© 2015 IJSRSET | Volume 1 | Issue 4 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Seasonal Distribution of Ambient Fungal Spore in Bengaluru, Karnataka, India

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ABSTRACT

Ambient viable fungal spore was studied for four years, 2010 to 2013. Meteorological parameter (Temp, RH, wind speed-direction and precipitation) was recorded to assess the association of fungal spore and seasonal meteorological parameters. Maximum annual average of fungal spore was recorded during the year of 2012 as 47,734 CFU/m3. Minimum was during the year 2010 as 31,618 CFU/m3. In seasonally, maximum number of fungal spore was recorded during winter, monsoon and post monsoon. Majority of fungal aerosol belongs to genera of Fusarium, Aspergillus, Helminthosporium, Cladosporium, Penicillium, Monosporium, Alternaria, Candida and Trichoderma. Fungal spore had strong correlation with relative humidity (r=0.754) than ambient temperature (r=0.369). Fungal aerosol had strongest correlation (r=0.437) with wind during monsoon, significant correlation in post monsoon (r=0.243). Bengaluru embrace the multidimensional wind pattern during the month of May which dispersed maximum fungal spore. Rain fall pattern in Bengaluru declined fungal spore number in the atmosphere during monsoon. But, precipitation during summer potentially enhanced fungal spore from source. Overall study concluded that fungal spore dominated during winter and post monsoon which is high risk of fungal related health problems in human, animal and plants.

Keywords: Airborne Fungal Spore, Metrological Parameters, Seasonal Variation.

I. INTRODUCTION

Exposure to biological agents including fungal organisms is associated with a wide range of major public health issues, such as infectious diseases, acute toxic effects and allergies. Fungi are ubiquitous eukaryotic organisms that produce spores with the capability of long-range dispersal throughout the lower troposphere (Breitenbach et al., 2002). Understanding the seasonal diversity of airborne fungal spore along with the spatial and temporal distribution is increasing importance because fungal spores and other propagules can potentially act as sources of plant diseases (Madelin, 1994), human allergens (Breitenbach et al., 2002; Kurup et al., 2000), animal and human infectious agents (Enoch et al., 2006), and produce mycotoxins along with other deleterious secondary metabolites (Garvey and Keller, 2010). The concentrations of fungal spores in the outdoor air may vary depending on the weather and the climate. The characteristics of an airborne fungal population may be related to different environmental factors, such as seasonality, location, meteorological parameters, relative humidity, and temperature (Burshtein et al., 2011; Fr¨ohlich-Nowoisky et al., 2009; Oliveira et al., 2005). Many fungal spores are transported across great distances and are also regularly found indoors. The fungal spores enter a building through outdoor air intakes and as contaminants on building materials and contents (Shelton et al., 2002). Outdoor spaces that have excess humidity and characteristic air movements as a result of heating and natural ventilation provide favorable conditions for the survival of fungi.

Temperatures between 21-30 °C and relative humidity higher than 75% could induce faster fungal germination and growth. Therefore, it is considered that fungi grow much easier in areas with humid-warm climate. Monitoring of ambient fungal spore of the city of Bengaluru in Karnataka, India is necessary, because weather pattern of Bengaluru characterized by a humid-warm climate with annual mean temperature of 24.2 °C and mean relative humidity of 65.2% (IMD, 2013). The aim of this study was to establish the seasonal variation of fungal spores in outdoor of Bengaluru; to evaluate the existing relation between the number of colony-forming units (CFU) and seasonal meteorological parameters using a multiple regression analysis.

II. METHODS AND MATERIAL

A. Sampling site

The Aerobiological study was carried out at the Department of Environmental Science, Bangalore University, Jnanabharathi campus, National Ambient Air Monitoring Program (NAMP) station code 583, lies between the coordination 77°30′ E and 12°50’ N in Karnataka with average Altitude of 920 m (3,018 ft). The area chosen for this investigation that the sampling site falling within fifteen kilometers from the center of the city. Bangalore University is located in the Garden City of Bengaluru aptly hailed as the “I.T. Capital of India”, was established in July 1964 with on a sprawling 1100 acres of land with dense green cover. Jnanabharathi campus of Bangalore University is situated in south western part of the Bengaluru City which receives maximum wind from the south east and from the northeast part of Bengaluru urban. Therefore the sampling site is ideal site for air pollution monitoring.

B. Collection of Fungal Spores

Air samples were collected using single stage Anderson impactor (Air petri sampling system Mark III, model No. LA474, HiMedia Laboratories Pvt.Limited, Mumbai, India) operating at about 100 L/minutes with a frequency of about twice in a week during all season (January to December) placing at about 1.5 m above the surface, to simulate the human breathing zone. Sampling has been carried out for all the season during day light hours, usually between 06.00 and 18.00 hrs for the period of 2010, 2011, 2012 and 2013. Fungal enumeration was done using Martin rose Bengal agar and potato dextrose agar with Gentamycin with a final concentration of 0.5 mg/ml added to the media to inhibit growth of Bacteria. The impactor was disinfected with 99% ethanol swabs before sampling and every change of sampled plates. The sampler was turned on for two minutes prior to sampling to allow the alcohol to evaporate and not affect the fungal count. Sampling interference like sneezing, coughing and handling are taken care for each sampling. After sampling of fungal aerosol, the sampled petri dishes were sealed with transparent adhesive tape (sellotape) and marked the date and time of sampling.

