Journal of Engineering Science 12(1), 2021, 1-8
DOI: https://doi.org/10.3329/jes.v12i1.53095

JES
an international Journal

METEOROLOGICAL INFLUENCES ON URBAN AIR QUALITY PARAMETERS IN DHAKA CITY

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Received: 07 May 2019 Accepted: 10 November 2020

ABSTRACT

This study aims at investigating the effect of meteorological parameters on seasonal variation of particulate matter(PM) (both $PM_{2.5}$ and PM_{10}) using a 4-year (2013-2016) monitoring data of air quality parameters from CASE project implemented by the Department of Environment (DoE). Using monthly data of the Continuous Air Monitoring Station(CAMS) of Darus-Salam, Dhaka, cross correlation analysisis performed between PM and meteorological parameters where inverse relationships of PM with temperature, rainfall and relative humidity are found. Increased biomass burning during low temperature period, washout effect of rainfall, wet deposition mechanism of higher humidity may be held responsible for these negative correlations. Significant seasonal variation is observed from daily data analysis of Darus Salam station and it is found that winter PM concentrations are 4.5-5.5 times higher than monsoon PM concentrations. Seasonal cross-correlation between PM_{10} and $PM_{2.5}$ shows lower correlation during winter (December-February) and monsoon (June-September) seasons. Two possible effects can attribute to this seasonal difference: i) presence of biomass burning during winter which increases $PM_{2.5}$ and ii) presence of rainfall during monsoon which decreases PM_{10}.$PM_{2.5}/PM_{10}$ ratios for different months indicate the contrasting influences of different mechanisms on different sized PM particles. $PM_{2.5}/PM_{10}$ ratio is found to be higher during December-February and lower during March-September with a rise in August, which indicates the effect of 3 mechanisms: i) dilution effect of wind speed on $PM_{2.5}$ during December-February, ii) re-suspension effect of wind speed on PM_{10} during March-September and iii) more pronounced scavenging effect of rainfall on PM_{10} during August. The study indicates the need for properly accounting the influence of meteorology for better understanding of PM variation in urban areas in Bangladesh.

Keywords: *Cross correlation; Meteorology; PM; $PM_{2.5}/PM_{10}$ ratio; Seasonal variation.*

1. INTRODUCTION

Particulate matter (PM) is defined as a complex mixture of different sizes of airborne particle having different chemical compositions. They are mainly classified in two categories, the finer particles ranging from 0.005 μm to 2.5 μm which is called $PM_{2.5}$ and the coarser particles with aerodynamic diameter ≤ 10 μm which is called PM_{10}. Like other countries, particulate matter (PM) in ambient air has become one of the major concerns in Bangladesh. According to the Global Air Report 2017, Dhaka city has become 2nd most air polluted city (HEI, 2017). PM concentration in the air has been found to have significant correlation with diseases such as chronic respiratory illness, cardiovascular morbidity etc. (Dockery *et al.*, 1993). To fully understand the process responsible for this distribution of particulate matters, analysis of the meteorological condition and detailed study on their influence on PM concentration are required. Different studies have shown that particulate matters are highly dependent on specific meteorological parameters (Dayan and Levy, 2005). It has been reported that wind speed, precipitation, relative humidity, temperature, time of day, atmospheric stability etc. are the major factors to drive the PM_{10} concentration in Germany (Gietl and Klemm, 2009). Several studies have been performed to evaluate the extent of urban pollution in the major cities of Bangladesh (Begum *et al.*, 2013). Although the relationship between meteorology and PM has been investigated, very little information is available on the dependence of urban aerosol on atmospheric parameter in the major cities of Bangladesh. In this study, attempt is taken to determine the inherent relation between PM and meteorological parameters in Dhaka city using common statistical techniques. The aim is to obtain a deeper understanding of the process involved in the variation of PM concentration over time.

