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Status of atmospheric particulate matter and black carbon concentration at Ashuganj in Brahmanbaria

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Abstract

Atmospheric particulate matter (PM) samples (both PM_{10} and $PM_{2.5}$) were collected simultaneously from Midland Power Company Limited at Ashuganj, in Brahmanbaria to monitor the seasonal fluctuations of particulate matter and black carbon (BC) concentrations from air samples. Total eight samples were collected from January 2016 to December 2017 using two Air Metrics MiniVol samplers and the quantity of $PM_{2.5}$ and PM_{10} was detected by weighing the filters before and after exposure. The concentration of PM ($PM_{2.5}$ and PM_{10}) and BC were analyzed at the laboratory of Chemistry Division, Atomic Energy Centre, Dhaka. The black carbon concentration from both $PM_{2.5}$ and PM_{10} samples were also determined by reflectance measurement. The concentrations of $PM_{2.5}$ varied from 12.2–145 μgm^{-3} where mean value was 67.09 μgm^{-3}. The mean concentration of PM_{10} was 103.64 μgm^{-3} whereas the concentration ranged from 20.5–220 μgm^{-3}. The ratios of $PM_{2.5}/PM_{10}$ fluctuated during different seasons, winter showed higher concentration and summer showed relatively lower concentration for both $PM_{2.5}$ and PM_{10}. Atmospheric dispersion due to increased wind speeds and wider mixing layer heights are recognized to be responsible for the lower PM concentrations in warmer months. The concentrations of BC in $PM_{2.5}$ also varied from 2.44–33.4 μgm^{-3} and BC in PM_{10} varied from 4.51–57.2 μgm^{-3}, respectively. The concentrations of particulate matter exceeded the Bangladesh National Ambient Air Quality Standard.

Introduction

Air pollution has become a public health concern in Bangladesh and regarded as one of the major environmental hazards in Bangladesh as well as worldwide. Globally, ambient air pollution caused by industries, cars and trucks and other sources caused 4.2 million deaths. Over 37,000 Bangladeshi peoples die annually from diseases related to air pollution, according to World Health Organization (WHO, 2016). Dhaka's air quality has been ranked as third most polluted in the world according to an air quality data compiled by the World Health Organization for mega cities with a population of 14 million or more (WHO, 2016). Atmospheric PM is of great concern to the public and to government agencies because of its significant impact on human health, visibility reduction, agriculture and atmospheric chemistry. Atmospheric PM is generally defined as a mixture of solid and/or liquid particles that remains individually dispersed in the air (Begum *et al.* 2012). Atmospheric PM ranges in size from a few nanometers to tens of micrometers (µm) in diameter (Seinfeld and Pandis, 2006). Commonly used indicators describing PM that are relevant to health refer to the mass concentration of particles with a diameter of less than 10 µm (PM_{10}) and of particles with a diameter of less than 2.5 µm ($PM_{2.5}$). These particles are dominated by sulfates, nitrates, organic carbon (OC) and elemental carbon (EC). BC is a sooty black material and also product of incomplete combustion of fuels, emitted from traffic, industry and the burning of fossil fuels and biomass. BC is one of the constituents of fine PM ($PM_{2.5}$) which scatters and absorbs solar radiation entering the Earth's atmosphere. It is the component of airborne PM which mostly absorbs light and is viewed as a major contributor to climate change (Bond *et al.*, 2013).

PM_{10} and $PM_{2.5}$ include inhalable particles that are small enough to penetrate the thoracic region of the respiratory system. $PM_{2.5}$ can travel deep into the lungs and become lodged there. Several epidemiological studies have shown that long-term exposure to PM for years is directly associated with mortality, mainly due to cardiovascular and respiratory diseases (Habre *et al.*, 2014; Madrigano *et al.*, 2013). Previous studies have indicated that the severe $PM_{2.5}$ pollution resulted in more than 3 million premature deaths around the world in the year of 2010 (Lim *et al.*, 2012). From the above discussion, it was observed that although particulate matter has significant impact on human health, very limited work have been conducted upon it. Considering PM, most of the researches focused only in urban background (Hasan *et al.*, 2016; Begum *et al.*, 2015) and traffic areas (Jahida *et al.*, 2014 and Begum *et al.*, 2012, 2008) whereas research related to PM focusing on

Power Company limited has not been well reported so far. Therefore, this study was carried out to i) observe the PM concentration in midland power company Ltd. at Ashuganj, in Brahmanbaria and to ii) determine BC concentration within the atmospheric PM.

