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Characteristics Of Ambient PM2.5 In Relation To Meteorological Parameters In Dhaka City, Bangladesh

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ABSTRACT

Air Pollution is one of the foremost environmental problem in Dhaka city. This study aims to assess the characteristics of Particulate Matter (PM2.5- diameter is less than 2.5 micrometers) in relation with meteorological parameters in Dhaka city. Data were gathered from the Air Now Department of State (Air Now DoS) collected through PM2.5 monitor (beta attenuation monitor BAM-1020) installed at the U.S. Embassy in Dhaka. The maximum monthly average concentration was found 203±69.906 µg/m3 in the month of January while minimum average concentration was found 30±16.040 µg/m3 in July in the year of 2018. This study also observed that 54% of the total hours AQI was "Unhealthy" while only 2% was "Good" and most of the time (77%) the condition was beyond livable. The annual concentration of PM2.5 was found 99.36±79 µg/m3 in 2018 which exceeds the NAAQS of Bangladesh and WHO standard. It is revealed from the study that, significant strong negative correlation exists between PM2.5 and meteorological parameters (Temperature, Humidity and Rainfall) individually and as a set these three parameters account for a significant 92.2% variation in PM2.5 concentration whereas singly temperature can attribute significant unique variance to the concentration. Hence winter season is found as most polluted on the basis of PM2.5 concentration compared to other. Furthermore, the concentration of PM2.5 is found high night and morning shift may be due to movement of Long-route buses and any kind of heavy-duty diesel trucks along with studied meteorological parameters.

KEYWORDS

Air Pollution, Particulate Matter, Seasonal Variation, Meteorology, Bangladesh.

Introduction

Air pollution in recent decades has become a major concern, primarily caused by industrialization and urbanization. It continues to receive a great deal of interest worldwide due to its negative impacts on human health and welfare. In many studies it has been found out that diseases like sore throat, breath, chest pain, nausea, asthma, bronchitis and lung cancer has a chance to occur because of air pollution (Shah *et al.*, 2013; Kim *et al.*, 2015). There are mainly five air pollutant like Particulate matter (PM_{10} and $PM_{2.5}$), Ozone (O_3), Nitrogen dioxide (NO_2), Carbon monoxide (CO) and Sulphur dioxide (SO_2); all of them PM is now of a major concern. Particulate Matters (PM) are a complex mixture of particles that can be solid, liquid or both vary in size, composition, and origin (Salam *et al.*, 2003). Though the specific composition

and size distribution of PM varies by region, time of year, time of day, weather conditions and other factors (WHO, 2001; Zahran *et* al., 2018) it is basically made up of different kinds of elements such as airborne particles and gas molecules. Of all of them atmospheric PM with aerodynamic diameter <10µm (PM_{10}) or <2.5µm ($PM_{2.5}$) are considerable concern for public health (Beckett *et* al., 1998; Hassanen *et* al., 2016). According to a recent World Bank Report, it has been estimated that every year in the Dhaka City around 10,800 premature deaths along with several million cases of illness are being caused by the air pollution. In three different locations of Dhaka City, Department of Environment is carrying out air quality monitoring program at the Continuous Air Monitoring Station (CAMS) since 2002. Concentration of PM_{10} (particles, which are less than 10 micrometers in diameter) and $PM_{2.5}$ (particles, which are less than 2.5 micrometers in diameter) are measured at all of these stations (DoE, 2019). The anthropogenic sources of PM industrial processes, combustion of fossil fuel, either by stationary sources or by transportation, construction and demolition activities, exciting of road dust in the atmosphere (especially in unpaved roads), domestic solid waste, smoking, and agricultural operations (USEPA, 2009; Zahran *et* al., 2018) where in Dhaka PM is emitting from diesel-powered old vehicles, brick kilns and transboundary issues (Salam *et* al. 2003; Begum *et* al. 2004, 2005, 2006) which is corresponding to the annual growth in the number of motorized vehicles ranged from about 7% to 16% for the last 10 years. Particulate emissions depend primarily on the engine design, fuel loss due to over fueling, fossil fuel burning, engines being underpowered and poorly maintained, lubricant oil consumption, and high sulfur content in the fuel. (Begum *et* al., 2008). However along with these, particulate matter concentration as an air pollutant also depend on washout effect of rainfall and inversion phenomena as stated by Hossain and Easa (2012). This statement is analogous to a study done by Rouf *et al.*, (2011) in Dhaka city. In that study it is shown that the concentration of PM_{10} ranges from 50 $\mu g/m^3$ to 80 $\mu g/m^3$during monsoon when naturally downpour is high while in winter the concentration ranges from100 $\mu g/m^3$ to 250 $\mu g/m^3$. In case of $PM_{2.5}$ the concentration ranges from 20 $\mu g/m^3$ to 60 $\mu g/m^3$ in monsoon to 70 $\mu g/m^3$ to 165 $\mu g/m^3$ in dry season.