2. METHODS AND DATA ARCHIVING

2.1 Data Collection

Under the Clean Air and Sustainable Environment (CASE) project, the Department of Environment (DoE) monitors real-time PM_{10} (24hr), $PM_{2.5}$ (24hr) as well as ambient temperature (1hr), rainfall (1hr), relative

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ISSN 2075-4914 (print); ISSN 2706-6835 (online)

humidity (1hr), through 11 Continuous Air Monitoring Stations (CAMS) throughout Bangladesh. Air quality and meteorological data of CAMS-3 (Darus Salam, Dhaka) and CAMS-8 (Red Crescent Campus, Sylhet) for the year of 2013-2016 are collected. However, the data of CAMS-3 (Darus Salam, Dhaka) is used for the analysis.

2.2 Approach for Analysis

Single linear regression model is used to quantify the correlation between $PM_{2.5}$ and PM_{10} with meteorological parameters. The regression equation is in the form of

$$y = \beta_0 + \beta_1 x + \varepsilon \quad (1)$$

Here, y is the concentration of $PM_{2.5}$ or PM_{10}, x is the meteorological parameters (Temperature, Rainfall, Relative Humidity and Solar Radiation), β is the regression coefficients and ε is the error term, where $\varepsilon = (y_i - \hat{y})$, y_i =observed y values, $\bar{y}$ = mean value of series y and $\hat{y}$= y values given by the equation. The coefficient of determination r^2 measures how related the PM concentration is with response to these meteorological parameters.

$$r^2 = \frac{S_t - S_r}{S_r} \quad (2)$$

Here, S_t is Total Sum of Squares, where

$$S_t = \text{Total Sum of Squares} = \sum_{i=1}^{n} (y_i - \bar{y})^2 \quad (3)$$

And, S_r is Error Sum of Squares, where

$$S_r = \text{Error Sum of Squares} = \sum_{i=1}^{n} (y_i - \hat{y})^2 \quad (4)$$

r^2 continues to increase with increasing terms to the model, which can deter the goodness of fit. Hence, adjusted r^2 is introduced, which modifies the r^2 based on the added terms to the model:

$$\text{Adjusted } r^2 = 1 - (1 - r^2) * \frac{m-1}{m-p-1} \quad (5)$$

Here, m is the number of elements in a series and p is the number of independent variables.

Besides, cross correlation analysis is performed between PM and meteorological parameters. Since the PM variation and meteorological parameters both vary with time, time dynamic analysis of cross correlation would be the best way to represent the actual relationship between PM and weather parameters through a lead-lag relationship. Basic cross correlation formula used in the analysis is written below:

For $k \geq 0$,

$$C_{xy} = \sum_{t=1}^{T-k} \frac{1}{T} \left[\{x(t) - \bar{x}\} * \{y(t+k) - \bar{y}\}\right] \quad (6)$$

For $k \leq 0$,

$$C_{xy} = \sum_{t=1}^{T-k} \frac{1}{T} \left[\{y(t) - \bar{y}\} * \{x(t-k) - \bar{x}\}\right] \quad (7)$$

Here, $x(t)$ is the concentration of PM at time t, $y(t+k)$ is the respective meteorological parameter at time $(t+k)$, k is the lag between two-time series x and y, T is the total number of elements in series x and y. In order to standardize the correlation values, the cross-correlation coefficient is calculated which is given by:

$$r_{xy}(k) = \frac{C_{xy}(k)}{S_x * S_y} \quad (8)$$

Here, $$S_x = \sqrt{C_{xx}(0)} \quad (9)$$

And, $$S_y = \sqrt{C_{yy}(0)} \quad (10)$$

3. RESULTS AND DISCUSSIONS

3.1 Average PM Concentration and Meteorological Conditions in Bangladesh

In Bangladesh, the year can be divided into four different seasons: Winter (December-February), Pre-monsoon (March-May), Monsoon (June-September), Post-monsoon (October-November) (Begum *et al.*, 2014). The climate of Bangladesh experiences prominent variation in weather during different seasons. It endures cold and dry air in winter as well as hot and humid air during the other three seasons. However, high temperature and high humidity is observed for most of the year. Precipitation shows marked distinction between seasons, maximum rainfall occurs in the monsoon and a minimum in winter. During winter, dry soil condition, scanty rainfall and low relative humidity prevails. During pre-monsoon, rainfall becomes moderately strong and relative humidity increases. During monsoon, moist air condition and high relative humidity prevails. Besides, the amount of rainfall also remains at its highest during this season. In the post monsoon, the amount of precipitation starts to decrease and so as the relative humidity.