Materials and Methods

Sampling Location and Duration

Midland Power Company Limited is a 50 MW heavy fuel based Power Plant Company situated at Ashuganj, Brahmanbaria. Two PM samplers (One for PM_{10} and other for $PM_{2.5}$) were set up in the north-corner of the plant (latitude 24°1'42.26"N; and longitude 90°59'17.22"E). In Bangladesh, the climate is characterized by high temperature, high humidity most of the year and distinctly marked seasonal variation of precipitation. According to meteorological condition, the year can be divided into four seasons, pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November) and winter (December-February) (Salam *et al.*, 2003). Therefore, collected data considering the four seasons (Table 1).

Table 1. Sampling date of the atmospheric PM

Season	Year	
	2016	2017
Pre-monsoon	7 May	26 March
Monsoon	3 September	15 July
Post-Monsoon	not available	6 October
Winter	11 January	17 December
	25 December	

Sampling and measurement of $PM_{2.5}$ and PM_{10}

The Air Metrics MiniVol sampler developed jointly by the U.S. Environmental Protection Agency (EPA) and the Lane Regional Air Pollution Authority was used for PM_{10} and $PM_{2.5}$ sampling. For sampling with MiniVol sampler the flow rate was maintained 5 liter per minute (lpm) at ambient conditions for proper size fractionation. The samplers were set up in the conventional manner with filters. Two samplers were placed at shared position in the north site for PM_{10} and $PM_{2.5}$ sampling for 24h. Both fractions of PM samples were collected on Teflon (2.0 μm pore size) filters.

PM Masses were measured at the laboratory of Chemistry Division, Atomic Energy Centre, Dhaka (AECD). The aerosol samples having PM were determined by weighing the filters before and after exposure using a micro-balance (METTLER Model MT5) maintaining room temperature approximately at 22 °C and relative humidity at 50%. The air filters were equilibrated at constant humidity and temperature of the balance room before every weighing. A U-shaped electrode charge eliminator (STATICMASTER) was used to eliminate the static charge accumulated on the filters before each weighing.

Black Carbon (BC) Measurement

The concentration of BC in both fine and coarse fraction of PM samples was determined by reflectance measurement by an Evans Electro Selenium Limited (EEL) type Smoke Stain Reflect meter.

Results and Discussion

Concentration of PM_{10} and $PM_{2.5}$

The statistics of PM and BC concentrations during the sampling periods is given in Table 2. At the power plant site, PM_{10} concentration in December is higher than the concentration of other months between the two sampling years 2016–2017 whereas $PM_{2.5}$ concentrations found higher in January as compared to other months (Fig. 1).

Table 2. Summary statistics of PM_{10}, $PM_{2.5}$, BC concentrations during the sampling periods

Parameter	PM_{10} (μgm^{-3})	$PM_{2.5}$ (μgm^{-3})	$BC\_PM_{2.5}$ (μgm^{-3})	BC_PM_{10} (μgm^{-3})	$PM_{2.5}/PM_{10}$ (μgm^{-3})	$BC\_PM_{2.5}/PM_{2.5}$ (μgm^{-3})
Maximum	220	145	33.4	57.2	0.88	0.26
Minimum	20.5	12.2	2.44	4.51	0.35	0.20
Mean	103.64	67.09	16.4	24.95	0.62	0.23

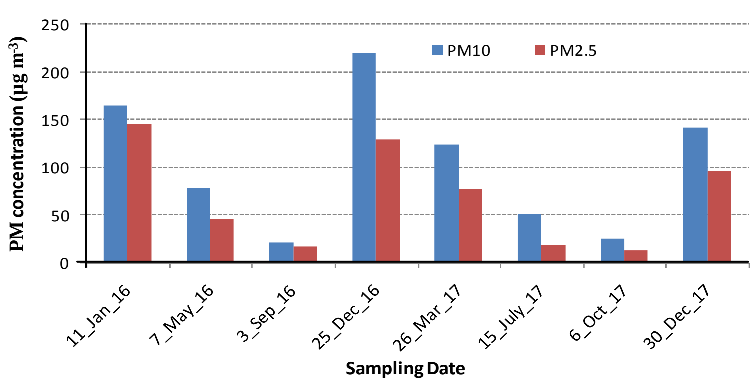

Fig. 1.Variation of the daily average value of PM_{10} and $PM_{2.5}$ from January 11, 2016 to December 30, 2017

During winter, the daily $PM_{2.5}$ and PM_{10} concentrations were higher than the 24-h average Bangladesh National Ambient Air Quality Standard (BNAAQS), which were set at 65 and 150 (μgm^{-3}), respectively (Table 3). Haque *et al.* (2015) conducted an experiment in Dhaka and found that the concentration of PM_{10} and $PM_{2.5}$ was 428.49 μgm^{-3} and 246.5 μgm^{-3}, respectively. Twenty four hour mean $PM_{2.5}$ concentration during the winter in Dhaka was 322 ± 69 μgm^{-3} in the traffic hotspot site and 254 ± 57 μgm^{-3} in the residential site whereas during the monsoon, 24-hr mean $PM_{2.5}$ mass in the Dhaka residential area was 57 ± 15 μgm^{-3} (Jacqueline, 2012).