Dhaka has been considered one of the most polluted city not only in Bangladesh but throughout the whole world. Air pollution has risen to such a level which was never experienced before. Population has increased in a large scale throughout the last decade and along with it the amount of vehicles also increased. So, this rising number of automobiles makes a huge impact on the contribution of pollutants in the air. At the same time, due to geographical location of Bangladesh and being Dhaka's location at the very central zone of this country, it observes a marked seasonal variation. Hence this research is carrying out to study the temporal variation of Particulate Matter ($PM_{2.5}$) in Dhaka city and assess the correlation between the Particulate Matter and Meteorological characteristics in Dhaka city in 2018.

Materials and Method

This study is based on meteorological and concentration of $PM_{2.5}$data. Meteorological data i.e. rainfall, humidity and temperature of Dhaka city in 2018 has been collected from the Department of Environment, Peoples' Republic of Bangladesh. The hourly concentration of $PM_{2.5}$ during the year 2018 in Dhaka Metropolitan region were gathered from the Air Now Department of State website which is a reliable source of real-time hourly Air Quality Index (AQI) maps and daily AQI forecasts based on the instrument installed at the U.S. Embassy in Dhaka. The instrument placed carefully approximately 10m above ground level to minimize highly

concentrated local sources of PM like mechanically generated dust, local traffic and construction. For better understanding the relationship between the PM2.5 and meteorological parameters with seasonal variation the observed months are categorized into four seasons; winter, pre-monsoon, monsoon and post-monsoon. SPSS and Microsoft Excel have been used for data processing, analysis and preparing necessary tables and graphs needed for interpretation and various statistical techniques have been applied to analyze on the basis of classified information.

Monthly Variation of PM2.5

Table 1 shows the Annual and Monthly mean ± S. E (standard error) concentration of air pollutants at the sampling sites in Dhaka Metropolitan area during the year of 2018.

Table 1: Monthly Variation of PM2.5with Meteorological Characteristics.

Month	$PM_{2.5}$ (µg/m³)	Rainfall (mm)	Relative Humidity (%)	Ambient Temperature (ºC)
January	203 ± 70	0	67.4	23.6
February	161 ± 87	20	59.1	24
March	109± 61	3	57.4	28
April	70± 43	309	66.6	27.85
May	43± 23	392	75.9	28.2
June	35 ± 17	366	77.3	29.9
July	30 ± 16	354	88.7	29.9
August	36±18	141	74.56	30.62
September	DNA	76	63.5	25
October	DNA	45	58.57	21.19
November	131 ± 65	13	67.4	23.6
December	153 ± 60	13	59.1	24
Annual Average	99.36±79	144.33	67.96	26.32
BD Standard (Annual)	15	-	-	-
BD Standard (24 Hour)	65	-	-	-
WHO Standard (Annual)	10	-	-	-

It can be seen form the table that in all of the months in the year 2018 except September and October (data is not available); the PM concentration exceeds the annual average BD standard (15 µg/m3). Hence the sampling annual average must exceed BD standard which is evident from the table. The monthly average of concentration in dry months (December-February) exceeds the 24-hour average of Bangladesh National Ambient Air Quality Standard (BNAAQS) (65 µg/m3). Only the monthly average of rainy months (June-September) was lower than the 24-hour standard whereas exceeded the annual average standard. It can also be said form the table that the hour to hour concentration of PM2.5 might be varied greatly as all of the months have large value of standard deviation. The data on atmospheric parameters also shown in the above table; the relationship between PM2.5 value and atmospheric parameter is discussed later.