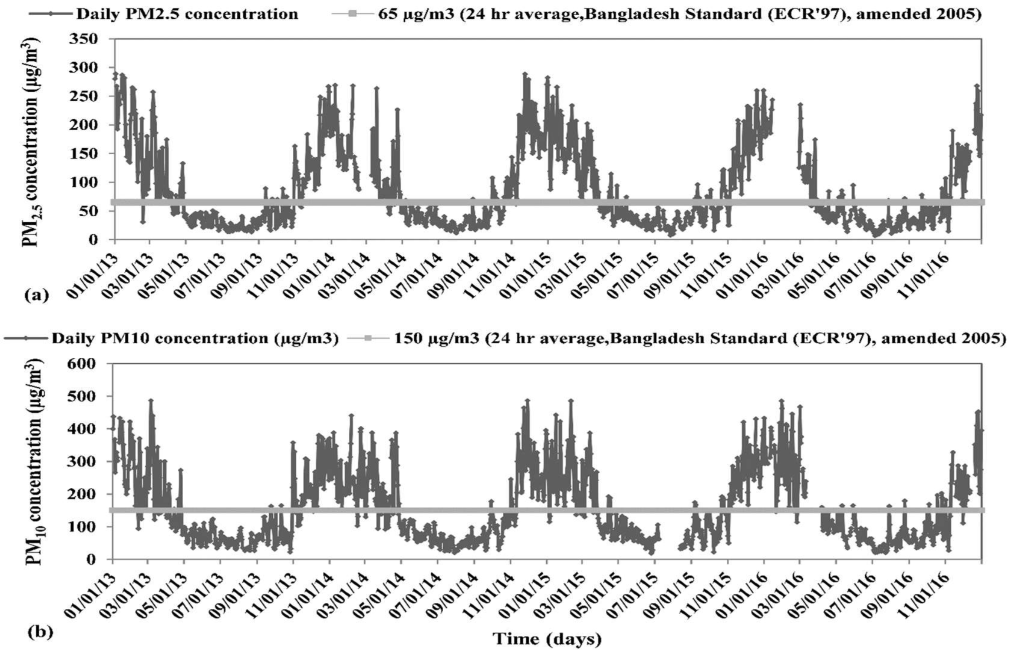

Figure 1: Daily average PM concentration with corresponding Bangladesh National Ambient Air Quality Standard (BNAAQS) for (a) $PM_{2.5}$ and (b) PM_{10}

Figure 1(a) and (b) show the daily 24hr average concentration for $PM_{2.5}$ and PM_{10}, respectively, spanning for the year of 2013-2016. The average $PM_{2.5}$ and PM_{10} concentrations during the study period are found to be 91.03μg/m^3 and 161.69 μg/m^3, respectively. To understand the PM variation throughout the entire year, seasonal and annual mean are calculated for the entire study period and the results are shown in Table 1. Winter PM concentration is found to be considerably higher than the Bangladesh National Ambient Air Quality $PM_{2.5}$ Standard of 65 μg/m^3 (daily 24hr average) and PM_{10} Standard of 150 μg/m^3 (daily 24hr average). For the year of 2013-2016, respectively 172, 194, 174 and 161 daily PM concentrations, corresponding 48, 53, 48 and 44% of the sampling days exceeded the BNAAQS $PM_{2.5}$ limit value. Similarly, for this four-year period, respectively 42, 44, 40 and 43% of the sampling days exceeded the BNAAQS PM_{10} limit value. From the above statistics, it is evident that $PM_{2.5}$ concentration is more prone to exceed the limit value compared to PM_{10}.