During monsoon the PM levels were found lowest at sampling site ($PM_{2.5}$- 45 μgm^{-3} and PM_{10}- 78 μgm^{-3}). Observed lower PM concentrations are due to washout of particles by rainfall. The winter season is characterized by dry soil conditions, low relative humidity, scanty rainfall and low northwesterly winds. The low wind speed and temperature in winter favors the accumulation of pollutants, while the high temperature in summer favors air convection and the dispersion of pollutants. Atmospheric dispersion due to increased wind speeds and wider mixing layer heights are recognized to be responsible for the lower PM concentrations in warmer months (Pecorari *et al.*, 2013; Khan *et al.*, 2016).

Table 3. Air quality standards for $PM_{2.5}$ and PM_{10} set by the Bangladesh National Ambient Air Quality Standard, European Union (EU), EPA and the WHO Air Quality Guidelines (AQG)

Pollutant	Average time	Bangladesh Standard (μgm^{-3})	WHO standard (μgm^{-3})	EU standard (μgm^{-3})	U.S. EPA NAAQS (μgm^{-3})
$PM_{2.5}$	24 hr	65	25	25	35
μgm^{-3}	Annual	15	10	-	15
PM_{10}	24 hr	150	50	50	150
μgm^{-3}	Annual	50	20	40	-
Black carbon	24 hr		20		

Actually, the Air Quality Guidelines (AQGs) set by the World Health Organization are stricter than the EU air quality standards (Table. 3). The AQGs set the limit value for $PM_{2.5}$ at 10 μgm^{-3} annual mean and 25 μgm^{-3} 24-h mean, while the limit values for PM_{10} is 20 μgm^{-3} annual mean and 50 μgm^{-3} 24-h mean. These values are considered acceptable and achievable objectives to minimize adverse effects on human health.

Concentration of Black Carbon

BC is produced during incomplete burning. Fig. 2 shows the concentrations of BC in PM_{10} and $PM_{2.5}$ fractions. The BC concentration is determined both in the fine and coarse fraction of the collected PM.

Between the years 2016 and 2017, the maximum concentration of BC in PM_{10} found in December 2016 and minimum concentration found in September 2016. The highest concentration of BC in $PM_{2.5}$ was 33.4 μgm^{-3} in January and the lowest was 2.44 μgm^{-3} in October. From the Figure it can be clearly said that PM concentration is predominantly higher in winter season and it gradually reduced in rainy season. The ratio of BC in $PM_{2.5}/PM_{2.5}$ also showed higher concentration in winter (0.26 μgm^{-3} in December, 2017) may be due to lower relative humidity and lower wind speed in winter. This result is comparable to the work conducted by Jahida *et al.* (2014).

Ratio of $PM_{2.5}/PM_{10}$

The calculated ratio of $PM_{2.5}/PM_{10}$ gives an idea about the sources of the particulate pollution in the atmospheric air. The calculated ratio of $PM_{2.5}/PM_{10}$ has been shown in Fig. 3.

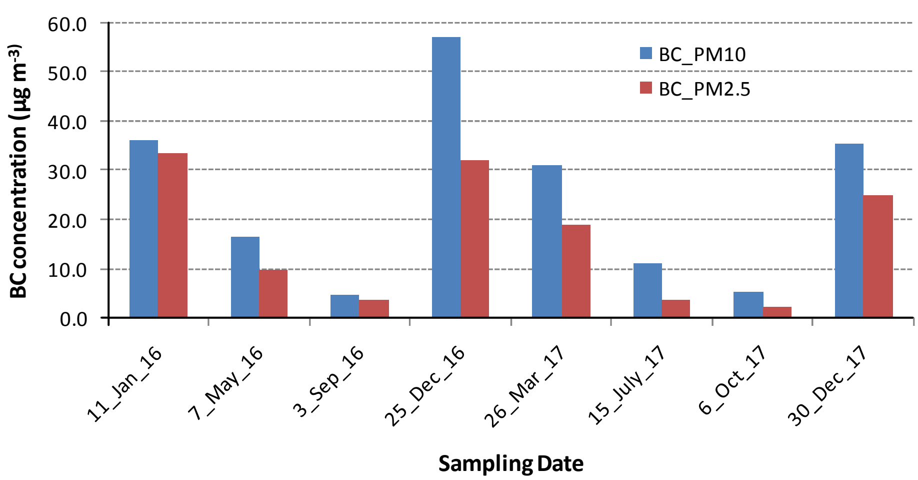

Fig. 2. The variation of daily average value of BC in PM_{10} and $PM_{2.5}$ respectively, from January 11, 2016 to December 30, 2017

