TREND ANALYSIS OF AIR QUALITY IN DHAKA CITY CONSIDERING METEOROLOGICAL PARAMETERS

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ABSTRACT

Dhaka with a population density of around 23,234 per square kilometer is experiencing major health impacts resulting from poor air quality (World population review, n.d.). The aim of this study was to understand the trend of air quality of Dhaka city considering meteorological and seasonal influences. The critical air pollutant for Dhaka city is particulate matter (PM), the primary sources of which are emission from brick kilns, vehicles, industries and re-suspension of dust. Analysis of data shows that the trend of air quality in Dhaka during the period 2012 to 2017 has a strong seasonal variation. Concentrations of both PM_{10} and $PM_{2.5}$ exceed national standard during winter by a large margin. Peak monthly average PM_{10} and $PM_{2.5}$ concentrations approach or exceed 200 µg/m^3 and 300 µg/m^3. Wind blowing from the north-western and western direction during dry season brings in pollutants from brick kiln clusters situated along northern to western periphery of the city. PM concentration decreases with the increasing of precipitation during rainy season which indicates that the water droplets settle down the ambient particulate matter. From the analysis, it is observed that the peak concentration of $PM_{2.5}$ goes slightly downward which could be due to improvement of brick kiln technologies and increasing use of CNG fuel. The concentration of $PM_{2.5}$ is slightly higher in Mirpur area possibly because of its close proximity to brick kiln clusters and ongoing infrastructure development activities.

Keywords: *PM, CAMS, Rainfall, Brick kilns, Trend*

1. INTRODUCTION

Dhaka, capital of Bangladesh, due to industrialization and urbanization processes polluted air quality. A five-year survey by the department of environment found Narayanganj has the most polluted air, followed by Dhaka. Third is Gazipur, which is followed by Rajshahi, Chattogram, Khulna, and Barisal. The air in Sylhet city, however, is cleaner. The survey was done between 2013 and 2018 with funds from the World Bank. Even though Dhaka came out second worst in the country, the World Health Organisation (WHO) in 2018 said Dhaka was the world's third worst city in terms of air pollution, behind Delhi and Cairo (Brick kiln top polluter, n.d.). Among all the criteria pollutants, Particulate Matter is of main concern as it causes several respiratory diseases such as acute respiratory distress, asthma, chronic obstructive pulmonary disease, and lung cancer. So, the parameters related to the concentration of PM need to be analyzed.

According to the data concentration of PM collected from CAMS at three location of Dhaka city, a trend can be seen over the past decade. The geographical location of Dhaka and meteorological parameters are important variables in controlling the concentration without considering the sources of PM. Due to adsorptive characteristics of rainfall, the concentration is reduced during monsoon. Wind coming from East-North direction brings PM originated most probably from brick-kilns. Sources of PM concentration are related with construction or industrial productions. Ziaul Haque, DoE director for air quality management, said that in 2017-18 fiscal year, half the air pollution in Dhaka was caused by brick kilns while construction work contributed around 25 percent and vehicle emission 10-12 percent (Brick kiln top polluter, n.d.).

A statistical analysis of concentration and meteorological parameters is a way of finding the relation among the variables and trend. A downward trend can easily be observed from the analysis at three locations of CAMS in Dhaka city. Both PM_{10} and $PM_{2.5}$ concentrations exhibit levels exceeding the World Health Organization (WHO) guidelines; they also exceed the national standards of annual PM_{10} (50 µg/m^3) and $PM_{2.5}$ (15 µg/m^3) by a factor of over two. On the basis of polluted air quality with the presence of particulate matter Dhaka is ranked as 45th among the 3000 cities of 103 countries (WHO, 2016).

2. METHODOLOGY

The trend analysis is based on the PM data collected from DoE (Department of Environment). 24-hr average concentrations of $PM_{2.5}$ and PM_{10} were measured at the CAMS and the daily and monthly data are available from April 2002 to December 2017. Data of last decade is taken to study the trend of concentration of PM. Meteorological data (Rainfall, Average temperature, Humidity, Wind direction and Wind speed) was collected from Bangladesh Meteorological Department because daily data of all the parameters are not available from DoE. The relation between PM and meteorological data are established using MS excel. The trends of PM of CAMS were obtained from plotting bar diagram using same software.

