease in humans (WHO, 1999). Therefore, the researchers paying more attention towards the study of bioaerosols on human health and atmospheric variability.

Studies found that the concentration of the bioaerosols varies with various meteorological factors (temperature, relative humidity, solar radiation and wind speed) in the environment. These factors can affect the residence time of the particles in the air (Jones & Harrison, 2004; Kowalski & Pastuszka, 2018; Lee et. al., 2016). For example, temperature positively correlates with bacterial and fungal bioaerosols concentration (Ho et. al., 2005; Salonen et. al., 2015). While a negative correlation was seen with the relative humidity for fungal bioaerosols (Ho et. al., 2005). However, in a few cases, no significant correlation of RH with bioaerosols concentration was observed (Hwang & Park, 2014). In the aerosolization process of microbes, wind waves and rain play an important role in reaching the bioaerosols into the atmosphere (Burrows et. al. 2009; Mayol et. al. 2017; Michalska et. al. 2021). During foggy events, human activity in the outdoor environment is adversely affected due to the loss of visibility (Hurtado et. al., 2014; Liang et. al., 2013).

During the atmospheric processes, the concentration of the bioaerosols is affected due to chemical transformation (from UV, gases, organics and free radicals) (Fröhlich-Nowoisky et. al., 2016; Kowalski & Pastuszka, 2018; Pan et. al., 2021). Since many studies were conducted to determine the concentration of bioaerosols during variable atmospheric conditions (Dong et. al., 2016; Xie et. al., 2018; Yang et. al., 2022). Also, the correlation between airborne microbes and meteorological factors was examined;

however, studies on atmospheric environmental indices were limited. Gas, particles and other chemical components are present and able to transformed in atmospheric air with airborne microbes. Since the Indo-Gangetic plain is the hotspot of the aerosols and variable atmospheric conditions and is very prominent in this region, including fog, the study of the bioaerosols during fog is very important.

Foggy days are the common weather phenomenon in the IGP during the winter, contributing to approximately 60% of the winter days during the month of December to January each year and still increasing in the last few years (Ghude et. al., 2017, Hameed et. al., 2000; Jenamani et. al., 2007; Ramanathan et. al., 2005). Over the last few decades of data on ground-based surface visibility measurements, it has been concluded that the number of foggy days increases, which causes a significant loss of visibility (Jaswal et. Al., 2013; Thomas et. at., 2019). There is an increase in organic carbon, inorganic carbon and water-soluble was 30% higher in foggy days, while inorganic constituents were 2-3 times higher during the foggy days compared to the non-foggy days during winter (Ram et. al., 2012). Many studies in IGP show that the increasing load of pollutants, sufficient moisture, and decreasing temperature can enhance the formation of the fog (Syed et. al., 2012; Ghude et. al., 2017), but how microbes interact during the fog is not well known during winter.

The main aim of this study is to investigate (1) the variation in the concentration and size segregation of the bacterial and fungal bioaerosols during the foggy and non-foggy days during the winter time, (2) explore the association of the meteorological variables and pollutant to the different bioaerosols concentration during the foggy and non-foggy days, (3) Finding the correlation of the bioaerosols with particulate matter, and (4) health risk assessment of the detected bioaerosols in these region during the foggy days. This study will help to understand the bioaerosols characteristics during the various changing environmental conditions and their health effect.

7.2 Materials and methods

7.2.1 Sampling site

The bioaerosols sampling was conducted at the terrace of the Department of Chemical Engineering and Technology, IIT (BHU) Varanasi (25.15°N, 82.59°E) premises in the Indo Gangetic Plain (IGP). The sampler was installed 10 m above the ground in the open space at the terrace to avoid the shade of buildings and trees. The surrounding of the city is dominated by vegetation, and the urban land dominates the central part of the city. No industrial activity were going near the campus, nearly 3 km from the national highway. The winter of Varanasi city lies between December to February, when wind speed is found calm (1-2 m/s) in nature during this season.

7.2.2 Sampling of bioaerosols

Air samples were collected during the foggy and non-foggy days (before and after the fog) in the winter from 2021 to 2024. Foggy and non-foggy days were distinguished on the basis of visibility where visibility <1km is considered as fog and above 1km it is considered as non-fog or clear weather condition. The forecast of India Meteorological Department (IMD) were used for distinguishing the foggy and non-foggy days. For the collection of the culturable bioaerosols, Anderson six-stage (Tisch Environmental, USA) viable bioaerosols sampler were used during this period. Anderson samplers consist of six different size diameters between 0.67 to 7 μm. The petri plate consisting of the different media like potato dextrose agar (Merck) for fungi and nutrient agar (Merck) for bacterial bioaerosols which were prepared by the standard method and installed in each cascade. All the standard procedures were done in the biosafety chamber, and the instruments including cascade were sterilized before use.