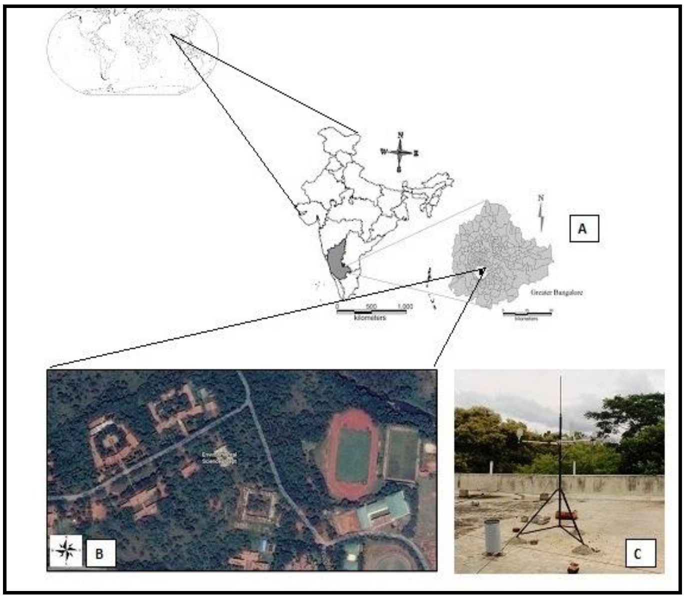

Figure 1 : A. Bengaluru urban district, B. Department of Environmental Science, Bangalore University, C. Automatic weather station at Jnanabharathi campus of Bangalore University

C. Sample Analysis

Fungal plates were incubated at room temperature 24-250C and the colonies were counted after 5 days. Further on each plate, approximately 50% of the entire colonies were isolated for partial identification by light microscopy based on fungal morphology following standard method (Barnett, 1960; Ellis, 1971).

D. Environmental Parameters

During air sampling, temperature, relative humidity, wind direction and speed were measured for all season. Ground based automatic weather monitoring station facility at Dept. of Environmental science; Bangalore University was used to study the association of meteorological parameters on fungal spores.

Meteorological parameters were recorded using meteorological monitoring system (WM 271, Envirotech Instruments, New Delhi). It has five inbuilt different sensor like Wind Speed (WS 10), Wind Direction (WD10), Temperature and Humidity (RT10). The temperature is expressed in 0C and the relative humidity is expressed in % and the wind direction and the wind speed is expressed in m/s.

E. Statistical Analysis

The correlation coefficients for different parameters were calculated using simple linear regression models.

Pearson correlation and Regression analysis was performed to explain the change of the fungal concentration (dependent variable) in relation to the meteorological factors (independent variable). All the statistical analyses were made using windows excel.

One-way analysis of variance (ANOVA) is a statistical tool of examining the influence of two different categorical independent variables on one continuous dependent variable. The two-way ANOVA was adopted to analyze the population difference of fungal spores between seasons during the study period (i.e.2010 to 2013).

III. RESULTS AND DISCUSSION

A Fungal aerosol were sampled and monitored for the period 2010 to 2013 and monthly average was recorded to assess the seasonal variations of fungal organisms in comparison for four years. Annual average of total fungal aerosol recorded during the year 2010 as 31,618 CFU/m3, for the year 2011 as 35, 514 CFU/m3, for the year 2012 as 47, 734 CFU/m3 and for the year 2013 was recorded as 40, 159 CFU/m3 (Fig.1). Members of the fungal genus like Fusarium, Aspergillus, Helminthosporium, Cladosporium, Penicillium, Monosporium, Alternaria, Candida, and Trichoderma were recorded in all the seasons. Total number of individual bacterial aerosol count varied seasonally during the study period from 2010 to 2013.

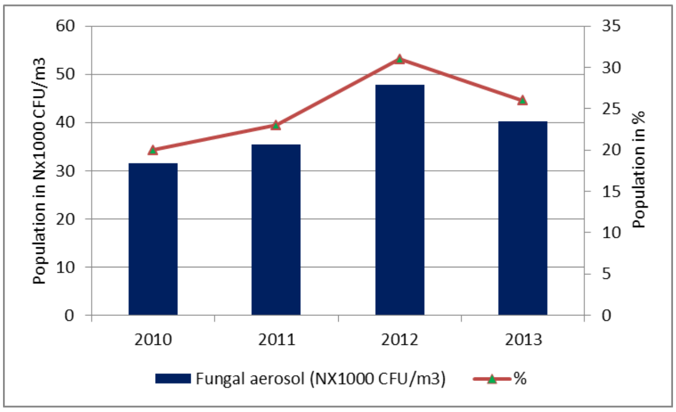

Figure 2: Variability of fungal aerosol for the period 2010 to 2013

Total fungal aerosol number ranged from 1, 785 CFU/m3 to 4,152 CFU/m3 during the year of 2010. Maximum was recorded during the month of May and minimum during October (Fig.2). In 2011, total fungal aerosol number ranged from 3,011 CFU/m3 and 3,565 CFU/m3. Maximum number of fungal aerosol was recorded during the month of January and May. The minimum number was recorded in October month. In 2012, recorded maximum fungal spore compare to the year of 2010, 2011 and 2013. The fungal spore number was ranged from 5,422 CFU/m3 to 2,286 CFU/m3. Maximum was recorded during the month of January and minimum was during the month of April . Maximum fungal spores during the year of 2012 attributed by dumping of municipal solid waste (MSW) around the city. Field observations have shown that municipal waste in the Bengaluru city was not managed properly (Fig 3). In proper waste collection at house hold level, lack of perception on solid waste management and lack of coordination of localities and Bengaluru city municipal authority resulted dumping of solid waste around the study area. Organic and inorganic waste in ventilated place around the study area might have influenced the fugal growth and dispersed the fungal spore (Fig. 3). In Bangalore urban generate a great amount of municipal solid waste which is dumped on land in a uncontrolled manner. Accumulation of solid waste in unscientific way leads to leachate formation that contains a large number of xenobiotic organic compounds and contaminates the air. Soil, and surface and ground waters in the vicinity of the site. Pathogens found in MSW, can be viruses, bacteria, protozoa or helminthes (Xu et al., 2008).