3. ASSESEMENT OF AIR QUALITY TREND IN DHAKA CITY AND EFFECTS OF METEOROLOGICAL FACTORS

Reliable air quality data is a prerequisite for air quality modelling and for development of policy options for managing air pollution and its adverse impacts. As most of the time particulate matter ($PM_{2.5}$) become “critical pollutant”, correlation of ambient PM with different meteorological parameters like rainfall, average temperature, humidity, wind speed and direction etc. have been analysed to understand their effects on ambient PM concentration.

3.1 Trend of Particulate Matter

From the monthly average PM data collected from three CAMS of Dhaka city, a regular pattern of variation of the concentration of PM with seasons was observed. Figure 1, 2 and 3 show the daily average concentration of $PM_{2.5}$ and PM_{10} from 2012 to 2017 at Sangshad Bhaban CAMS, BARC CAMS and Darussalam CAMS respectively. It shows that both $PM_{2.5}$ and PM_{10} values are well above the national standard during the dry season (November to March), while during the wet season (April to October) these concentrations comfortably meet the standards. These seasonal variations are seen in almost all the years for which data are available. From October the concentration starts to increase much and reaches peak around January. Then from February the concentration starts to decrease. From April when wet season starts the concentration become lower.

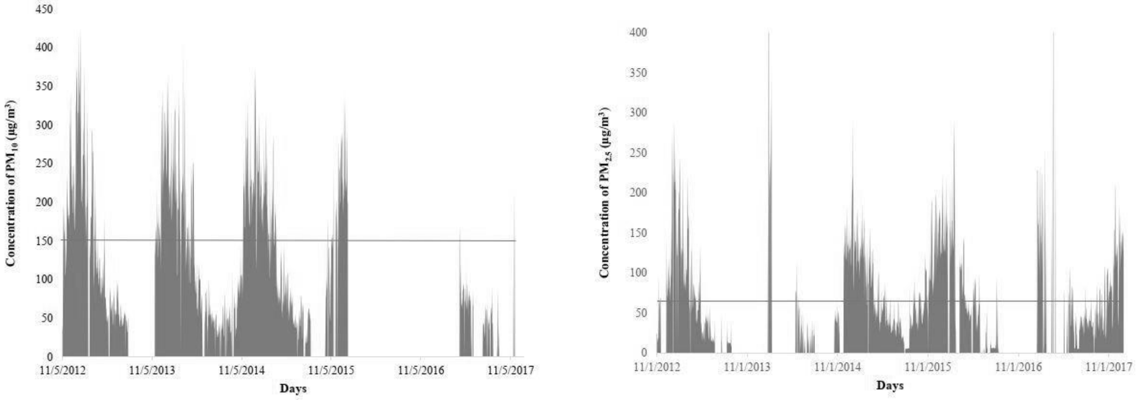

Figure 1: Daily average concentration of PM_{10} and $PM_{2.5}$ of Shangshad Bhaban CAMS