Air sampling was conducted in foggy conditions with the impactor at the flow rate of 28.3 L/min and a duration of 20 min in each sampling. After the sample collection, the cascade were opened in the biosafety chamber, and each plate was sealed and put in the incubator for the given temperature (for bacteria 25°C for 72 hr and for fungi 35 °C for 48 hr) for the optimum growth of the microbes.

7.2.3 Isolations and characterization

After incubation of the different plates consisting of nutrient agar and potato dextrose agar, the colonies of microbes appeared. The colonies were counted with the help of a colony counter, and the concentration of bioaerosols were measured using the formula:

Total bioaerosols concentration= total no. of colonies (C')/ (flow rate x sampling duration in minutes) x 1000

$$C' = \sum_{i=1}^{6} C_i$$

Where C' is the airborne cumulative concentration of bioaerosols (CFU/m^3) and C_i is the bioaerosol concentration of *i* stage of Anderson six-stage impactor (CFU/m^3).
This way, the concentration of the bioaerosols was measured. In each case of sampling, blanks were stored in the laminar, which shows no growth (negligible) in the samples. The pure culture of the microbes was isolated from the mix culture plate. After the purification, pure culture was obtained from the samples and the samples were identified. Initially, samples were preidentified on the basis of their colony, colour and shapes using light microscope and comparing with the standard online description available.

For the confirmation of the samples, DNA sequencing method was performed using the following steps: (1) isolation of the genomic DNA, (2) fragment of DNA was amplified using polymerase (forward and reverse). Here, for bacteria 5’-GGATGAGCCCGCGGCCTA-3’ (16s Forward) and 5’-CGGTGTGTACAAGGCCCGG-3’(16s Reverse) were used and for fungi 5’-TCCGTAGGTGAACCTGCGG-3’ (ITS-1 Forward) and 5’-TCCTCCGCTTATTGATATGC-3’ (ITS-4 Reverse) primers were used, (3) PCR product sequenced bidirectionally and in the last step sequenced data were analyzed and identified to their nearest neighbour.

7.2.4 DNA Extraction and sequencing

The sample was mixed with 1 mL of extracted buffer solution and placed on mortar. After homogenization, the mixture was transferred to 2 mL micro-centrifuge tube and equal amount of phenol, chloroform and iso-amyl alcohol were added in the ratio of 25:24:1 and mixed well by shaking. The mixture was centrifuged at 14000 rpm for 15 min at room temperature. When centrifugation completed the upper aqueous phase was collected in new microcentrifuge tube. This collected sample again mixed with equal amount of chloroform and isoamyl alcohol (in 24:1 ratio) and centrifuged at 14000 rpm for 10 min at room temperature. After centrifugation the upper aqueous phase was collected and by adding 0.1 volume of 3M sodium acetate (at pH 7.0) and 0.7 volume of isopropanol, the DNA of the sample precipitated in the solution. After incubation and centrifugation at

4000 rpm for 15 min at 4°C, the DNA pallets precipitated and then were washed with 70% and 100% of ethanol and dried in the air.

Dried DNA was dissolved in TE solution (Tris-Cl 10 mM pH 8.0, EDTA 1 mM). For purification of the DNA (to remove RNA), 5 μL of DNAse free RNAse (10 mg/mL) was mixed. Now, extracted DNA (of 133 ng) and 10 pM of each primer were used for amplification purposes. The Composition of TAQ Master MIX contains High-Fidelity DNA Polymerase, 0.5 mM dNTPs, 3.2 mM $MgCl_2$ and PCR Enzyme Buffer. The Sequencing mix Composition and PCR conditions include 10 μL Sequencing Reaction, 4 μL Big Dye Terminator Ready Reaction Mix, 1 μL Template (100 ng/ul), 2 μL Primer (10 pmol/λ) and 3 μL milli-Q Water.

During the 25 cycle of the PCR the following process was carried out, (1) initial denaturation (at 96°C for 5 min), (2) subsequent denaturation (at 96°C for 30 sec), (3) Hybridization (at 50 °C for 30 sec) and (4) Elongation (at 60 °C for 1.30 min). Genetic Analyzer (ABI 3130) were used for sequencing the given strain, and the product was analyzed by System Software aligner using Phylogenetic Tree Builder for making a phylogenetic tree (Bruno et. al., 2000).