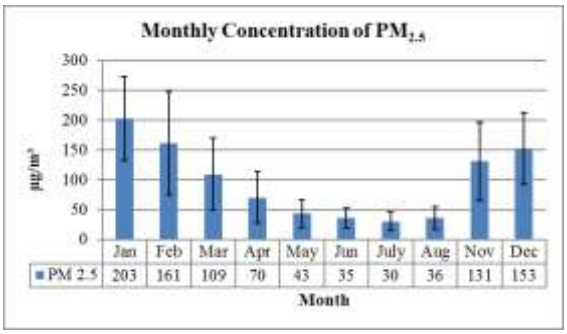

Figure 1: Monthly Variation of $PM_{2.5}$during 2018

During dry months the concentrations of PM2.5were higher than rainy months, therefore the day-to-day variation might be higher in the dry season than rainy season. It can be observed that the concentration of PM2.5 is highest in January (dry season) and lowest in July (rainy season).

Seasonal Variation of PM2.5

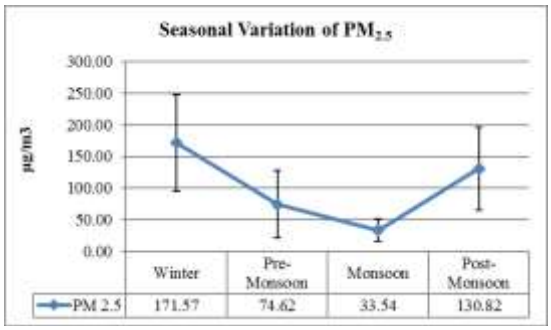

Figure 2: Seasonal Variation of $PM_{2.5}$ during 2018

Strong seasonal pattern is detected and the maximum concentration of $PM_{2.5}$ (171.57 µg/m^3) is found during winter time which is as high as about 3 fold compared to BNAAQS (65 µg/m^3). Differences of PM concentration between winter and monsoon is identified since the mean ± S.E. concentration of $PM_{2.5}$ was much higher in winter than during the monsoon season (Figure 2). In addition to that the variation in the concentration in post-monsoon, winter and pre-monsoon was great than the concentration of monsoon.

During winter, transboundary pollution and the high emissions from brick kiln industries are thought to contribute to the increased PM concentration in Dhaka city (Nayeem et al., 2019). Winter is known as dry with low relative humidity, low wind speed, low temperature and low precipitation in Bangladesh. Along with these natural influence factors, the suspended road dust and soil dust might also amplify the PM concentration during winter.

Shifting Variation of $PM_{2.5}$

The shift-wise pattern of pollution concentration is analyzed in this study based on 2018 data. The peak $PM_{2.5}$ concentration (111.72 ± 93.284µgm./m^3) is observed at morning, between 06:01AM – 12:00PM as well as at night (111.34 ± 83.064) between08:01PM – 06:00 AM (Table 2).

Table 2: Shift Wise Average Concentration of PM2.5

Shift	Duration (GMT+6, Local time)	$PM_{2.5}$ (µgm./$m^{3)}$
Morning	06:01AM – 12:00PM	111.72 ± 93.284
Afternoon	12:01PM – 05:00PM	73.55 ± 52.580
Evening	05:01PM – 08:00PM	75.40 ± 50.482
Night	08:01PM – 06:00 AM	111.34 ± 83.064

Changes in changing directions are driven by interactions between sources of emissions, photochemical processes and weather. The local traffic regulations in Dhaka (diesel-powered buses and freight trucks may be used on city Dhaka only at night between 8 pm and 6 am) and at night (Rahman, 2018; Guttikunda et al., 2017) the result in a high pollution concentration measured during nighttime. Long-route buses and any kind of heavy-duty diesel trucks are barred from using any highway inside Dhaka during the night time. So, the Shift-wise variations in road traffic emissions especially from long-route buses, heavy-duty diesel run freight trucks are the key factor of emitting high PM2.5, in between night time in Dhaka. The concentration of PM2.5 is almost same at morning and night, where it gets lowest during afternoon and evening.