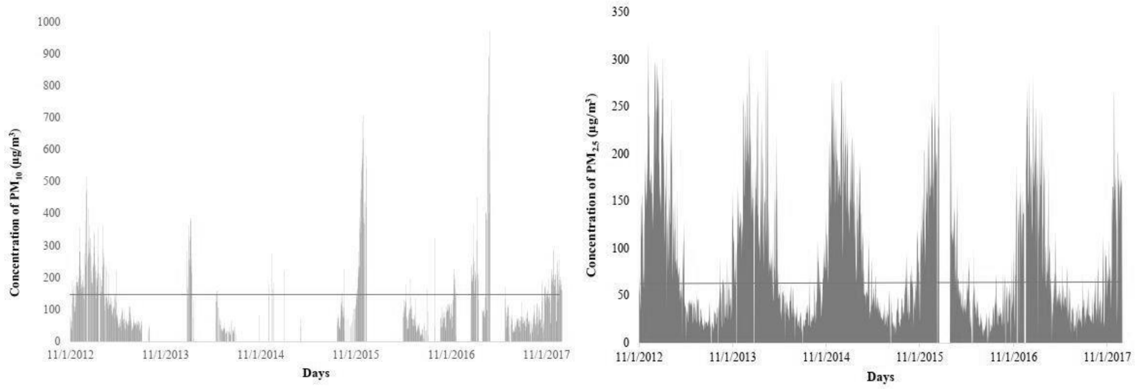

Figure 2: Daily average concentration of PM_{10} and $PM_{2.5}$ of BARC CAMS

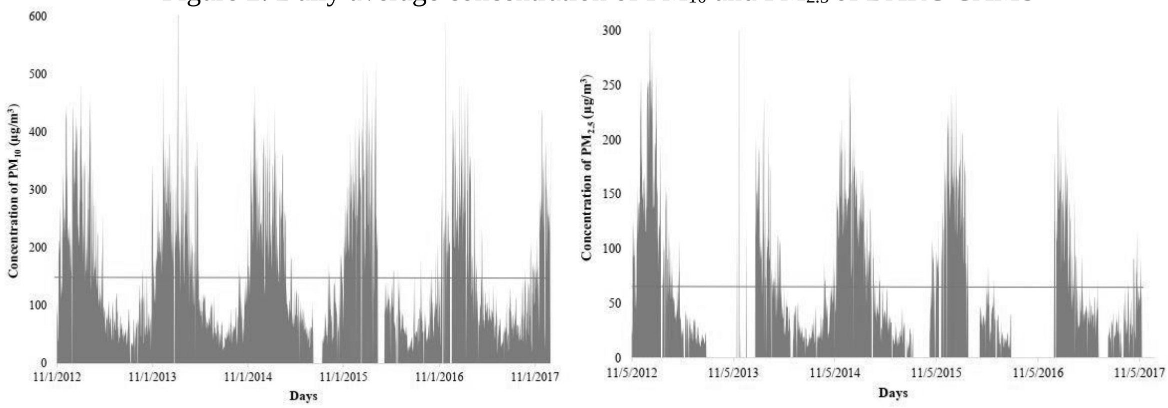

Figure 3: Daily average concentration of PM_{10} and $PM_{2.5}$ of Darussalam CAMS

3.2 Effects of Meteorological Parameters

3.2.1 Relation of PM with Precipitation

Precipitation has a significant impact on $PM_{2.5}$ and PM_{10} concentrations. From daily average concentrations of $PM_{2.5}$ and PM_{10}, we observed a huge variation of concentrations during dry season (November to March) and during wet season (April to October) (Figure 1, 2 and 3). The average concentrations of both PM are very high during dry reason relative to the wet season. One of the possible reasons behind this variation is that the water droplets settle down the ambient particulate matter in wet season.

Besides, from figure 4 a negative correlation is observed from the scattered plot of $PM_{2.5-10}$ vs rainfall. With the increase of the amount of precipitation the concentration of particulate matter decreases. It indicates that the amount of precipitation has a great impact on reducing the amount of ambient particulate matter in air. The correlation between the number of days of occurring rainfall and $PM_{2.5-10}$ are also significant (Figure 5). These two graphs show that both the amount of rainfall and number of rainy days have major impact on the decrease of particulate matter in ambient air.

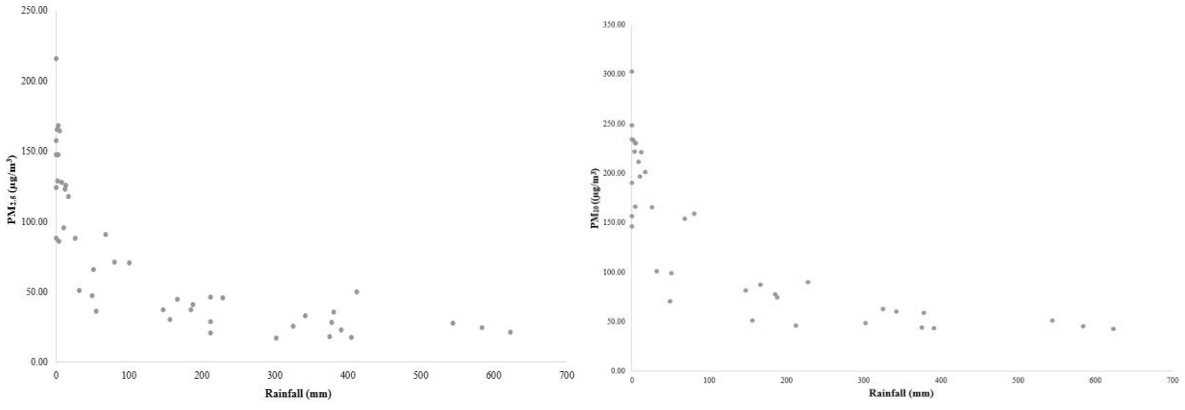

Figure 4: Scattered plot of monthly average concentration of $PM_{2.5}$ and PM_{10} against monthly average rainfall in Dhaka City