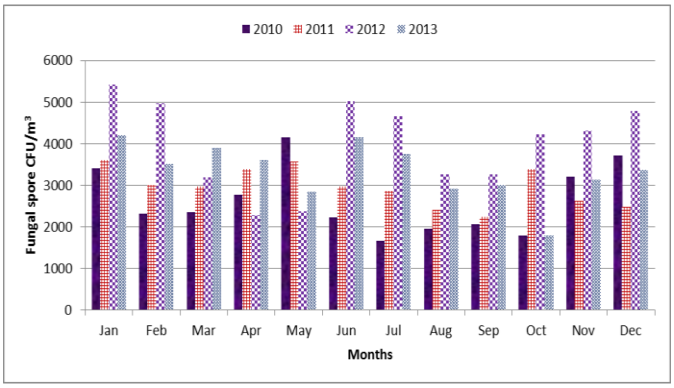

Figure 2: Monthly distribution of fungal spore for the year of 2010, 2011, 2012 and 2013.

Our earlier study Sivasakthivel and Nandini, (2014) found that municipal solid wastes Management are a large scale disposal problem in Bangalore. It has been estimated those 3600 tons per day in 2012 with the population 8,465,752. In which 1,139 tones are collected and sent to composting units such as Karnataka composting Development Corporation. The remaining solid waste are collected by the municipality is dumped in open spaces or non-roadsides outsiders the city. Solid waste management failure in Bangalore during 2012 cause Solid waste dumping crisis in cities and its impacts are pathogenic Bioaerosol mission, deterioration of air and water quality. Un scientific disposal of solid waste in are the major source of fungal aerosol in Bengaluru city during the year of 2012.

Figure 3: Dumping of garbage in open place around the Bengaluru city

In 2013, annual average of fungal spore recorded as 40, 159 CFU/m3. Maximum was recorded during the month of January as 4,206 CFU/m3 and minimum during the month of October as 1,786 CFU/m3 (Fig.2). The annual fungal record shows that second most in fungal spore occurred in air. The second most fungal occurrence during the year of 2013 attributed by effect of solid waste crisis around the study area. Solid waste management problem around the study area since 2012 contributed massive fungal spore in air during the year of 2013.

A. Seasonal Variability of Fungal Spore

Seasonal variation of fungal spores depends on meteorological parameters such as temperature, relative humidity and rainfall. Population and type of fungal spores change with the time of the day, weather conditions, season, geographical location and the presence of sources.

The experimental data of fungal aerosol for the period of 2010 to 2013 are compiled and classified season wise to reveal the variability of fungal spore during different seasons of Bengaluru. The seasons are classified according to Indian Meteorological organization (IMO). The season are i. winter (December, January and February); ii. Pre-monsoon or summer (March, April and May); iii. Monsoon (June, July and August); iv. Post monsoon (September, October and November).

Seasonal record shows that maximum number of fungal spores was recorded during winter as 45, 686 CFU/m3, premonsoon as 39, 717 CFU/m3 and post monsoon as 37, 805 CFU/m3 (Fig 4). Many investigation on fungal spore in air suggested that maximum population of fungal spore was recorded during winter, monsoon and premonsoon. Minimum fungal species were recorded in summer season (Shaista Parveen, et al., 2013). Umesh and Hemalatha, (2012) studied seasonal variability of fungal diaspora in Nagpur, India and recorded highest incidence of spores between August to January (monsoon and winter) while March-May (summer) was the lean period. Dispersion of maximum fungal spore in air caused by moisture, dew in winter and rain in the monsoon may enhance the growth of fungi and subsequent sporulation into atmosphere. Fungi needs water in the form of moisture to digest the organic matter. In the presence of moisture, fungi releases enzymes to break down complex materials into simpler ones that can be absorbed by the fungus and release the spores into air. The presence of fungal spores produces the mycotoxins which are secondary metabolites that can cause various health problems in humans and animals.

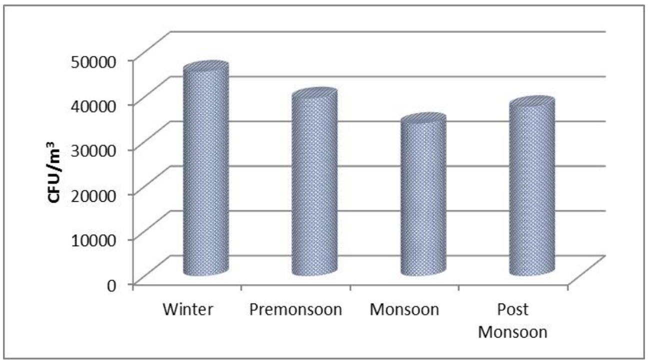

Figure 4: Seasonal variation of fungal spore of Bengaluru

The two-way ANOVA was adopted to analyze the population difference of fungal spores between seasons during the study period (i.e.2010 to 2013) and calculated. The estimated p- value (0.0036) between the seasons is less than 0.05, which indicates that the fungal spores significantly varied from season to seasons. Similarly, the estimated p-value (0.015) between the years is less than 0.05, which indicates that the fungal spore's number moderately varied from 2010 to 2013.

In season wise, highest variation of fungal spore was calculated in premonsoon data ($\sigma 2$ – 42.0). The statistical computational result indicates that high degree of changes in meteorological parameters during 2011 and pre monsoon season. This evidence directly proves that frequent weather fluctuation during 2011 responsible for the variation of fungal spore in air. Eventually, changes of rain pattern in Bangalore altered the meteorological parameter in premonsoon season.

Meteorological parameter during different season plays a crucial role in the variability of bacterial and fungal aerosols in Bangalore. Dispersion of fungal spore in air is affected by variations of meteorological parameters such as temperature, pressure, wind speed and humidity. These are associated with change of weather during different seasons.

B. Role of Meteorological Parameters on Fungal Spores

Meteorological parameters recorded during different season to evaluate the association of fungal spores with meteorological factors (Table 1).