Performing the analysis on seasonal basis, the exceedance is found to be highest for winter season (99.45% for $PM_{2.5}$ and 95.85% for PM_{10}) and lowest for monsoon season (4.5% for $PM_{2.5}$ and 1.23% for PM_{10}), while exceedance during other seasons are moderate. Significant monthly variation has been obtained for both PM fractions. The winter to monsoon ratio of $PM_{2.5}$ and PM_{10} concentration during 2013-2016 were 6.09, 5.56, 5.04 and 6.2 as well as 4.22, 4.54, 4.11 and 4.95, respectively (Table 1). Comparing with other studies, our observations of the difference between PM concentration of winter and monsoon season have been found very high. For example, the winter to monsoon PM ratio has been found to be 2.9 for PM_{10} and 2.2 for $PM_{2.5}$ in India (Kulshrestha *et al.*, 2009) whereas winter to summer ratio of 2.14 forPM_{10} has been found in Egypt (Elminir, 2005). This may be because, during winter, higher atmospheric stability as well as dry weather condition favors suspension of particulate matter in the air. Along with it, brick kilns in Bangladesh remain operational during this season. Aerosol concentration in monsoon was minimum due to scavenging effect of precipitation and the higher winter to monsoon ratio for PM_{10} indicates that this scavenging effect is more pronounced on PM_{10} compared to $PM_{2.5}$.

3.2 Seasonal PM Concentration Prevalence

Figure 2 shows frequency distribution of $PM_{2.5}/PM_{10}$ ratio for all seasons which is divided into nine categories starting from <0.2 to <1. Here, during high PM prevailing season i.e. in winter, $PM_{2.5}/PM_{10}$ ratio curve shows a symmetric pattern with its peak at 0.6-0.7 (above 40% of the cases). It indicates that, this ratio fits normal distribution during winter and the contribution of $PM_{2.5}$ remains higher. Similarly, during low PM prevailing season i.e. in monsoon, symmetric pattern is also observed with peak at 0.4-0.5 (above 35% of the cases), which indicates that this distribution too follows normal distribution. However, slightly right skewed distribution is observed for pre-monsoon and post-monsoon season with peak at 0.4-0.5, which indicates that during these seasons, contribution of $PM_{2.5}$ concentration starts to decrease after winter. During pre-monsoon, monsoon and post-monsoon season, approximately 40, 35 and 45%, respectively are observed to be in the range of 0.4-0.5

whereas it is only 5% during winter. During winter highest ratio is in the segment between 0.6-0.7, however fewer value 8, 12 and 16% are found for pre-monsoon, monsoon and post-monsoon, respectively. High $PM_{2.5}/PM_{10}$ ratio during winter indicates that significant portion of pollution particles fall under the size distribution of $PM_{2.5}$.

Table 1: Average PM concentrations, their seasonal ratio and annual exceedance from Bangladesh National Ambient Air Quality Standard (BNAAQS)

Year	$PM_{2.5}$ Average Concentration	PM_{10} Average Concentration	$PM_{2.5}$ Win/ Mon. ratio	PM_{10} Win/ Mon. ratio	Annual $PM_{2.5}$ exceedance from BNAAQS (%)	Annual PM_{10} exceedance from BNAAQS (%)
2013						
Winter	187.41 ± 57.37	277.24 ± 84.43				
Pre-monsoon	78.96 ± 52.17	155.22 ± 96.12				
Monsoon	30.77 ± 14.68	65.68 ± 28.22	6.09	4.22	47.12	41.87
Post-monsoon	78.69 ± 40.88	136.94 ± 80.05				
Annual	89.61 ± 73.62	152.31 ± 108.65				
2014						
Winter	168.98 ± 47.93	260.55 ± 68.95				
Pre-monsoon	89.28 ± 52.55	175.58 ± 89.83				
Monsoon	30.42 ± 11.55	57.34 ± 20.35	5.56	4.54	53.15	43.53
Post-monsoon	117.76 ± 69.83	181.72 ± 117.00				
Annual	95.11 ± 70.50	159.63 ± 108.53				
2015						
Winter	173.48 ± 46.14	258.45 ± 76.65				
Pre-monsoon	72.89 ± 43.28	139.16 ± 81.85				
Monsoon	34.39 ± 16.11	62.92 ± 30.21	5.04	4.11	47.67	40.5
Post-monsoon	93.32 ± 46.09	169.04 ± 85.18				
Annual	88.32 ± 65.34	148.13 ± 100.82				
2016						
Winter	188.28 ± 34.84	301.96 ± 76.72				
Pre-monsoon	69.70 ± 43.59	151.52 ± 77.20				
Monsoon	30.38 ± 14.91	61.06 ± 28.68	6.20	4.95	44.11	43.01
Post-monsoon	79.14 ± 48.10	148.32 ± 78.37				
Annual	87.88 ± 70.43	158.55 ± 112.23				