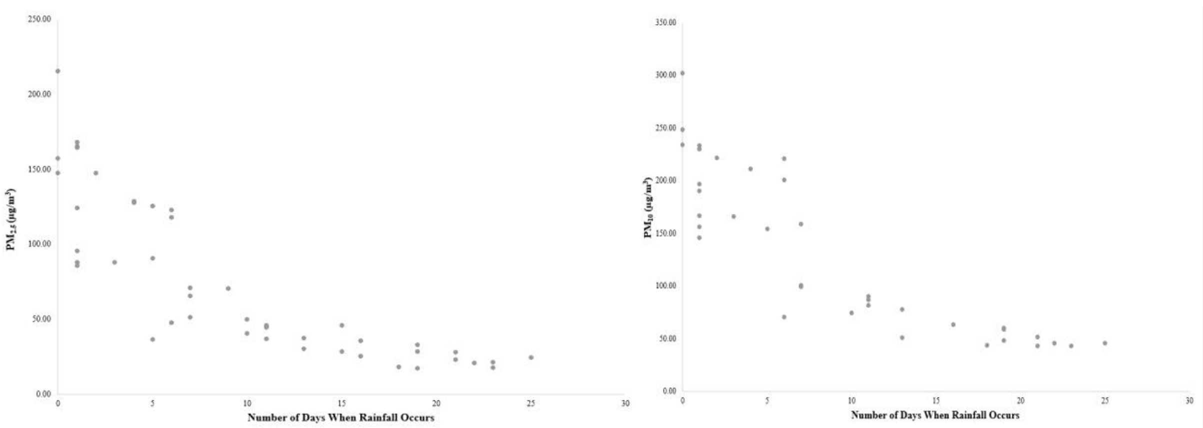

Figure 5: Scattered plot of monthly average concentration of $PM_{2.5}$ and PM_{10} against the number of rainy days in Dhaka City

3.2.2 Relation of PM with Temperature

There is a significant negative correlation of PM with average temperature. Seasonal variation is indicated by average temperature. From Figure 6 we can observe that when temperature is low, concentration of PM is high. By low temperature winter season is indicated when no rainfall occurs which helps to settle the suspended particulate matter in ambient air. Besides high concentration of PM tends to reduce atmospheric temperature due to its net negative radiative forces.

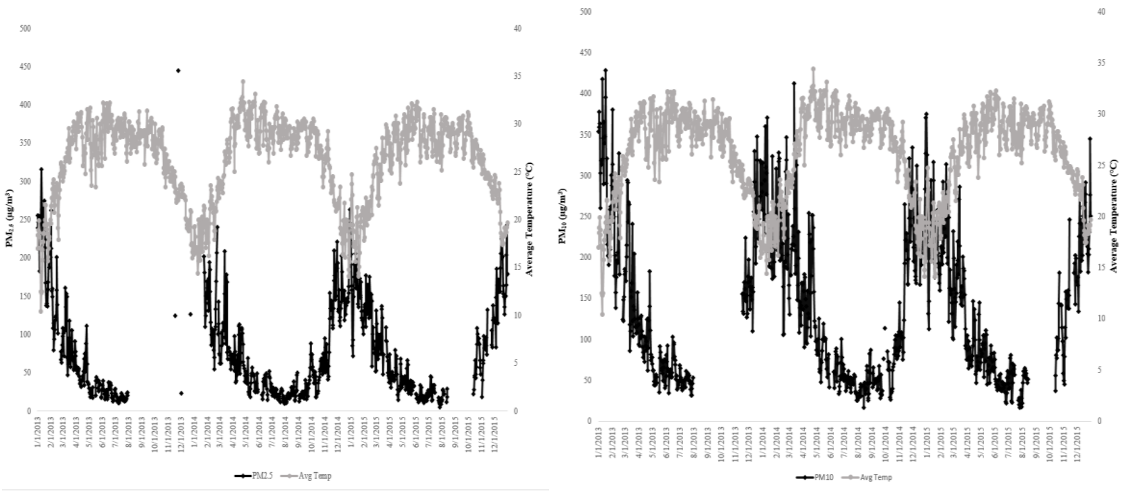

Figure 6: Scattered plot of monthly average concentration of $PM_{2.5}$ and PM_{10} against average temperature in Dhaka City