7.2.5 Health risk assessment

The health risk assessment of the bioaerosols were estimated by calculating Annual Daily Dose (ADD), according to USEPA methodology (Izhar et. al., 2016; Wang et. al., 2022) as mentioned by,

$$\mathrm{ADD}_{\mathrm{inhalation}} = \frac{C * IR * EF * ED}{BW * AT}$$

$$\mathrm{ADD}_{\mathrm{skin}} = \frac{C * SA * ABS * AF * EF * ED}{BW * AT}$$

Where, C is the concentration in CFU/m^3, IR is the inhalation rate of air (taken as 20 m^3/day for adult and 7.6 for children), EF is the exposure frequency (taken as 60 days), ED is the lifetime exposure duration (taken as 24 hr). BW is body weight (taken as 70 kg for adults and 20 for children), and AT is the average lifetime (taken 75×365 for adult and 12×365 for children. SA is the area of contact skin surface (m^2) (taken as 0.2 for adult and 0.01 for children); ABS is the dermal absorption factor (m/h) (taken as 0.001); AF is the skin adherence factor (taken as 0.07 for adult and 0.2 for children) (Li et. al., 2024; Wang et. al., 2022)

For the subsequent risk assessment, the Hazard Quotient (HQ) and Hazard Ratio (HR) were calculated using the following equation (Izhar et. al., 2016; 210 Wang et. al., 2022).

$$HQ = \frac{ADD}{RfD}$$

where RfD = RfC* IR/BW (Samadi et. al., 2021)

and $HR = \Sigma HQ(bacteria) + HQ(fungi)$

HQ is the exposure ratio of a substance to its reference concentration (RfC) at which no unfavourable effects are anticipated, whereas HR is the summation of HQ affecting the same target organ system. The HR value greater than one suggests increased health risk from exposed substances and vice versa. The RfC for both bacteria and fungi were taken as 500 CFU/m^3 (ACGIH, 1999; Li et. al., 2015; Zhang et. al., 2020).

7.2.6 Meteorological data collection

Meteorological data were collected from the automatic weather station installed a few meters away from the sampling sites where the data of temperature, RH, wind speed, and wind direction were collected. This weather station collects the real-time data of the atmosphere of the surrounding area. For the particulate measurements (PM_{10} and $PM_{2.5}$), data from the CPCB station in the campus were taken.

7.2.7 Data analysis

Data analysis was done using the MS excel and Origin pro 2024 software where the variation in the concentration were calculated during the foggy and non-foggy days of the winter. The average value of the particulate matter was used in the analysis while the real time average of the other meteorological variable during the sampling was taken.

7.3 Results and discussion

7.3.1 Variation in the concentration of the bioaerosols during hazy and non-hazy days

The total microbes (TMC) in the air increase during the foggy days of the winter in comparison to the non-foggy days. For foggy days, the concentration of total bioaerosols (bacterial and fungal) was 2223±553 CFU/m^3, whereas during non-foggy days it was 1478±490 CFU/m^3. This increase in the microbe's concentration fraction is near to the value reported by Dong et. al., 2016. This finding also supports the study done by Saikh et al (2023) where an increase of 36% to 48% in bioaerosols concentration were observed during the foggy days as compared to non-foggy. The total bioaerosols concentration variation of different bioaerosols were plotted during foggy and non-foggy days during winter in the Figure 7.1. During the 9 days experiment on the foggy days the following results were obtained as plotted in Figure 7.2 and 7.3. The concentration of the bacterial bioaerosols (BB) during foggy and non-foggy days were 1175±370 CFU/m^3 and 801±287 CFU/m^3 respectively whereas fungal bioaerosols (FB) concentration were found 1048±243 CFU/m^3 for foggy days and 676±274 CFU/m^3 for non-foggy days.

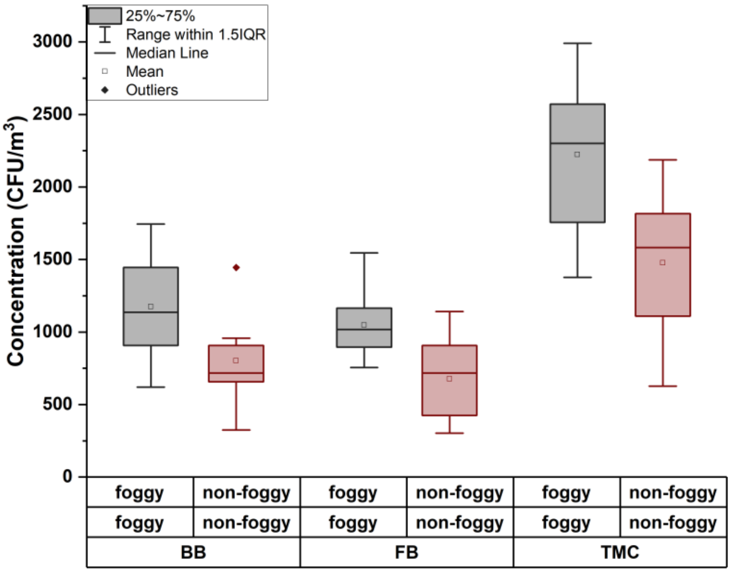

Figure 7.1 Variation of the bioaerosols concentration during foggy and non-foggy days