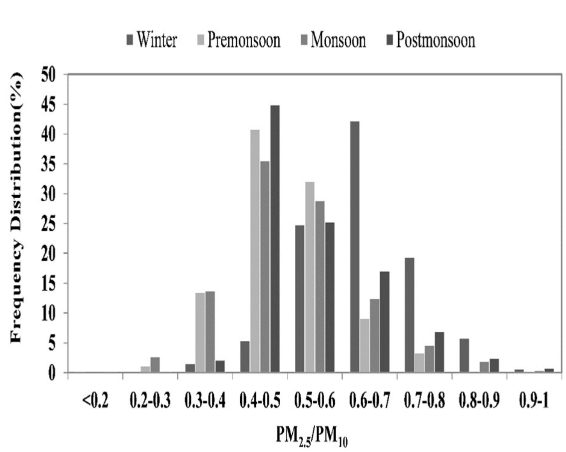

Figure 2: Frequency distribution of $PM_{2.5}/PM_{10}$ ratio

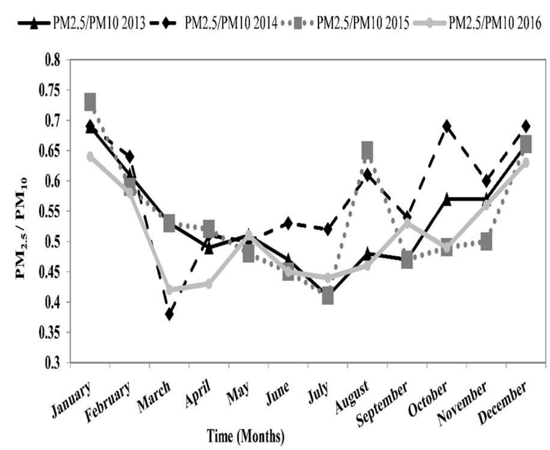

Figure 3: Annual variation of $PM_{2.5}/PM_{10}$ for the years of 2013, 2014, 2015 and 2016

3.3 Meteorological Parameters Influencing PM Levels

As the dispersion condition of atmosphere is primarily responsible for the accumulation of PM particle in air, the primary focus is on the role of temperature, relative humidity and precipitation for the variation of PM levels. The results of the correlation analysis between meteorological parameters and different sized PM particles are shown in Table 2. A significance level of 5% ($p=0.05$) has been chosen to be the threshold for determining the significance of correlation analysis. Table 2 shows that, dominant meteorological parameters those drive PM around Dhaka city are temperature (*adj.* r^2= 0.681 for $PM_{2.5}$; *adj.* r^2=0.566 for PM_{10}) and relative humidity (*adj.* r^2= 0.244 for $PM_{2.5}$; *adj.* r^2= 0.413 for PM_{10}). Solar radiation (*adj.* r^2= 0.232 for $PM_{2.5}$; *adj.* r^2=0.131 for PM_{10}) and rainfall (*adj.* r^2= 0.141 for $PM_{2.5}$; *adj.* r^2=0.157 for PM_{10}) are observed to exert weak influence over PM variation. Temperature is found to have strong negative relation with particulate matters ($r_{x\text{-}corr}$= -0.825 at lag 0 for $PM_{2.5}$; $r_{x\text{-}corr}$= -0.752 at lag 0for PM_{10}). This represents the fact that, with increase of temperature, PM decreases and vice versa. When temperature becomes lower i.e. during winter season, formation of stagnant air condition occurs and simultaneous biomass burning activities increases in the kilns, which gives rise to the particulate matter concentration.