3.2.3 Relation of PM with Humidity

We can see the Relation of particulate matter with average humidity in Figure 7. There exists no significant correlation between the concentration of PM. So, we can say that humidity has no significant impact on ambient particulate matter.

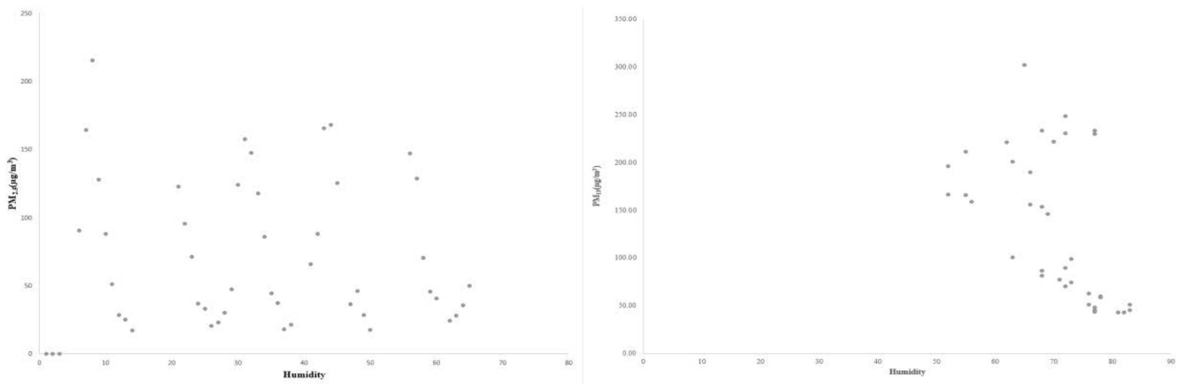

Figure 7: Scattered plot of monthly average concentration of $PM_{2.5}$ and PM_{10} against average humidity in Dhaka City

3.2.4 Relation of PM with Wind Speed and Direction

The air pollutants can get airborne from the ground surface (e.g. re-suspension of particulates due to vehicular movement in the urban environment), they can be emitted from an elevated stack (e.g. emission from a brick kiln) and they can be formed in the atmosphere (secondary PM). Their residence in the atmosphere and transport are controlled not only by the rate of emission/ formation but also by certain physical parameters such as wind speed and direction. The direction and speed of the prevailing wind may significantly affect the concentration, distribution and translocation of the particles (Giri, 2008; Van der Wal, 1996, 2000). Wind speed and direction provide real-time information on pollutant transport in a region and can be used to assess the relationships between sources and pollutant levels.

In order to understand whether wind speed has any bearing on the PM concentrations of Dhaka city, the wind speeds were plotted against the corresponding daily $PM_{2.5}$ and PM_{10} concentrations and the scatter plots are shown in Figure 8. However, this plot indicates that wind speed does not appear to have a significant influence on PM concentration in Dhaka.