The mean concentration of the bacterial and fungal bioaerosols on foggy days was 1.4 times and 1.5 times more than on non-foggy days, respectively. Fuzzi et al. (1997) found that the concentration of bioaerosols significantly increases in the foggy days of the winter. Since fog in the winter protects the reach of the sunlight to the airborne microbes, this can prevent them from getting sterilized and increase the survival of the microbes in the air in the form of bioaerosols. Also, a higher occurrence of bioaerosols in fog is due to some favourable environmental conditions like low temperature and nutrient in the floating water droplets (Fuzzi et. al., 1997; Dong et. al., 2016; Saikh et. al., 2023). The highest concentration of the bacterial bioaerosols during the foggy days were 1745 CFU/m^{3,} and the lowest concentration were reported 621 CFU/m^{3,} whereas fungal bioaerosols concentration varied between 1545 CFU/m^3 to 756 CFU/m^3 respectively.

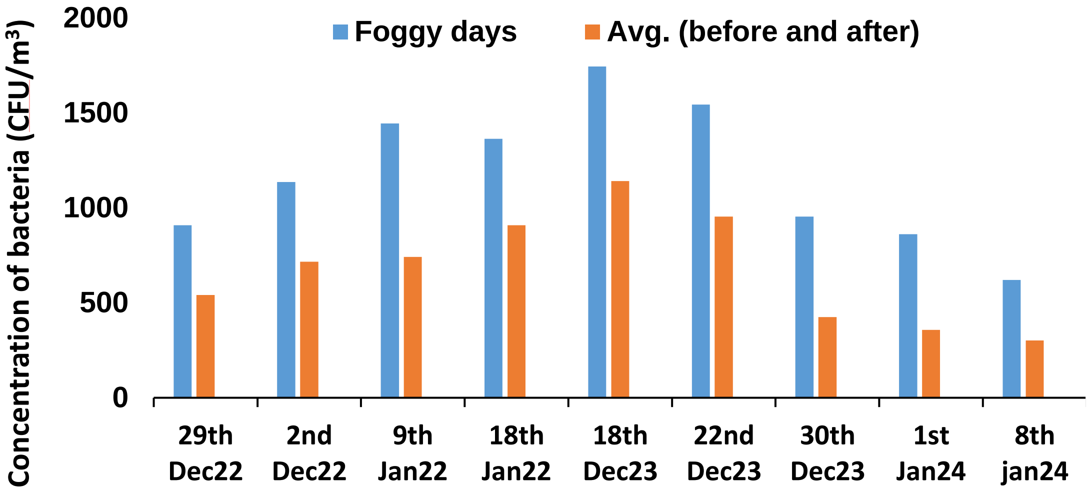

Figure 7.2 Total concentration (CFU/m^3) of bacteria on foggy and non- foggy days during winter

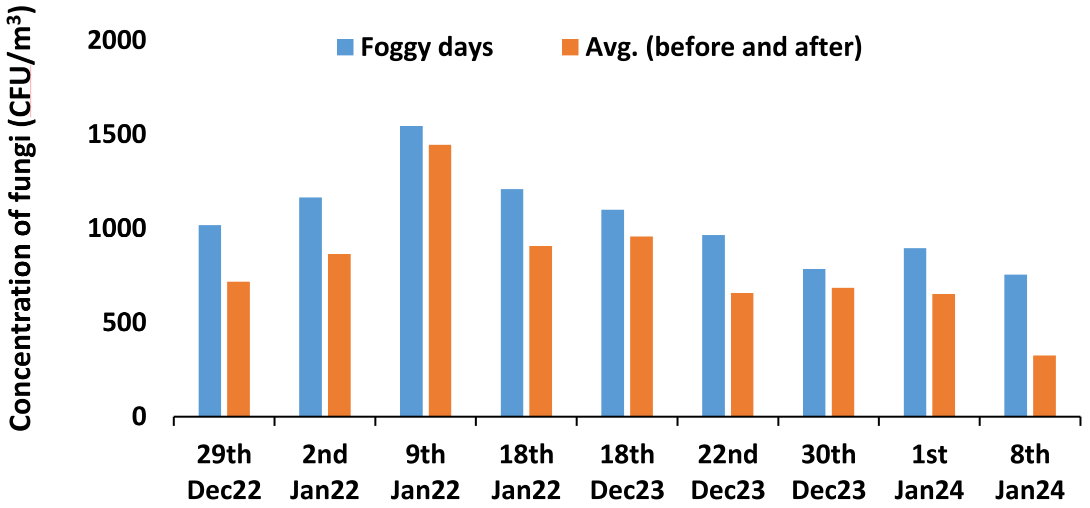

Figure 7.3 Total concentration (CFU/m^3) of fungi on foggy and non- foggy days during winter

7.3.2 Size segregation of the various bioaerosols in foggy and non-foggy days in winter

During the foggy days the size distribution of the bioaerosols changed in comparison to the non-foggy days as shown in the Figure 7.4 (a) and Figure 7.5(a).

