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Meteorological Influences on Seasonal Variations of Air Pollutants (SO_2, NO_2, O_3, CO, $PM_{2.5}$ and PM_{10}) in the Dhaka Megacity

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ABSTRACT

The study was conducted to evaluate the meteorological influences on seasonal variations of air pollutants load in Dhaka city. In this study we collect air quality data from Darus-salam Continuous Air Monitoring Station (CAMS) and were analyzed to find out their seasonal trends and relation with meteorological parameter. The highest concentration of the major air pollutants showed high values in the dry season (October-April) (SO_2=23.45 ppb, NO_2=55.33 ppb, O_3=11.17 ppb, CO=3.66ppb, $PM_{2.5}$=125.66 µg/m^3, PM_{10}=219 µg/m^3) than those of the wet season (May-September) (SO_2=10.26 ppb, NO_2=16.36 ppb, O_3=2.40 ppb, CO=1.23 ppb, $PM_{2.5}$=39.65 µg/m^3, PM_{10}=76.5 µg/m^3). These results indicate that higher pollutants load in winter are associated with large scale polluted air transported from the brick kilns situated in the northern surrounds of the observing station which are also related with lower boundary atmospheric heights during winter. However, a reverse relation between rainfall and atmospheric pollution load throughout the wet season was observed. This finding revealed that the lowest concentration levels of pollutants during wet season are associated with their atmospheric wash out by precipitation. A strong correlation (R^2=0.742) was observed between CO and O_3 during the study, which indicating huge production of oxidant with increasing CO concentration. Interestingly, O_3 showed positive correlation with NO_2 (R^2=0.391). This result may indicate that NO_2 is the important precursors of O_3 in this study. Similarly, CO and NO_2 showed good correlation (R^2=0.68), indicating that both of NO_2 and CO are produced from similar pathways of photochemical oxidation of VOC. However, $PM_{2.5}$ and PM_{10} concentrations showed decreasing trends with the onset of monsoon, indicating washout of atmospheric dust load through rainfall during wet season.

Keywords: Meteorological influences, Dhaka city, O_3, NO_2, $PM_{2.5}$, Seasonal variations, and PM_{10}

1 INTRODUCTION:

Clean air is basic requirement for life but the quality of urban air is deteriorating continuously (Bhattachary *et al.*, 2013). Pollution has become the first enemy of the mankind. Environmental catastrophe of the present world is happening due to industrial uprising around the globe and the world is more scared of environmental pollution than atomic explosion (Alam, 2009). Pollution of air is any atmospheric condition in which certain substances are present in the air in such concentration that can produce undesirable effects on man and its environment (Bhattachary *et al.*, 2013). Bangladesh is currently facing serious health problems due to severe air pollution which is triggered by population growth, industrialization and urbanization (Ahmed and Hossain, 2008; Uddin *et al*., 2014). Biomass fuels burning during cooking with poor ventilation in rural areas causes indoor air pollution. However, emissions from industries and automobiles are the prime sources of outdoor air pollution (Alam, 2009), which deteriorates ecological conditions (Tripathi and Gautam, 2007).

Air pollution is most dangerous among all type of pollutions because man and even plants need fresh air for their normal metabolic pathways (Azim *et al.*, 2013). According to the World Health Organization (WHO), air pollution is a contamination of the indoor or outdoor environment by any chemical, physical or biological agent enters into the atmosphere and finally modifies the natural characteristics of the atmosphere called air pollution and it sources includes home furnace, vehicular emission, industrial chimney and forest fire (WHO, 2013).

At present, rapid increase in the demand of brick manufacturing and the bunching of brick furnaces are environmental distresses throughout the world. Combustion of coal besides other biomass fuels in brick kilns results in the emissions of particulate matter (PM), sulphur dioxide (SO_2), oxide of nitrogen (NOx) and carbon monoxide (CO) (Maithe *et al.*, 2002). Air pollution due to enhanced anthropogenic activities has become an important environmental concern globally, especially in urban areas, in view of its adverse health effects (Dockery *et al.*, 1989; Dockery *et al.*, 1993; and Dockery *et al.*, 1994). Presently, awareness has been created to a great extent among the public and the Government as to the impact of chemical pollutants on the quality of human life and in general the ecosystems. Urban air pollution is acknowledged to be exceedingly deteriorating to community health in Dhaka, and other major cities in Bangladesh. It is estimated that if the exposure to urban air pollution were reduced by 20% to 80% it would result in saving 1200 to 3500 lives annually (WB, 2006).