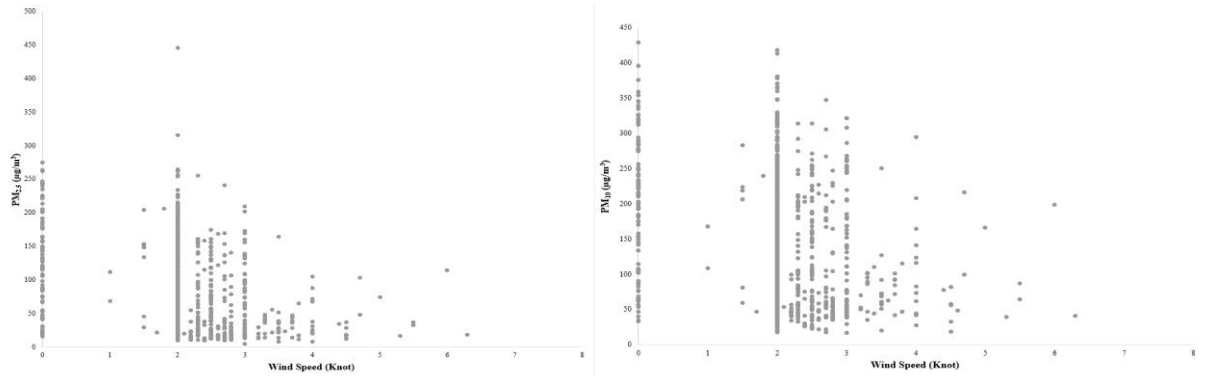

Figure 8: Scattered plot of monthly average concentration of $PM_{2.5}$ and PM_{10} against wind speed in Dhaka City

The two radar plots for Dhaka city in Figure 9 shows that the predominant wind direction for dry and wet periods are north-west (NW) and south (S) / south-east (SE) respectively. In order to study the effect of wind speed and direction on PM concentrations, the dry period dataset during 2013-2017 (from November to April) has been used. The wet period was not considered in the analysis because the major pollution sources located outside the city boundary (i.e. the brick kilns) remain closed during that period.

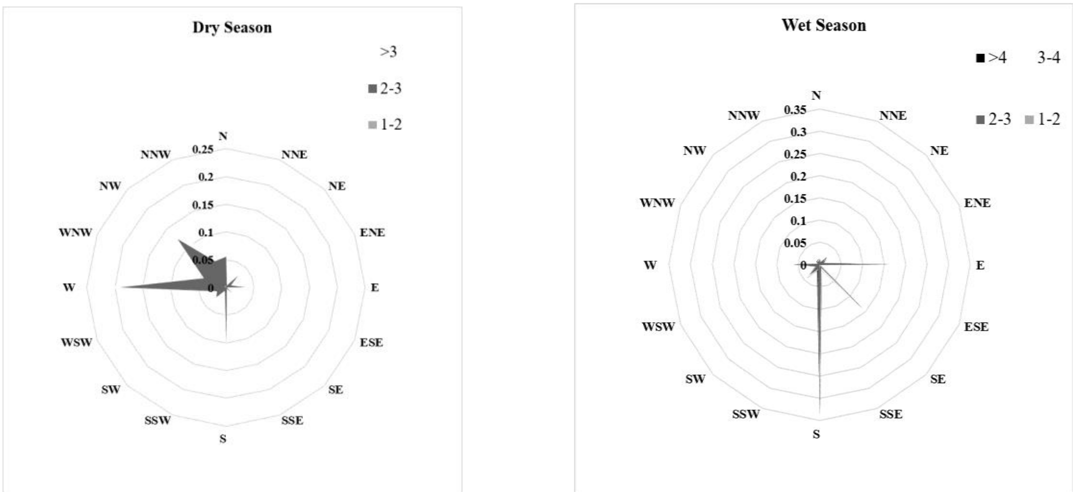

Figure 9: Radar plot of wind direction and speed of Dry season and Wet Season in Dhaka City

The radar plot in Figure 10 shows in the dry period, PM shows higher concentrations when winds come from north-west direction. This is expected as the major brick clusters of Gazipur, Savar and Dhamrai are situated along the northwestern periphery of Dhaka city (Figure 11), and wind blowing from those directions will likely carry the particulate pollution load. The strong association between wind blowing from the north and northwestern direction and PM concentrations supports the hypothesis that during the dry period brick clusters of Gazipur, Savar and Dhamrai significantly dominate the air quality of Dhaka city.