Table 1: Seasonal Meteorological parameters for Bangalore

Study Period	Avg. Temp (Celsius)	Avg. Relative Humidity (%)	Avg. Rain fall (mm)	Avg. Wind speed (Km/h)	Sum of Fungal aerosol (Nx1000 CFU/m3)
2010	**29.3**	**70.2**	**480**	**5.9**	**31.6**
Pre Monsoon	34.7	61.3	200	5.6	9.2
Monsoon	28	79.3	910	9.4	5.8
Post monsoon	27.5	76.3	750	6.3	7.0
winter	27.1	64.2	60	2.3	9.4
2011	**29.1**	**67.7**	**337.5**	**7.9**	**35.5**
Pre Monsoon (Summer)	32.6	58.5	210	6.7	9.9
Monsoon	27.8	79.6	670	13.4	8.2
Post monsoon	28.4	77.3	410	7.4	6.6
winter	27.7	55.6	60	4.3	9.1
2012	**29.7**	**63.1**	**322.5**	**8.5**	**47.7**
Pre Monsoon (summer)	33.8	53.4	180	8.2	7.8
Monsoon	29.4	72.5	680	11.2	12.9
Post monsoon	28.1	69.6	400	9.4	11.1
winter	27.6	57.1	30	5.2	15.1
2013	**29.7**	**67.0**	**327.5**	**5.9**	**40.1**
Pre Monsoon (summer)	34.6	55.2	220	5.4	10.3
Monsoon	27.7	79.1	590	8.8	10.7
Post monsoon	28.9	77.1	460	6.3	7.6
winter	27.9	56.9	40	3.1	11.0

Transport of microorganisms in the atmosphere is primarily governed by hydrodynamic and kinetic factors, while their fate is depend upon the meteorological parameters to which they are exposed. The most significant environmental factors influencing viability are Relative humidity (RH), Temperature and Oxygen. Transport of fungal spore from one place to another place mainly is governed by wind speed and wind direction. Meteorological parameter varies geographically and seasonally.

Meteorological parameters recorded during different season and Karl Pearson rank correlation were used to evaluate the association of bacterial, fungal aerosol dispersion and temperature, Relative humidity, rainfall, wind speed, wind direction. The correlation between fungal spore and meteorological parameters revealed that meteorological parameters have significant impact on bacterial and fungal spores.

D. Temperature and Relative Humidity

Temperature and relative humidity data were recorded simultaneously during sampling. Fungal spores respond to temperature and relative humidity during different seasons (Fig.5 & 6). The temperature record from 2010 to 2013 shows that there is a mild increasing tendency of temperature in Bangaluru weather. Minimum annual mean of 29.12^{0}C were recorded in 2011 and maximum annual mean of 29.77^{0}C was recorded in 2013.

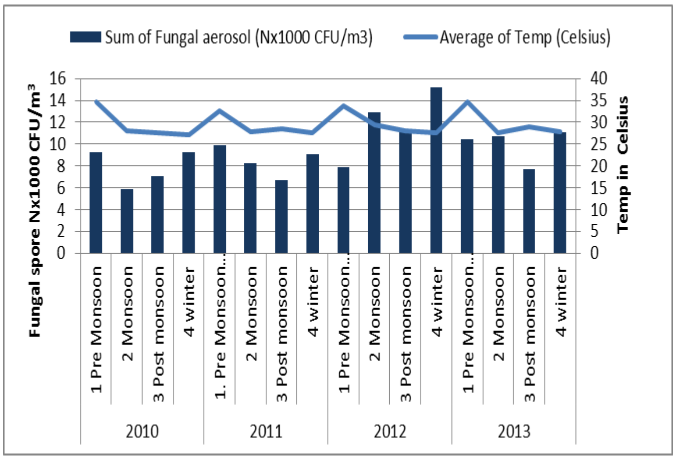

Figure 5: Association of fungal spores and temperature

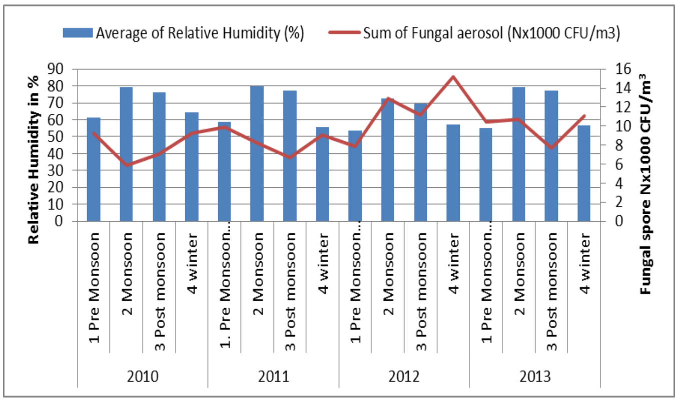

Figure 6: Association of fungal spore and Relative humidity

Similarly, highest percentage of relative humidity was recorded in 2010. Annual mean as 70.32. Minimum percentage of relative humidity was recorded in 2012, the annual mean as 63.1. Correlation analysis between fungal aerosol on temperature and relative humidity showed that fungal aerosol showed strong correlation with relative humidity than temperature (Table 2). Correlation rate between fungal and relative humidity in post monsoon is r=0.754, monsoon is r=0.673 and winter is r=0.431 are very close to 1, considered as high correlation rate. Whereas, least correlation was observed with temperature. The high correlation rate in post monsoon, monsoon and winter draw a clear interpretation that excess of moisture (relative humidity) in these seasons significantly enhanced the population of fungal spores in air.

Table 2: Spearman's correlation coefficient between meteorological parameters and fungal spores in different season

	Avg. Temp	Avg. Relative Humidity	Avg. wind speed	Avg. precipitation
Pre-monsoon (Summer)	0.069*	0.147***	0.126**	0.0132**
Monsoon	0.024*	0.673***	0.437***	-0.142***
Post monsoon	0.059*	0.754***	0.243***	-0.084***
Winter	0.023*	0.431***	0.046**	-0.034***

* P<0.05, ** P<0.01, *** P<0.001

The meteorological parameter temperature and relative humidity data of Bengaluru collected from Weatheronline meteorological service Ltd, United Kingdom to assess the changes of ambient temperature and relative humidity of Bengaluru during the study period. Meteorological sensor data shows that relative humidity (RH) and temperature (Temp) fluctuated during winter and post monsoon season of the year 2011 and 2012 (Fig.7). In the year 2010 Fig.7 C and E represents the sudden increase and decrease state of temperature during post monsoon and winter season. Fig.7 D represents the sudden increase and decreasing state of relative humidity during post monsoon and winter. The weather fluctuations may be attributed by occasional rain fall during postmonsoon and winter season. The rain fall during postmonsoon and winter increases the relative humidity which enhanced fungal spores. The sudden drop of relative humidity may affect the settling of particles and enhanced emission of fungal spore from environmental sources. The higher number of fungal spores during winter and postmonsoon season will have impact on children who are highly sensitive to spores.