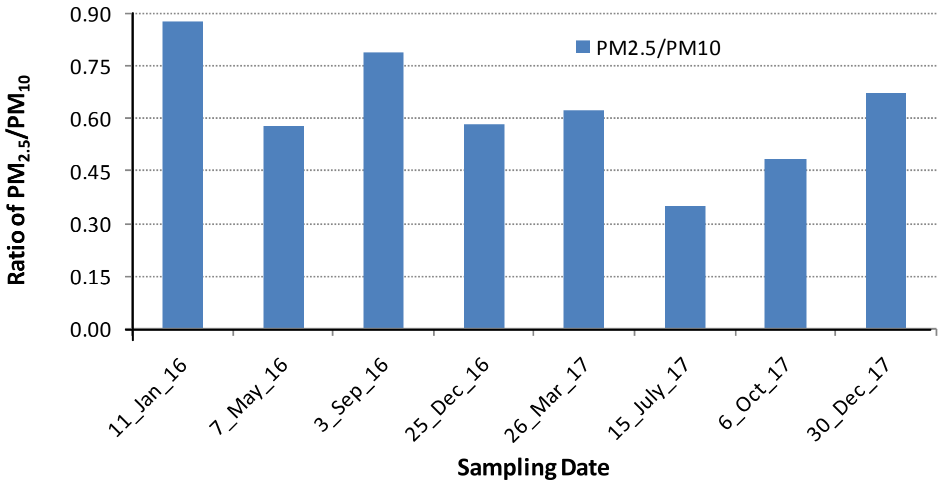

Fig. 3. The variation of ratios between $PM_{2.5}$ and PM_{10} concentration

The ratio of $PM_{2.5}/PM_{10}$ ranged between 0.35 to 0.89 μgm^{-3} with a mean value of 0.62 μgm^{-3}. From the ratio, it examined that about 62% of PM_{10} is $PM_{2.5}$. It was also observed that about 61% of $PM_{2.5}$ is black carbon. From the Figure, it is obvious that the ratio is higher in winter compared to summer indicate that fine particles comprise a large fraction in $PM_{10.}$ The reasons for the high peak in $PM_{2.5}$ concentration during the winter are not only influenced by seasonal fluctuation of emissions but also by meteorological effects (Islam *et al.,* 2014). Higher ratios (>0.48) are generally associated with the emissions from combustion processes (such as 0.95 for vehicle exhausts) whereas smaller ratios (0.28<) indicating that a higher proportion of the emitted PM mass in the coarse mode and are associated with the emissions from more mechanical, non-combustion sources such as mining, quarrying and agriculture (Munir, 2017; AQEG, 2012).

Conclusion

In this paper the seasonal variation of atmospheric $PM_{2.5}$ and PM_{10} and the concentration of black carbon during the recent two years (2016–2017) were analyzed from Midland Power Company Ltd. using Air Metrics MiniVol sampler. The quantity of $PM_{2.5}$ and PM_{10} was detected by weighing the filters before and after exposure whereas, the black carbon concentration was determined by reflectance measurement using an EEL-type Smoke Stain Reflect meter. Result showed that the concentration of PM_{10} ranged between 20.5-220 μgm^{-3} where mean value was 103.64 μgm^{-3} and for $PM_{2.5}$, the ranges vary between 12.2–145 μgm^{-3} whereas, mean value was 67.09 μgm^{-3}. Considering the concentration of particulate matter, it could be concluded that these values exceeded the Bangladesh National Ambient Air Quality Standard. Result also showed that the ratio of $PM_{2.5}/PM_{10}$ ranged between 0.32-0.88 whereas, the mean value was 0.62 μgm^{-3} which indicates that the most of the particles are form the fine fractions and are generally associated with the emissions from combustion processes. The ratio of BC in $PM_{2.5}/PM_{2.5}$ fluctuated between 0.20 μgm^{-3} to 0.26 μgm^{-3} whereas, mean value was 0.23 μgm^{-3} that indicated BC highly contribute to increasing PM concentration in these sampling site. It can also be seen that there is a change in BC concentration in the ambient air over the period.

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