AQI of Dhaka City based on PM2.5 in 2018

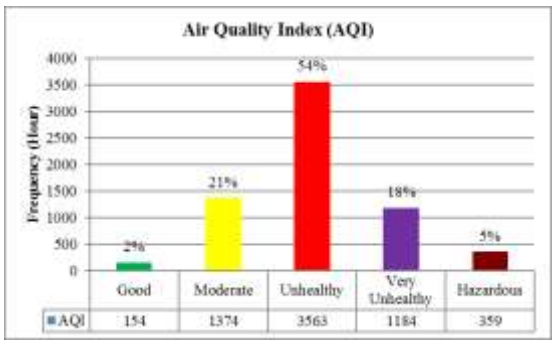

Figure 3: Hourly AQI in Dhaka city on 2018

In 2018, 154 hourly AQI was "Good", 1374 were "Moderate," 3563 was considered "Unhealthy", 1184 was rated "Very Unhealthy" and 359 was found "Hazardous" (Figure 3). It can be observed that the highest fraction that is 54% of hourly AQI was "Unhealthy" and the lowest proportion, only 2% of total hour falls in the "Good" category of AQI..Being the Unhealthy, Very Unhealthy and Hazardous most of the time (77%), the air of Dhaka could have an adverse effect on the human health.

Relationship between PM2.5 concentrations and Meteorological Parameters (Rainfall, Humidity and Temperature)

To identify the relationship between PM2.5 concentrations and Meteorological Parameters (Rainfall, Humidity and Temperature) statistical analysis is (Pearson Correlation and Regression) performed on the related data from the year of 2018.

Table 3: Correlation between PM and Meteorological Parameters

		$PM_{2.5}$	Rainfall	Humidity	Temperature
$PM_{2.5}$	Pearson Correlation	1	-.841**	-.724**	-.929**
	Sig. (2-tailed)		.001	.009	.000
	N	12	10	10	10

**. Correlation is significant at the 0.01 level (2-tailed).

From the Table 3 it is evident that strong negative correlation exits between the rainfall, humidity and atmospheric temperature with PM2.5 individually. Therefore, decrease in any of these three parameters can increase the concentration of PM2.5 significantly as all of their significance value is less than 0.01. Moreover, among these three parameters, temperatures relation is the strongest with significance value < 0.001.

Table 4: Regression analysis between PM2.5 and metrological parameters

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.960[a]	.922	.883	21.49194

a. Predictors: (Constant), Temperature, Humidity, Rainfall

A linear regression analysis (Table 4) was performed to predict the rate of change in $PM_{2.5}$ concentration (Dependent Variable) in Dhaka city by considering rainfall, humidity and temperature as independent variable. It can be seen from the Table 4, taken as a set meteorological parameters (humidity, rainfall and temperature) account for 92.2% variance in concentration of $PM_{2.5}$ and it is statistically significant as the sig. value is less than 0.05. The coefficient part of the Table 4 shows that, while as a set rainfall, temperature and humidity can change the concentration of $PM_{2.5}$ by 92.2%, individually only temperature has significant influence on the concentration. This result is corresponding to the output of correlation analysis where it is seen that among these parameters temperature has strongest relationship with the concentration of $PM_{2.5}$ (Table 3).

Seasonal distribution of the concentration of $PM_{2.5}$ in relation with meteorological parameters