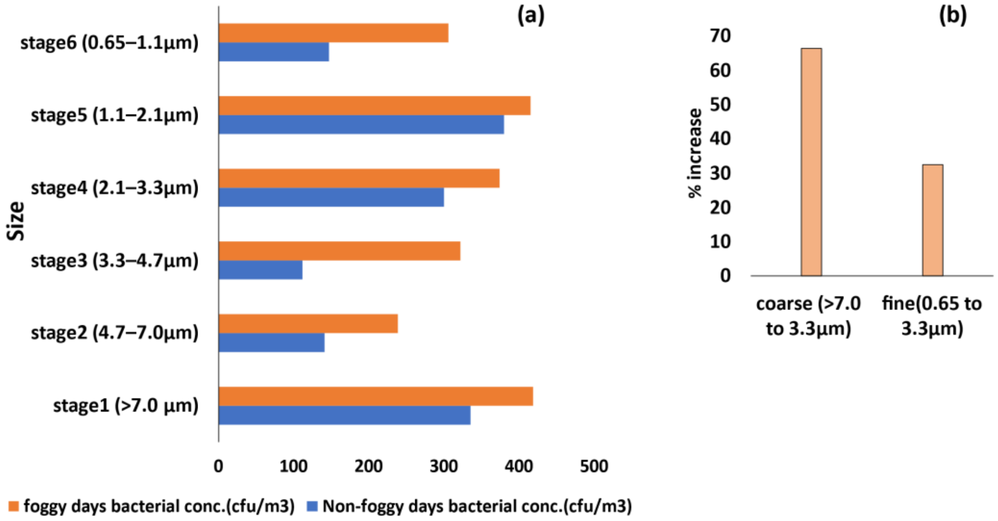

Figure 7.4 Size distribution of bacterial bioaerosols in (a) foggy and non-foggy days and (b) percentage increase in the concentration of coarse and fine bacterial bioaerosols

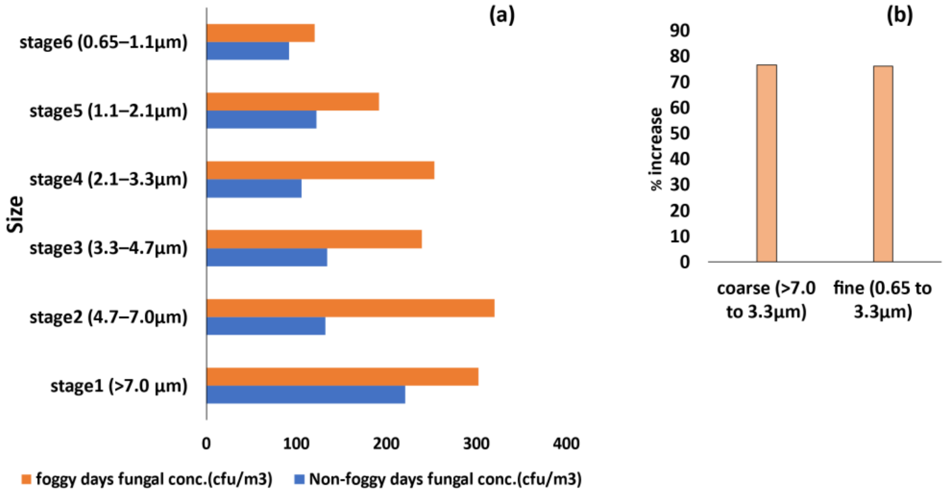

Figure 7.5 Size distribution of fungal bioaerosols in (a) foggy and non-foggy days and (b) percentage increase in the concentration of coarse and fine fungal bioaerosols

During the foggy days, the concentration of the bacterial and fungal bioaerosols increases more in the coarse particle size range compared to non-foggy days. Bacterial bioaerosols concentration in coarse size range (>7.0 to 3.3 µm) were increased about 66%, whereas 76% increased concentration were observed for fungal bioaerosols. In finer size range (between 0.65 to 3.3 µm) of the bioaerosols, bacterial concentration was increased by 36% and for fungi it was 76% increment (Figure 4 (b) and Figure 5 (b). These findings are similar as reported in the study of Dong et al (2016) where during foggy days major concentration of bioaerosols found in coarse (>3.3 µm) size range size range. However, the finer size range of bioaerosols (<3.3 µm) (both bacterial and fungal) concentration found in the significant amount that are causing more harm to the human health mainly in the human respiratory tract (Wei et. al., 2022). From the given data, it has been observed that during winter, bacterial bioaerosols increase more in the coarse size range in comparison to fine particle size range. But the fungal size distribution was not varied much during foggy events.