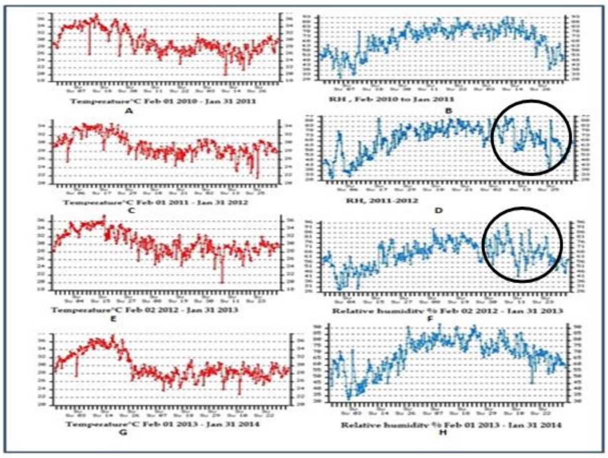

Figure 7: Remote sensing data of meteorological parameters (RH and Temp) fluctuation in Bangalore (Weather online meteorological parameter Ltd, United Kingdom).

Many research suggested that relative humidity in air and soil are essential for the fungal spore germination. Hassouni, et al., (2007) found that all fungal species germinated under the condition of 70-80% relative humidity in air. High rate of fungal germination was observed at 98% relative humidity in air and soil. The relationship between fungal aerosol and temperature is moderately correlated (r=0.059) in post monsoon. The correlation result demonstrates that excess relative humidity with mild temperature in post monsoon significantly enhanced the fungal population. Similar finding was reported by Yenping et al., (1975) who states that fungal spore production, germination, and root colonization were reported to be maximum at optimum soil moisture with mild temperature.

E. Wind Speed and Wind Direction

Wind speed data was recorded during fungal spore sampling and the seasonal average was calculated to study the relationship between the wind speed and fungal spore concentration. The wind speed in Bengaluru varied annually and seasonally as well (Fig.8). The wind speed data for the year 2010 to 2013 indicates that 2012 recorded highest wind (8.5 Km/h) which enhanced the maximum transport of fungal spore. The least wind was recorded in 2010 and in 2013 as an annual average of 5.9 Km/h for each. Maximum velocity of wind was observed during monsoon season and least in winter. Pearson's rank correlation is applied to study the relationship between wind speed and fungal spores. The correlation results showed that wind speed is positively correlated with fungal spores. But, the degree of correlation between wind and fungal aerosol varied for different seasons. The fungal aerosol had strong correlation with wind (Table 2).

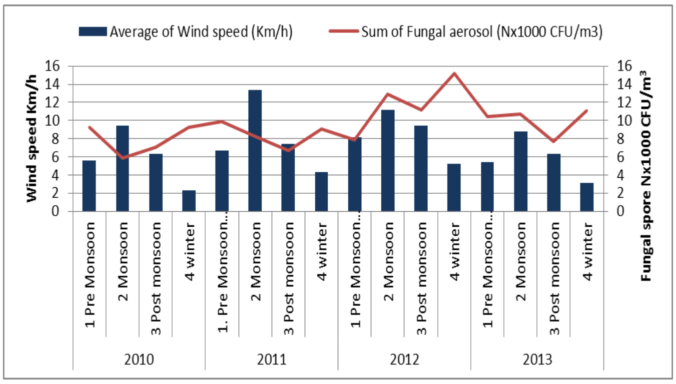

Figure 8: Association of fungal aerosol with wind speed in different season

Seasonal fungal aerosol had strongest correlation (r=0.437) with wind during monsoon, significant correlation in post monsoon (r=0.243), moderate in pre-monsoon (r=0.126) and least correlation in winter (r=0.046). The statistical results revealed that high velocity of wind during monsoon and post monsoon caries maximum fungal aerosol from the source. In other hand, high rate of correlation was found with fungal aerosol in monsoon and post monsoon which proves that excess moisture during these seasons enhanced the germination of fungal spore and was transported by wind. Fungal species thrive well on trees, plant leaves and soil. Wind speed disrupts fungal organisms present material on plants and soil is lead to high density of fungal aerosol in air.

Similar finding supported by Aylor and Parlange (1975) study revealed that removal of fungal spores from the surface depends on the variations in the wind speed across the surface. Wind speed of average 0.5 meter/s to 3 meter/s enhanced the release of fungal spore from barley plant. Release of fungal spores are accelerated by turbulent air that significantly disturbed the leaf surface.
Wind direction during different seasons was studied to understand the magnitude of fungal spore transportation and dilution. Wind direction during different seasons was considered to understand the horizontal dilution of fungal spores. Wind direction is reported by the direction from which it originates. The annual wind direction distribution chart shows that Bengaluru receives wind from two different directions (Fig.9). Maximum percentage of wind received from East (E), South-West (SW) and minimum from South- East (SE) and North-West (NW). During the month in January, February, March and April wind direction is from East and South – East (Fig 10-14).