In addition, it produces negative economic externalities for investment in the country. The level of pollution in these cities if remain upswing due to unplanned urbanization, industrialization and motorization there will be more loads of harmful pollutants in the urban areas and consequently incidences of air pollution related diseases like asthma, bronchial disease, pulmonary diseases and lung cancer will increase manifold which in a way will have profound public health implications in the foreseeable future (CASE, 2016).

Moreover, great dissimilarities can be observed in seasonal variants of concentrations of the main atmospheric pollutants in various urban region of the world. The complex pattern of the air pollutant concentration variations in different seasons is inhomogeneous (Mikhailyuta *et al.*, 2007). Meteorologically, Bangladesh is a subtropical country, which is experienced an extensive periodic dissimilarity in rainfall, soberly warm temperatures, and huge relative humidity having few local climatic metamorphoses (Hossain *et al*., 2019).

A great periodic distinction is observed among Dhaka air quality (Islam *et al.*, 2015). Dhaka is one of the mega cities in the world, which has perceived a quick progression of municipal inhabitants recently. At present, number of automobiles has amplified expressively in Dhaka city (Ahmad *et al*., 2018). Similarly, diverse combination of old and date expired vehicles has been amplified in the city area together with narrowing of road space, which finally contributing traffic congestion (Rubel *et al*., 2019). Consequently, many busy areas of the city have transformed into area of atmospheric pollution from traffic exhausts. Furthermore, atmospheric level of particulate matter (PM) in Dhaka is increasing day by day having contributions from brick field operation, traffic emission, industrial and residential discharges. During winter season brick kilns goes in operation. The pollution due to vehicles and brick kilns is then expected to be high during winter (Hoque *et al.*, 2015).

To obtain reliable information for the urban air quality management, one needs comprehensive information about the seasonal and the diurnal variations of pollutants concentration in Dhaka city. Air pollutants can travel thousands of miles (Yadav *et al.*, 2013), these air pollutants may destroy the atmospheric stability which in turn can create an environmental menace (Rahman *et al.*, 2010).

Thus, it is needed to make an experimental study based on the impacts of brick field clusters during dry season and motor vehicles which have serious impact on the seasonal variation in the atmospheric concentration level of SO_2, NO_2, CO, O_3, $PM_{2.5}$ and PM_{10} in the Dhaka city. Present study was carried out to meet the following objectives:

i) To find out the level of SO_2, NO_2, CO, O_3, $PM_{2.5}$ and PM_{10} in ambient air of Dhaka city.
ii) To find out the seasonal variation in the atmospheric concentration level of SO_2, NO_2, CO, O_3, $PM_{2.5}$ and PM_{10} in the study area.
iii) To assess the relationship between PM with meteorological parameters (rainfall and temperature).

2 MATERIALS & METHODS:

2.1 Study area - The study was conducted at Darussalam (October 2016 to September 2017) in Mirpur of Dhaka city, which is situated at the latitude 23.78ºN and longitude 90.36ºE. Darussalam is a hot spot site for air quality study since several major roadway intersection and large numbers of vehicles plying through this area. This continuous monitoring station is situated about 100 meters away from the main road. The roof height was about 7 m above from the ground and the sampler was located 1.8 m beyond from the roof (CASE, 2016).

2.2 Data collection procedure - Measurements of trace gases were done in CAMS in Darus-salam of Dhaka during both dry (October, 16-February, 17) and wet (March, 17-September, 17). This location is also characterized as traffic because huge traffics entered in Dhaka city through this way from the northern part of the country and is also influenced by the emission from brick kilns located at northern side of Dhaka during winter season.

2.3 Methods of analysis - There are four gas analyzers at Darussalam CAMS including sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NOx) and Ozone (O_3) analyzer. They are continuously measuring the concentration SO_2, CO, NOx and O_3 present in the ambient air. These analyzers work in different method. A number of commercial instruments were used for continuous measurement of trace gases. O_3 was observed with a UV photometric analyzer (Teledyne Monitor Labs, Inc., model 9810B). CO was measured using non-dispersive infrared spectrometer (TML, model 9830B). NO, NO_2 and NOx were measured using chemiluminescence analyzer (TML, model 9841B) and SO_2 was measured using a pulsed UV fluorescence analyzer (TML, model 9850B). All instruments were housed in an air-conditioned room. Times to time calibration were performed. All calibration processes were traceable to National Institute of Standards and Technology (NIST) standard.