Relative humidity increases during the fog, and it affect more the survival of the bioaerosols in atmosphere. Also, fog is responsible for increasing the coarse droplet in the air and coarse droplets tends to adhesion of the microbes therefore increased the size of the bioaerosols. During foggy days, due to stable atmospheric stratification the diffusion of the particulate matter is very difficult hence increase the load of particulate matter during foggy days.

7.3.3 Association of the bioaerosols with meteorological parameter during foggy days

To examine the correlation between environmental factors and bioaerosols concentration spearman correlation analysis was determine. Figure 7.6 (a) and (b) shows the correlation matrix for the variables during foggy and non-foggy days, respectively. The concentration of the different bioaerosols is affected with meteorological factors, including temperature, relative humidity, wind speed and concentration of the particulate matter present in the atmosphere of the region (Dong et. al., 2016). Different pollutant concentrations in the environment like NO, NO_2, NO_x, NH_3 SO_2, CO and O_3, also affect the bioaerosols concentration. Figures 7.6 (a) and (b) show the correlation of the meteorological parameter and particulate load with bioaerosols in the correlation matrix.

In this study, during the fog, the particulate matter and meteorological parameters did not show significant correlations with bioaerosols. For example, Temperature, RH, wind speed and wind direction did not show the significant correlation during both foggy and non-foggy days. As the surface temperature drops, the atmospheric layer becomes more stable, and hence, the mixing of pollutants does not occur. If there was no precipitation or high velocity of wind then this period may continue, and pollutants in the air would be hard to disperse. Hence, the concentration of particulate and associated bioaerosols would increase. According to Gao et al. (2014), temperature was negatively correlated with the culturable microbes on fine particulate but positively correlated with the coarse particulate for airborne microbes. These two results might be because of variation in the type of culturable microbes present.

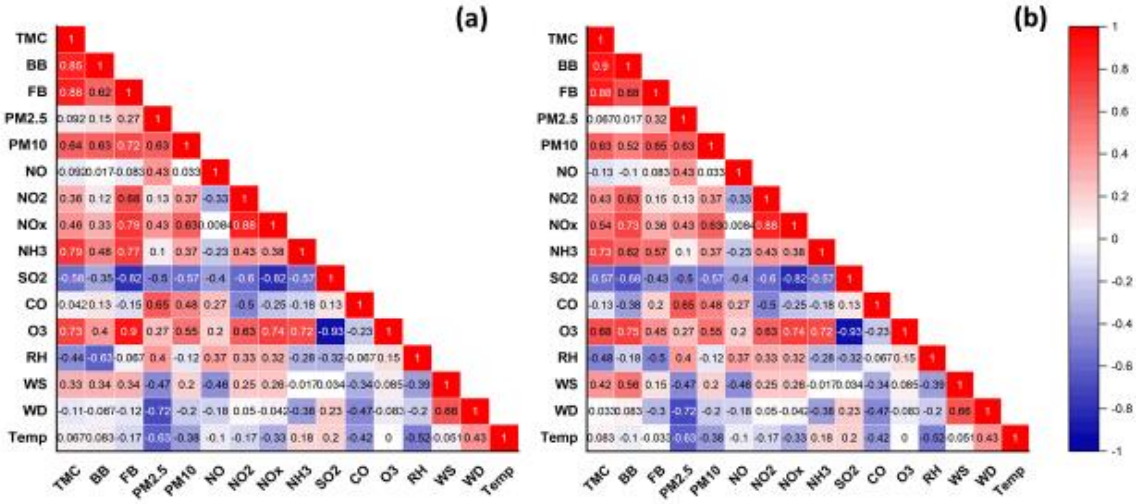

Figure 7.6 Correlation matrix for bioaerosols with different meteorological parameters and atmospheric pollutants during (a) foggy days and (b) non-foggy days

In the present study, meteorological parameters, including temperature, RH, wind speed and wind direction, show a significant correlation with bacterial and fungal bioaerosols. This least difference was most likely because of lower variation in the related environmental parameter during foggy and non-foggy days.