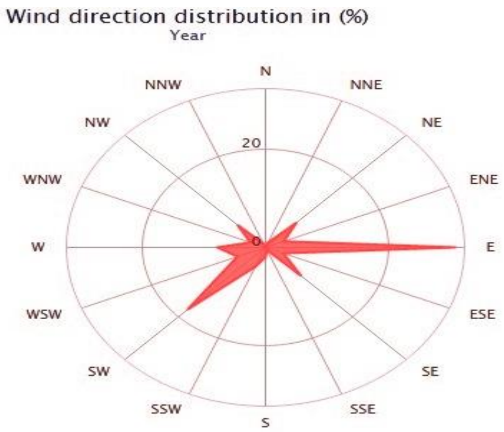

Figure 9: Over all annual Pattern of wind direction in Bangalore

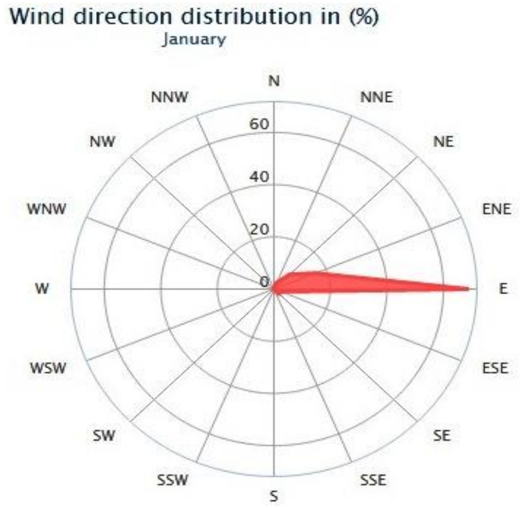

Figure 10: Wind direction during January

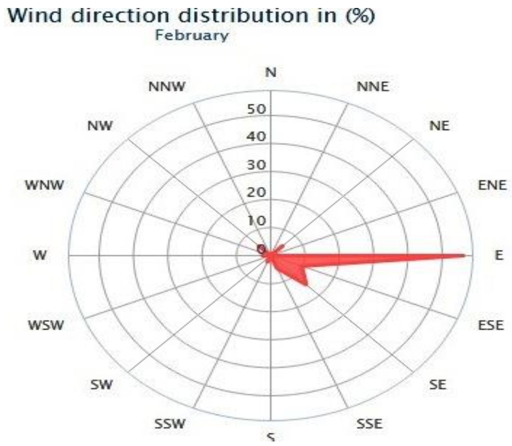

Figure 11: Wind direction during February

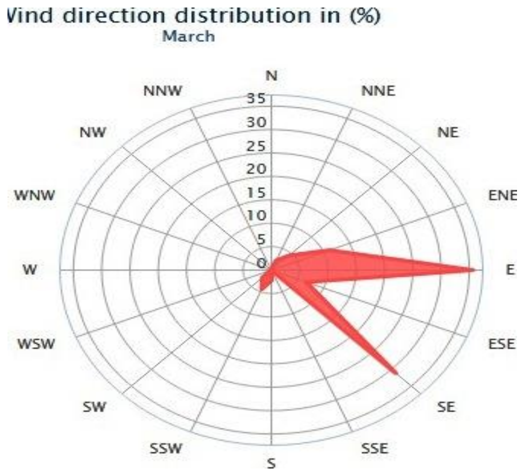

Figure 12: Wind direction during March

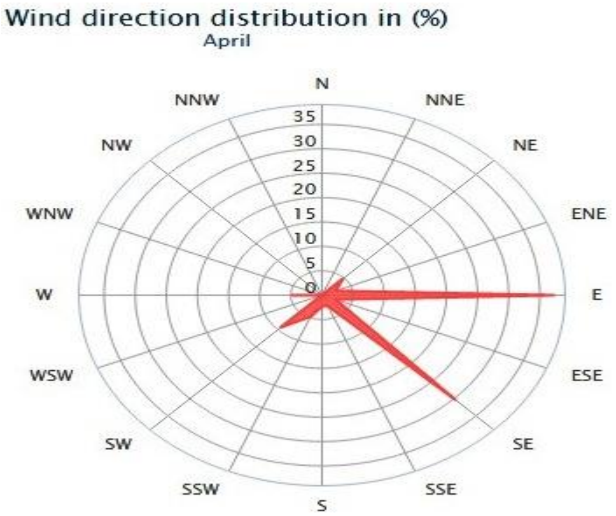

Figure 13: Wind direction during April

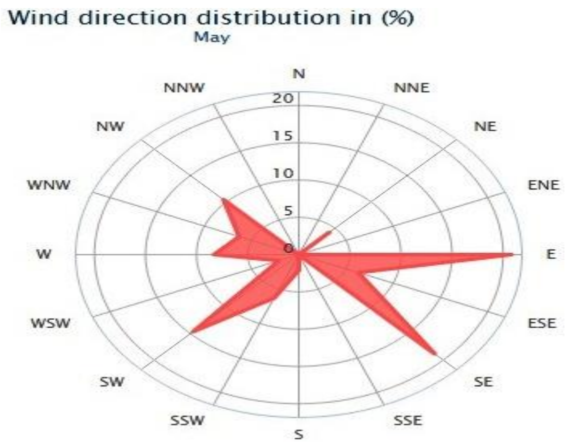

Figure 14: Wind direction during May

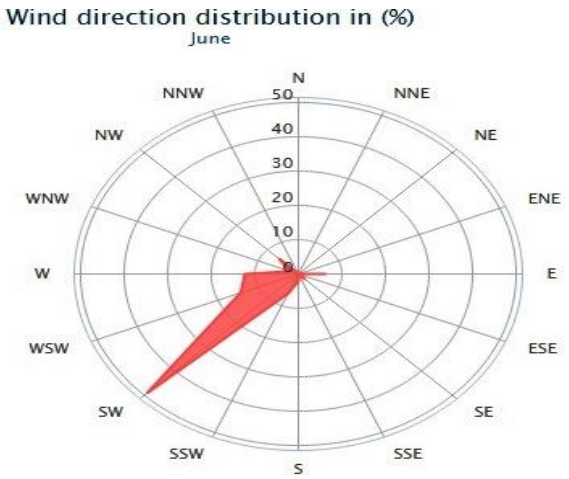

Figure 15: Wind direction during June

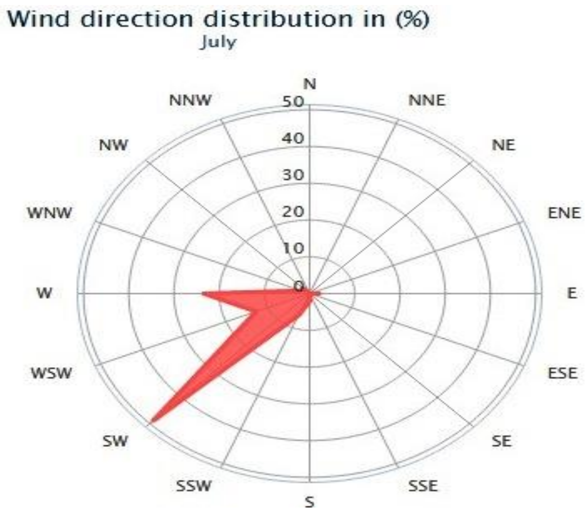

Figure 16: Wind direction during July

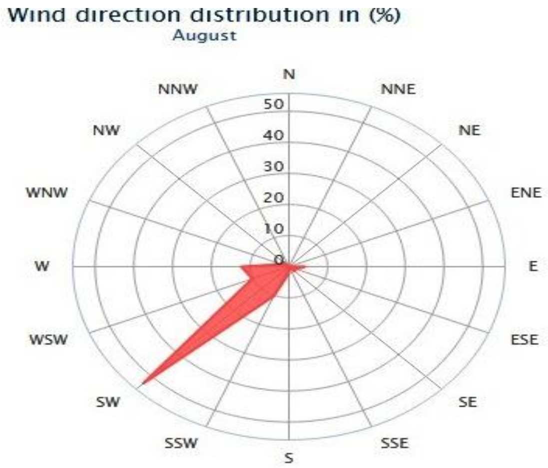

Figure 17: Wind direction during August

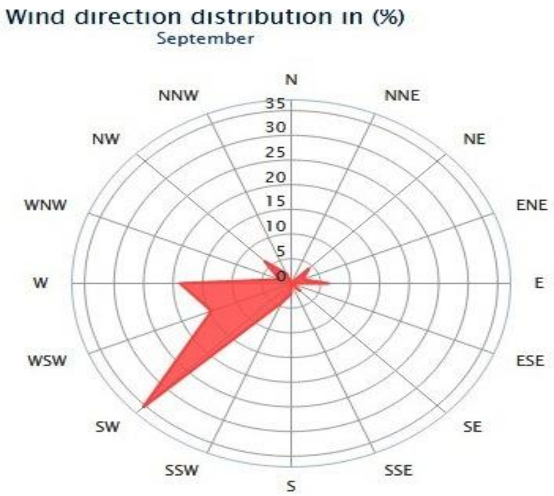

Figure 18: Wind direction during September

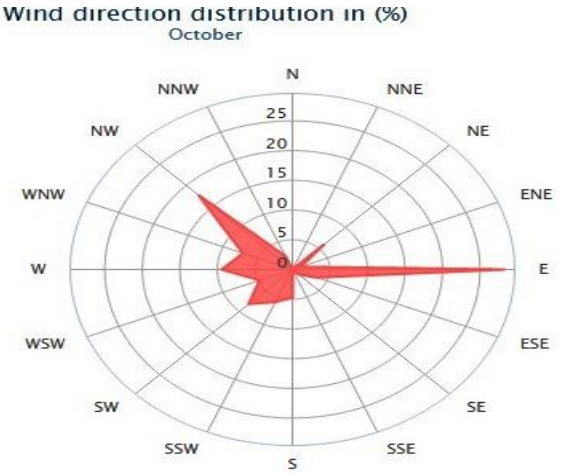

Figure 19: Wind direction during October