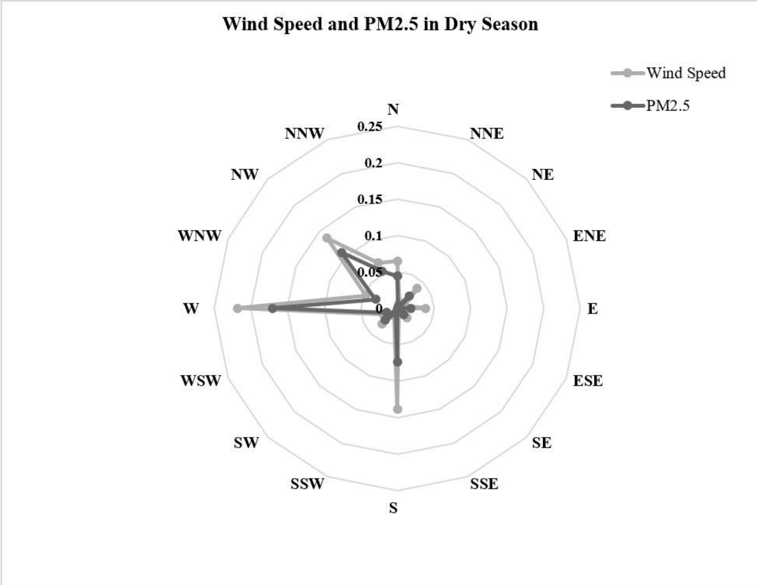

Figure 10: Radar plot of wind direction and $PM_{2.5}$ concentration of dry season in Dhaka city

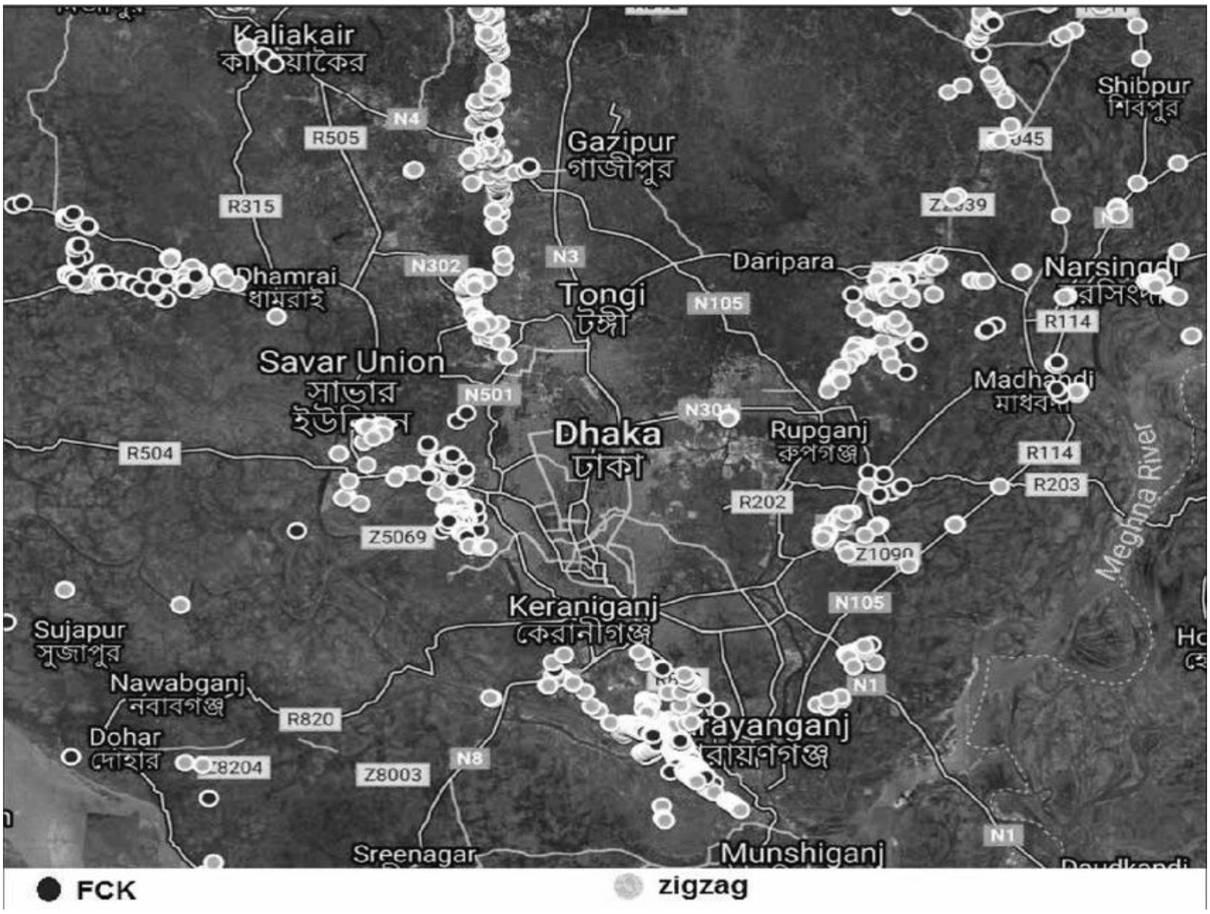

Figure 11: The brick kiln density around Dhaka city (Source: DoE)