The correlation coefficient between air pollutants and relative humidity is found to be significant ($r_{x\text{-}corr}$= -0.494 at lag 0 for $PM_{2.5}$; $r_{x\text{-}corr}$= -0.643 at lag 0 for PM_{10}). High humidity indicates higher precipitation events with in cloud scavenging, reduction in the formation of OC (Organic Carbon) and EC (Elementary Carbon), higher moisture absorption and subsequent settling down of particles, all of which eventually result in low concentration of particulate matters. Relative humidity has been found to have slightly higher correlation with coarser particle. This is because the wash out effect of humidity and precipitation is more profound for the case of coarser particles. Negative correlation is observed between solar radiation and PM ($r_{x\text{-}corr}$= -0.482 at lag 0 for $PM_{2.5}$; $r_{x\text{-}corr}$= -0.362 at lag 0 for PM_{10}). This relation might indicate the phenomena that, increase of incident solar radiation leads to surface warming which cause rise of boundary layer height (BLH). When BLH increases, PM gets more space for dispersion. Higher dispersion results in decrease of PM concentration in the ambient air.

Table 2: Cross correlation and single linear regression analysis results between PM concentrations and meteorological variables

Predict-ion Variable (CAMS 3)	Using Monthly Data (n=48)			
	Cross Correlation	Single Linear Regression (SLR)		
	r(lag)	r^2	Adjusted r^2	Error Sum of Square
$PM_{2.5}$				
Temperature	-0.825(0)**	0.681**	0.674**	57763
Rainfall	-0.376(0)*	0.141	0.123	155600
Humidity	-0.494(0)*	0.244*	0.228*	136990
Solar Radiation	-0.482(0)*	0.232	0.215	139210
PM_{10}				
Temperature	-0.752(0)**	0.566**	0.556**	178320
Rainfall	-0.396(0)*	0.157	0.138	346130
Humidity	-0.643(0)**	0.413*	0.401*	240850
Solar Radiation	-0.362(0)*	0.131	0.112	356600

Statistical significance indicators are as follows: **, $p < 0.001$; *, $0.01>p > 0.001$, otherwise $0.05>p>0.01$

Table 3: Annual cross correlation coefficients between PM and other meteorological parameters (Rainfall & Temperature) at CAMS-3 and CAMS-8

Meteorological Parameters	CAMS No.	$PM_{2.5}$		PM_{10}	
		n	[a] Correlation Coefficients	n	[a] Correlation Coefficients
Temperature					
	CAMS-3(Dhaka)	48	-0.825**	48	-0.752**
	CAMS-8 (Sylhet)	47	-0.855**	48	-0.862**
Rainfall					
	CAMS-3 (Dhaka)	48	-0.340*	48	-0.396*
	CAMS-8 (Sylhet)	47	-0.731**	47	-0.732**

[a] Cross correlation coefficients at zero lag. Statistical significance indicators are as follows: **, $p < 0.001$; *, $0.01>p > 0.001$, otherwise $0.05>p>0.01$

Correlation analysis between PM concentration and rainfall is also carried out where weak negative correlation is found between them ($r_{x\text{-}corr}$= -0.376 at lag 0 for $PM_{2.5}$; $r_{x\text{-}corr}$= -0.396 at lag 0for PM_{10}). However, a strong negative correlation has been reported between average monthly PM and rainfall in Sylhet (CAMS-8) (Table 3). (r= -0.731 at lag 0 for $PM_{2.5}$; r= -0.732 at lag 0 for PM_{10}) (Table 3). In Dhaka, amount of rainfall is low compared to Sylhet where consistent rainfall is a distinct feature (in Northeastern part of Bangladesh). In