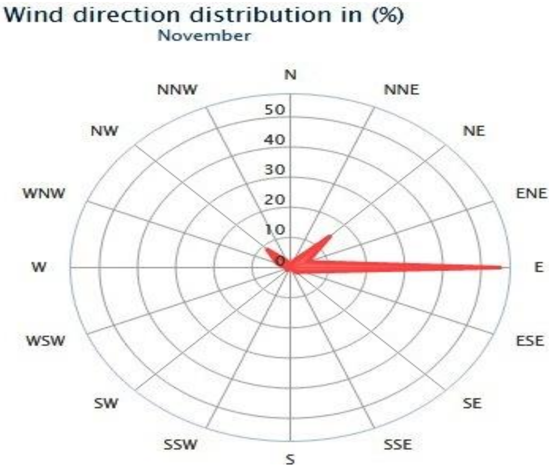

Figure 20: Wind direction during November

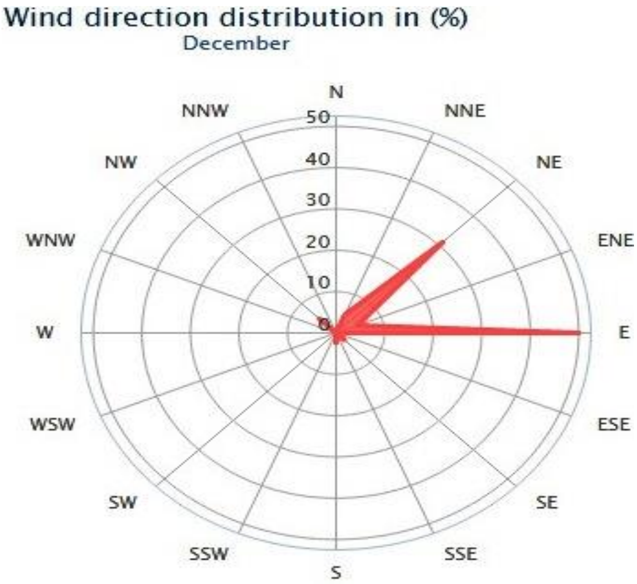

Figure 21: Wind direction during December

The Eastern wind caries the fungal spores from Eastern zone of Bangalore and has spread it towards Western zone of Bangalore. In the month of May Bangalore is facing multidirectional wind pattern (Fig 14). The wind originates from East (EE), South- East (SE), North-west (NW) and South-west (SW). The multidimensional wind pattern during the month of May disperses the fungal spores in multidirectional which is vulnerable to health of people in Bangalore. During June, July, August and September wind is received from south-west and it spreads the fungal spore towards North-East part of Bangalore (Fig 15-18). In October, wind originated from North-West and East. In November, December wind received from East and North East (Fig 19-21).