Principal component analysis (PCA) was performed to determine the effect of pollutant and meteorological variables on the concentration of the bioaerosols during foggy and non-foggy days (Figure 7.7 (a) and (b)).

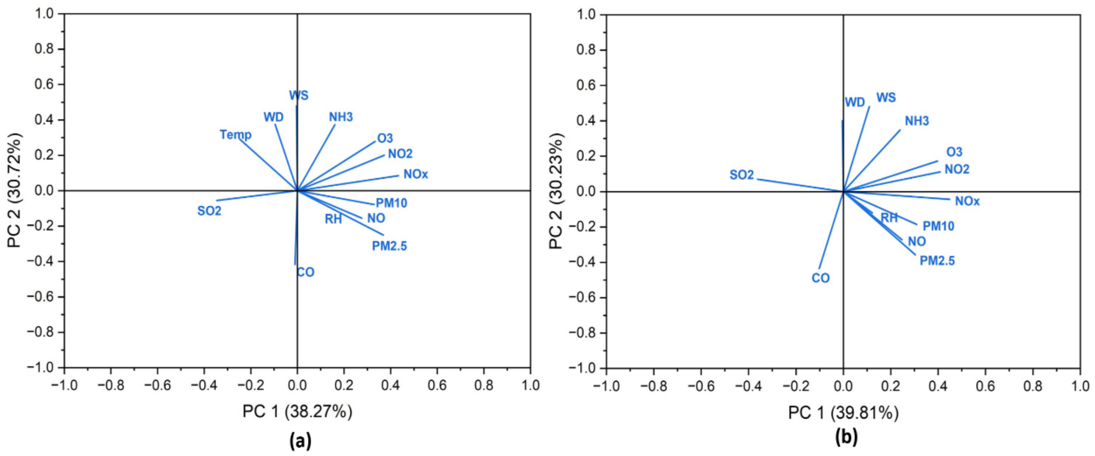

Figure 7.7 Principal component analysis (PCA) of pollutant and meteorological on the concentration of the bioaerosols during (a) foggy and (b) non-foggy days

In the PCA of pollutant and meteorological data during foggy days, the first four components have eigenvalues greater than 1. The Eigenvalues index in the data determines how effectively it summarizes the data. PM_{10} contributes the most in the first principal component (i.e 0.329) followed by PM $_{2.5}$ (0.368), NO (0.276) and NO_2 (0.372). Since the values of four components were positively correlated with all these variables, increasing these values increases the first component value.

Additionally, these four components explain the 92.65% variation in the data, so these factors can decide the microbial concentration in the data. Likewise, in the non-foggy days, the first four principal components have eigenvalues greater than 1. These four components explain 93.9% variation in the data. The variables that can correlate the most with the first principal component are $PM_{2.5}$ (0.303), PM_{10} (0.309), NO (0.247) and NO_2 (0.408). The first principal component is positively correlated with these four variables, and the first four principal components explain 93.9% of the variation in the data.

7.3.4 Association of the bioaerosols with particulate matter during foggy days

The total microbes in the collected samples were significantly positively correlated with the particulate matter ($PM_{2.5}$ and PM_{10}) during the foggy days of the winter. In the particulate, PM_{10} shows a strong correlation with both bacterial and fungal bioaerosol concentrations. Similar findings were also reported by Pitten et al. (1999) and Haas et al. (2013). During the foggy days, the atmospheric conditions were quite stable, so vertical mixing do not occur, and the pollutants in the region could not disperse in the surroundings resulting in the increase of the bioaerosols in the air. Moreover, some microbes were very complex, and some of them became new dominant species while changing the atmospheric conditions (Wu, 2010). So, the change in the community structure and accumulation of the higher concentrations of the particles may be the result of higher concentrations of the bioaerosols in the foggy days of the winter.

7.3.5 Association of gaseous pollutant with concentration of the bioaerosols during foggy days

The total microbial count in all the collected six size ranges of the samples was significantly correlated with the SO_x, NO_x, CO, NH_3 and O_3. Ho et al. (2005) reported that the concentration of the fungal bioaerosols were positively correlated with SO_2 and NO_x. Sulphate and nitrate in the aerosols particles were positively correlated with the microbes of the fine particle range (1.1-2.1 μm), which might be because of nitrogen and sulphur as nutrients (Liu et. al., 2012). In this study, NH_3 showed a positive correlation with total microbes count, which may result in NH_3 acting as nutrient for microbial growth. O_3 is toxic to the microbes, and studies found that the concentration of microbes decreases with the increase of O_3 concentration (Delfino et. al., 1997; Ho et. al., 2005; Lin and Li, 2000). But in our case, it has been seen the significant positive correlation with the O_3 to microbes in the air this may be due to the interaction of O_3 and other gases to the microbes in air. There are many discrepancies shown in the results, so further studies must be done to explore the mechanism of the interaction between various pollutants to microbes in air.