3.3 Probable Reason Behind Observed Trend

The major cause of the increase of concentration of PM in dry season in Bangladesh is the brick kilns operated in fry season only. Operation of brick kilns starts from October and continues up to April. The concentration of PM suddenly increases significantly from November and its concentration is higher from November to March.

Though there is a periodic change of concentration of PM occurs with seasonal change but the annual peak concentration of PM shows descending pattern in spite of increasing the number of industries, brick kilns, transports etc. The probable causes behind this are the use of modern technology and equipment in industries, modernization of brick kilns, use of environment friendly fuel in transport etc. As the peak concentration of PM occurs in dry season, so we can say that modern environment friendly technology like zigzag, hybrid Hoffman, tunnel kiln, alternative technology used in brick kilns has a great significance on it.

4. CONCLUSIONS

The main target of this study was to analysis the trend of air quality in Dhaka considering the change of concentration of PM which has the concentration beyond standard and so having much effects on AQI. Major conclusions from the present study are as follows:

a. Air quality trend-
   i. The trend of the concentration of particulate matter show a sinusoidal variation, which increases beyond standard during winter season and decreases during rainy season.
   ii. The peak concentration of particulate matter shows a slightly downward slope which may occurs due to improvement of brick kiln technologies.

b. Effect of meteorological Parameters on air quality-
   i. The scattered plot of $PM_{2.5}$ and PM_{10} with precipitation indicates a negative correlation which may occur due to settlement of the suspended particulate matter by water droplets in rainy season.
   ii. The scattered plot of $PM_{2.5}$ and PM_{10} with temperature indicates the increase of $PM_{2.5\text{-}10}$ concentrations in low temperature. Low temperature indicates winter season when brick kilns are operated, which is a major source of emission of particulate matter.
   iii. The scattered plot of $PM_{2.5}$ and PM_{10} with relative humidity indicates there is no significant effect of humidity on the concentration of $PM_{2.5\text{-}10}$.
   iv. The north-western wind in dry season brings the pollutants from brick kiln clusters situated along northern to western periphery of Dhaka city.

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REFERENCES

AQMP, Department of Environment, Air Quality Data, Agargaon, 2012-2017.

AQMP, Department of Environment, Air Quality Data, Farmgate, 2012-2017.

AQMP, Department of Environment, Air Quality Data, Mirpur, 2012-2017.

DoE, Brick Kilns data up to 2018.

Brick kiln top polluter. (n.d.). Retrieved from https://www.thedailystar.net/frontpage/news/brick-kilns-top-polluter-1701871

Giri, D., Murthy, K. V., & Adhikary, P. R. (2008). The Influence of Meteorological Conditions on PM_{10} Concentrations. Kathmandu Valley. Int. J. Environ. Res., 2(1), 49-60, ISSN: 1735-6865.

Van der Wal, J. T., & Janssen, L. H. J. M. (1996). How contribute emission of PM_{10} and meteorology to concentrations of fine particles. Netherlands. J. Aerosol Sci., 27, S681–S682.

Van der Wal, J. T., & Janssen, L. H. J. M. (2000). Analysis of spatial and temporal variations of PM_{10} concentrations in using kalman filtering. Netherlands. Atmos. Environ., 34, 3675–3687.

World Health Organization (2006), WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide: Global Update 2005, Summary of Risk Assessment, World Health Organization, Geneva, Switzerland.

World Health Organization (2016), Review of Evidence on Health Aspects of Air Pollution: Final Technical Report, available at: www.euro.who.int

World population review. (n.d.). Retrieved from http://worldpopulationreview.com/world-cities/dhaka/