F. Rainfall

Seasonal rainfall data was collected to study the association of rain on fungal spores. The rainfall data recorded shows that maximum rains during 2010 and minimum in 2012 with an average of 480mm and 322 mm. Moderate rains were observed during the year 2011 and 2013 with an annual average of 337mm and 327mm (Fig 22). Highest rain fall was recorded during monsoon season around 910mm during the year 2010. Minimum rain fall was recorded during monsoon of 2013 as 590mm (Table 1).

The data analysis between rain fall and fungal spore showed that rainfall had significant impact on fungal spore number. The fungal spore number varied with rain fall pattern. The fungal spore number decreased during rain fall (Fig.23). This phenomenon directly proves that maximum rain fall during the year of 2010 cleared atmosphere resulted minimum number fungal spore. The Spearman correlation between rainfall and fungal spore showed that fungal spore had negative correlation during monsoon, post monsoon and in winter.

However, bio aerosols had positive correlation during pre-monsoon (summer) season which means that rain fall during pre-monsoon (summer) enhanced the fungal spore in air. The correlation result draws the clear interpretation that rain fall during summer enhanced the fungal spore in air and decreases the number of fungal spore during monsoon season (Table 16 & 17). Many researches like Himanshu Lal, et al., (2013) had recorded similar findings and state that lesser number of fungal spore in rainy season is due to rains which clear the atmosphere resulting in a remarkable decrease in fungal spore number in monsoon season. Fungal spore had positive correlation during pre-monsoon. This evidence proves that rain fall during summer enhances the dispersion of fungal spore in the air. Lesser rains in summer may enhance the fungal spore emission. The ideal temperature and moisture driven by occasional rain in summer may favor the dispersion of fungal spore from the source.

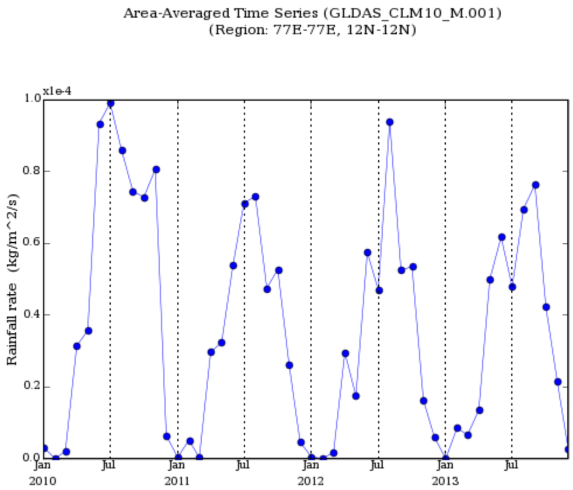

Figure 22: Rainfall pattern for the study period

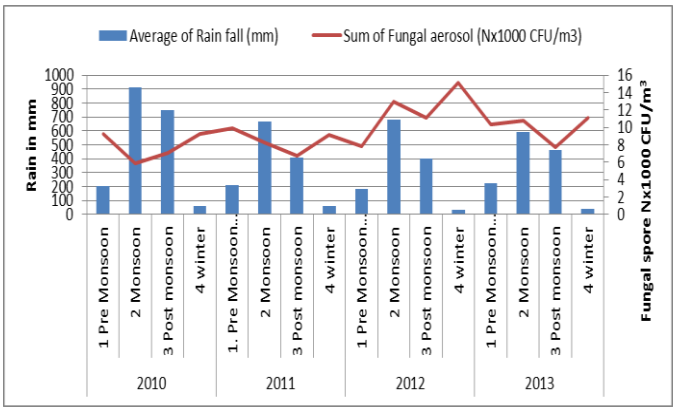

Figure 23: Impact of rainfall on fungal spore

Mild rain in summer triggers the emission of bacterial and fungal aerosol from contaminated soil, infected plants, garbage dumping site etc., Similar findings have been reported by Livingston., et al., (1963); Crawford,et al., (2014) that after rain, near ground level there is often various kinds of air spora during summer. These evidences prove that the rain fall during monsoon decreases the fungal spore in Bangalore. But, mild rain in summer potentially raises the fungal spore in air.

IV. CONCLUSION

Monitoring of fungal spore for the study period revealed that highest fungal spore in air occurred during the year of 2012 and minimum during the year of 2010. The air quality during the year of 2011 and 2013 are moderately polluted by fungal aerosol. Accumulation of municipal solid waste, Fluctuation in temperature and relative humidity, maximum wind velocity, minimum rain fall resulted massive emission of fungal spore during the year of 2012. Seasonal study proved that maximum fungal pollution occurred during winter and post monsoon. Minimum fungal pollution was recorded in monsoon season. Bengaluru received maximum wind from East (E), South-West (SW) and minimum from South- East (SE) and North-West (NW). In the month of May, Bangalore as multidirectional wind pattern like, wind originates from East (EE), South- East (SE), North-west (NW) and South-west (SW) created multidimensional wind pattern which transported maximum fungal spore. Precipitation study for the period of 2010 to 2013 confirmed that precipitation in Bengaluru is moderately declined. Precipitation had significantly reduced the fungal spore number during monsoon and precipitation during premonsoon (summer) potentially enhanced the fungal aerosol. However, fungal spore had positive correlation with rainfall during pre-monsoon (summer) season enhanced the fungal aerosol in air. From this it is evident that the rain fall during monsoon decreases the fungal aerosol in Bengaluru. But, mild rain in summer potentially raises the fungal aerosol. Overall study concluded that Bengaluru city embrace the risk of fungal related allergy by anthropogenic activity.

V. ACKNOWLEDGMENT

The authors acknowledge the Central Pollution Control Board (CPCB), New Delhi, Government of India, New Delhi and Karnataka State Pollution control Board (KSPCB), Government of Karnataka for providing infrastructure and financial assistance which buttressed the work comfortably.

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