Bangladesh, rainfall is caused by the influence of the Southwest monsoon (Hossain *et al.*, 2013). Total precipitation in Dhaka in 2016 is 462.02 mm with highest rainfall recorded in July (157.74 mm) and total precipitation in Sylhet in 2016 is 1606.8 mm with the highest rainfall recorded in the month of April (567.4 mm). Therefore, lower correlation in Dhaka may occur due to the long interval of consistent rainfall occurring in this area. This leads to the conclusion that, rainfall amount and duration both contributes combinedly in PM fluctuation. Like RH, higher correlation is observed between PM_{10} and rainfall which indicates that scavenging effect is more effective on PM_{10} than on $PM_{2.5}$.

3.4 Global Comparison of Correlation Coefficients

A comparative analysis has been conducted between this study and other literature values, based on the calculated correlation coefficients for $PM_{2.5}$ and PM_{10} with meteorological parameters and is presented in Table 4. From Table 4, it is evident that, our results show similarity with the analyses conducted in India, Turkey and Egypt, whereas contradictory relation has been observed for studies conducted in Greece, Germany and USA.

Negative correlation for temperature with PM has been observed for Bangladesh, India, Turkey and Egypt whereas, positive correlation has been obtained for Greece, Spain, Germany and USA. This variation mainly occurs due to the difference in weather condition and chemical composition of particulate matters all over the world. Weather patterns are similar for Bangladesh, India and Turkey, since all of them fall under the subtropical region. Biomass burning activities during winter season contribute to the higher concentration of PM. During low temperature period, particulate matter concentration becomes high and thus inverse relationship is formulated between PM and temperature. However, considering USA, Greece and Germany, high temperature is favorable for atmospheric chemical reaction. Hence, secondary particle formation is favored by temperature increase which produces positive correlation between PM and temperature.

Table 4: Pearson's correlation coefficients between PM_{10} and meteorological parameters in different regions

Reference	Country	Tempera-ture	Relative Humidity	Wind Speed	Precipitation
$PM_{2.5}$					
(Galindo *et al.*, 2011)	Spain(yearly)	-0.016	0.048	-0.496	--
(Tai *et al.*, 2010)	USA(yearly)	0.4-0.7	(-0.1)-(-0.15) (South) 0.05-0.14 (North)	(-0.05)-1.0	--
(Bhaskar, and Mehta, 2010)	India(yearly)	-0.64	--	-0.53	0.01(Northern) - 0.74(Southern)
(Akyuz, and Cabuk, 2009)	Turkey(winter)	-0.324	-0.108	-0.350	--
(Chaloulakou *et al.*, 2003)	Greece(winter)	0.46	--	-0.54	--
--	Bangladesh	-0.681	-0.244	--	-0.141
PM_{10}					
(Elminir, 2005)	Egypt(yearly)	-0.48	0.252	--	--
(Galindo *et al.*, 2011)	Spain(yearly)	0.601	0.189	-0.334	--
(Hien *et al.*, 2002)	Germany(yearly)	0.17	-0.15	-0.49	-0.38
(Akyuz, and Cabuk, 2009)	Turkey (winter)	-0.155	-0.237	-0.409	--
(Bhaskar, and Mehta, 2010)	India(yearly)	-0.34	-0.44	-0.17	-0.53
(Chaloulakou *et al.*, 2003)	Greece(yearly)	0.39	--	-0.43	--
--	Bangladesh	-0.566	-0.413	--	-0.157

Considering Relative humidity (RH), high humidity condition leads to higher moisture absorption and subsequent settling down of particles in the subtropical region. Therefore, negative correlation occurs for RH with PM in Bangladesh, India and Turkey, whereas around the European countries i.e. in USA, Greece and Germany, ultrafine particulate formation is found to be positively affected in the presence of high humidity, thus resulting in positive correlations between particulate matter and relative humidity.