7.3.6 Characterization and possible health effects of the bioaerosols on the human health

Bioaerosol samples of the pure culture were isolated from the mixed culture plates for characterization purposes. Some of the bacterial and fungal colonies were identified from morphological analysis and visual identification. The colonies of the bioaerosols were mainly white, yellow and orange in colour. In gram staining analysis, 60-70% of the bacteria were found to be Gram-negative in nature, whereas 30-40% of the bacterial colonies were Gram-positive. *Coccus* and *Bacillus* are very dominant in the samples.

Similarly, for fungi, white, black, brown and grey colour colonies were seen and identified from the literature. Some of the bioaerosols were easily identified, but for confirmation, few were identified by DNA sequencing methods. In the present work, *Aspergillus, Fusarium, Periconia, Penicillium* and *Cladosporium* were identified as the dominant fungi, whereas for bacterial bioaerosols, *Bacillus, Stenotrophomonas, Acinetobacter, Enterobactor* and several *Cocci* showed their dominance. Some of the detected bioaerosols cause health risks to humans. For example, *Periconia* causes eye infection in humans, whereas *Cladosporium* is an allergen which mainly causes respiratory health-related problems (Nakatsu et. al., 2020; Stetzenbach, 2009; Viegas et. al., 2015). These bioaerosols are not only able to cause infection in humans but also can cause problems in the plant *fusarium* is non-pathogenic for humans, but it can affect the growth of plants by reducing water capacity.

7.3.7 Health risk assessment by exposure

The health risk assessment of the bioaerosols was done during the foggy days of winter for adults and children. The values $HQ_{inhalation}$ and HQ_{skin} were 6.6×10^{-2}- 4.66×10^{-8} and 5.55×10^{-1}- 1.46×10^{-7} for adults and children, respectively. During the foggy days the exposure risk of bioaerosols was found to be higher in children than adults. In the estimation of the health risk of bioaerosols, the higher concentration of the bioaerosols contributes to higher exposure dose, hence leading to higher health risk. This may link to spatial and temporal variability of bioaerosols (Shi et al., 2018). The results of exposure risk of inhalation and skin in children were much higher than in adults, so this indicates that inhalation is the main cause of health risk from bioaerosol exposure and depends on the contact path. Since during the fog, many pathogenic bacterial and fungal bioaerosols were detected, and their concentration is significantly higher during the winter, so the health risk was also higher. Apart from this, the concentration of the finer bioaerosols is higher than that of the coarse bioaerosols. So, it can be inhale deep into the respiratory system of human body and causing different types of respiratory problems.

7.4 Conclusions

This study found that the bioaerosols (fungal and bacterial) concentration exceeded during the foggy days of winter. Bacterial bioaerosol concentration was higher than the fungal bioaerosol concentration during both foggy and non-foggy days of winter. Bacterial and fungal bioaerosols were found in a ratio of 1.12 overall to the samples during the foggy days. The major portion of the bacterial bioaerosols found in the coarse size range in comparison to the finer range. Whereas, for fungi, there was very less variation in the coarse and fine range of the particles. As the PM concentration increases, an increase in the microbial concentration were observed this may be because of an increase in atmospheric loading. Meteorological variables also play an important role in transportation and the survival of the concentration of bioaerosols. This study showed a positive correlation between the NO_x, NH_3, and bioaerosol concentrations. So, the pollutant also plays an important role in the variation of the concentration of the bioaerosols. The concentration and the biological nature of the bioaerosols may affect the human health. From the hazard ratio, it has been estimated that during both foggy days, exposure risk of inhalation and skin in children were much higher than adults so this indicates that inhalation is the main cause of health risk from bioaerosols exposure and children were on the more risk. From the hazard ratio, it has been estimated that during both foggy and non-foggy days, significant health risks (>1) were observed, therefore suggesting a greater bioaerosols-associated risk. Further, bacteria shows more potential adverse effects compared to fungi, as estimated by higher hazard quotient value. In this region, bacteria such as *Bacillus, Enterobacter,* and *Coccus* were found during the foggy days of winter. In comparison, fungi, mainly *Aspergillus, Cladosporium* and *Penicillium,* were prominent during the foggy days of winter. In our study, some of the detected microbes are harmful to human health. The symptoms of respiratory issues, eye irritation and skin irritation are very common issues caused by these microbes. Very few studies were reported on the bioaerosols during foggy days and their association with several pollutants, meteorological variables and particulate matter, especially in this region. So, further studies are needed to explore the relationship between foggy weather and bioaerosols and their possible health implications.