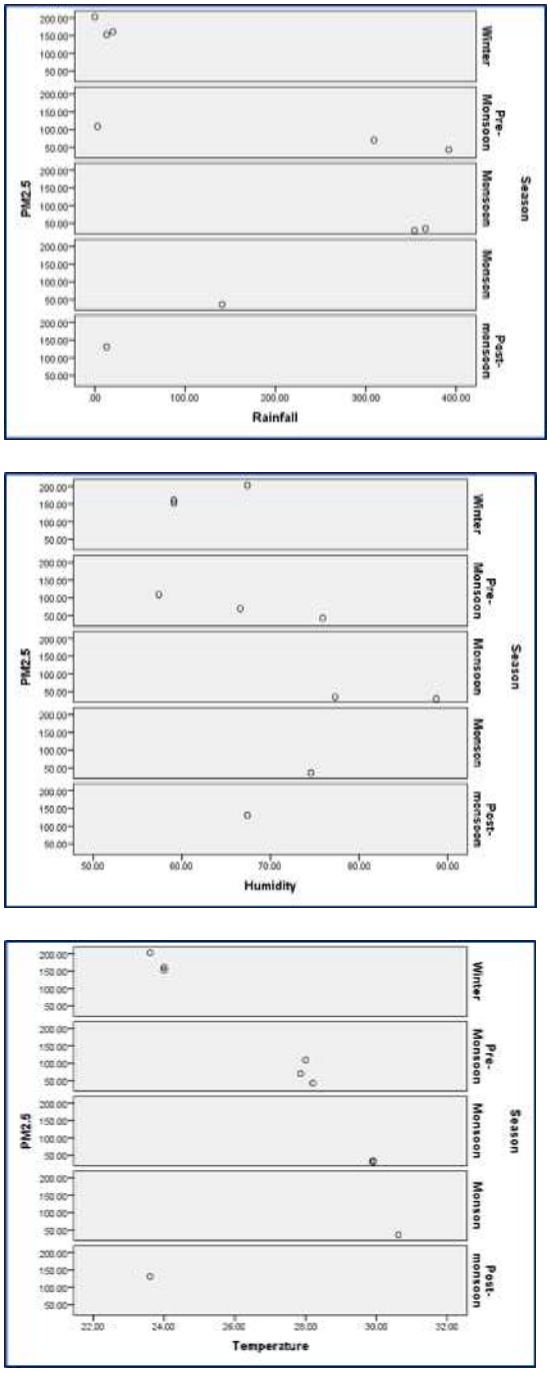

Figure 4: Seasonal Distribution of PM2.5 in Relation with Meteorological parameters

Figure 4 is presenting the seasonal distribution of the concentration of PM2.5 in relation with meteorological parameters at Dhaka city in 2018. It shows that, when the temperature is low the concentration of PM2.5 is very high like during winter and pre-monsoon with the temperature range between 22-30ºC and vice versa. Again, it is also evident from the Figure 5 that less humidity and scant rainfall can attribute to increasing of PM2.5 since winter season has the highest concentration and monsoon season contented the least compared to others. Hence it can be said that low rainfall due to low humidity which is because of low temperature might increase the concentration of PM2.5 in the air of Dhaka city.

Conclusion

Air pollution is at an alarming level in Dhaka City. It has been afflicted with severe Air pollution where particulate matter is being identified as the main pollutant. This study investigates the characteristics of PM2.5 at Dhaka city in 2018 in relation with meteorological parameters (rainfall, temperature and humidity). It has been found that, there is a considerable change of PM2.5 concentration with different months in a year. The maximum concentration was found in January (203±69.906 µg/m3) while minimum was in the month of July (30±16.040 µg/m3). In case of variation, it shows that, winter season had the maximum concentration whereas monsoon season had the lowest in 2018. This can be explained from the fact that, during the winter season brick kilns start their productions which contribute to total air pollution beside the other sources in Dhaka city since the winter wind blows over the brick kilns situated at the northern side of Dhaka in the direction from north to south coming from Himalaya. In addition to this, the study of the shifting variation of the concentration of PM2.5 indicates that night and morning were more polluted time of the day compared to evening and afternoon. These variation leads to the probability of having influence of meteorological parameters on the concentration of PM2.5.

which is unveiled through correlation and regression analysis. The analysis found a significant and strong negative relationship between PM2.5 concentration and meteorological parameters (rainfall, temperature and humidity). As a set of these three parameters account for 92.2% unique variance in the concentration of PM2.5 being the temperature acting as significant factor. Hence it suggests that low humidity and low rainfall due to mainly low temperature is responsible for high concentration of PM2.5 in the air. This study also reveals that most of the time (77%) in 2018, the quality of air was beyond livable in Dhaka city. Though this study helps to have idea on the concentration of PM2.5 of Dhaka city in 2018 and its relationship with selected meteorological parameters, the lack of data of two months namely September and October of post-monsoon season might affect the result. Again, to identify the natural control on the concentration of PM2.5 more meteorological parameters like wind speed, wind direction is required.

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