3.5 Relationship between Different PM Size Fractions

The relationship between fine particles $PM_{2.5}$ and coarse particle PM_{10} is studied using cross correlation coefficients. The data are divided into four seasons for this analysis. The results are presented in the Table 5. Winter and monsoon correlation coefficients have been found to be lower than the other seasons. These differences between the coefficients are due to meteorological conditions those drive the PM concentration to change. It is linked to the seasonal changes of the weather conditions. During winter, there are major natural sources of PM, such as biomass burning activities, fossil fuel burning form vehicles and burning of agricultural soil and clays in the brick kilns which operate mainly during winter. These activities produce significant number of fine particles i.e. $PM_{2.5}$. Therefore, the contribution of fine particles becomes much higher in winter. Besides, during monsoon season, significant reduction in PM_{10} occurs by the wet deposition mechanism of continuous precipitation. Thus, increase in $PM_{2.5}$ in winter and decrease in PM_{10} in monsoon leads to the reduction of correlation coefficients between $PM_{2.5}$ and PM_{10} during these seasons. During other seasons, the contribution of abovementioned sources, which mainly enriches $PM_{2.5}$, becomes low. As a result, the obtained coefficients are higher for other seasons compared to winter.

Annual $PM_{2.5}/PM_{10}$ variability is examined from 2013 to 2016 and it is found that the ratio remains low during the period of March to September i.e. pre-monsoon-monsoon season (Figure 3). During this period, wind speed remains at its maximum which induces the re-suspension effect of PM_{10}. Therefore, the concentration of PM_{10} becomes higher in the atmosphere compared to $PM_{2.5}$. Due to these reasons, the $PM_{2.5}/PM_{10}$ ratio remains low during March-September. Besides, a distinct rise of $PM_{2.5}/PM_{10}$ ratio can be observed in August. During August, rainfall remains at its maximum, which induces scavenging mechanism that works more effectively on PM_{10}. As a result, average concentration of PM_{10} drops more compared to $PM_{2.5}$, resulting in a distinct rise in $PM_{2.5}/PM_{10}$ ratio. Therefore, this figure is indicative of 3 mechanisms: i) dilution-effect of wind speed (WS) on $PM_{2.5}$ during December-February, ii) re-suspension effect of WS on PM_{10} during March-September, and iii) more pronounced scavenging-effect of rainfall on PM_{10} during August.

Table 5: Cross correlation analysis results between $PM_{2.5}$ and PM_{10} concentrations

$PM_{2.5}$ \ PM_{10}	Winter	Pre-monsoon	Monsoon	Post-monsoon	All Data
Winter	0.792(0)**				
Pre-monsoon		0.922(0)**			
Monsoon			0.812(0)**		
Post-monsoon				0.954(0)**	
All Data					0.944(0)**

Statistical significance indicators are as follows: **, $p < 0.001$; *, $0.01>p > 0.001$, otherwise $0.05> p>0.01$

4. CONCLUSION

The influence of meteorological parameters on seasonal variation of particulate matter (PM) is examined using a 4-year (2013-2016) monitoring data of air quality parameters. Using monthly-data of the Continuous Air Monitoring Station (CAMS) of Darus Salam, Dhaka, cross-correlation and Pearson's correlation analysis are performed between PM and meteorological parameters. Significant seasonal variation is observed and it has been found that winter PM concentrations are 4.5-5.5 times higher than monsoon PM concentrations. Major meteorological parameters that control PM in the air of Dhaka city are – temperature and relative humidity. Inverse relationships of PM with temperature, rainfall and relative humidity have been found. Increased biomass burning during low temperature period, washout effect of rainfall, dry deposition effect of higher humidity may be held responsible for these negative correlations. Besides, comparison of correlations between rainfall and PM for CAMS-3 (Dhaka) and CAMS-8 (Sylhet) indicates that, rainfall duration along with rainfall amount play major role to dominate PM. Dry deposition and scavenging effect are more effective to drive coarser particles (PM_{10}) compared to finer particles ($PM_{2.5}$).

ACKNOWLEDGEMENTS

The authors would like to thank the Department of Environment (DoE) for providing the background air quality and meteorological data.

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