3 RESULTS & DISCUSSION:

3.1 Ambient air quality in Dhaka city - Six air pollutants (SO_2, NO_2, O_3, CO, $PM_{2.5}$ and PM_{10}) from Darus-salam CAMS were collected to evaluate the seasonal variation. The monthly average concentrations of SO_2, NO_2, O_3, CO, $PM_{2.5}$ and PM_{10} are shown in **Table 1**.

3.2 Seasonal variation of SO_2 - Fig 1a shows the seasonal variations of SO_2 concentrations of Dhaka city. Concentration of SO_2 of the study area shows increasing trends from the month of October to February (**Fig 1**). During the observations, lowest concentration of SO_2 (1.2 ppb) was measured in the September, 2017 and highest concentration of SO_2 (37.1 ppb) was measured in February, 2017 (**Table 1**). After the February, 2017 peak concentration of atmospheric SO_2 in the study area shows a decreasing trend up to May, 2017.

Similar seasonal distributions of SO_2 concentration also observed by Kirillova (2003), where maximum concentration was showed in February at St. Petersburg. High peak of SO_2 in dry season and base concentration in wet season may happen in Dhaka due to their emission sources are associated with brick fields operation in the dry season (Sikder *et al.*, 2010). Average concentration of SO_2 showed high value (21.7 ppb) in dry season (October-February) and low value (13.4 ppb) in wet season (March-September) (**Table 1**).

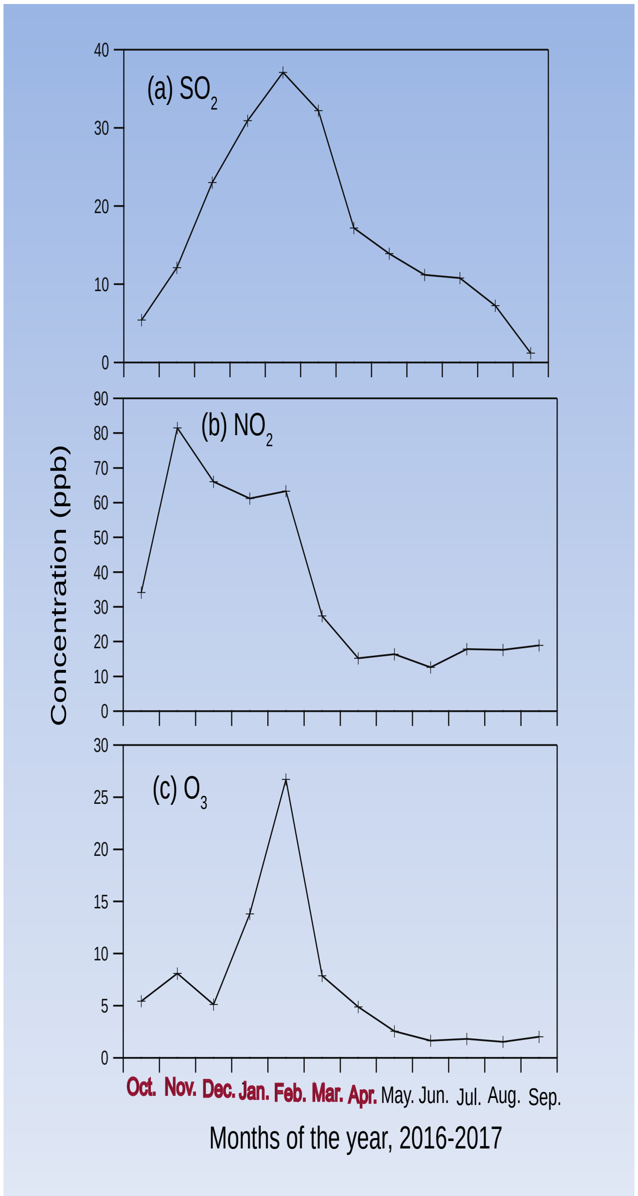

Fig 1: Seasonal variations in the atmospheric concentration of (a) SO_2; (b) NO_2, and (c) O_3 in Dhaka city.

This may happen, because of low temperature in dry season together with high emissions of sulphur from brick kilns, where coal used as the major fuel for burning. Moreover, SO_2 cannot spread out through the atmosphere and exist in lower atmosphere during winter season due to difference in atmospheric pressure.

Table 1: Monthly variation of SO_2, NO_2, O_3, CO, $PM_{2.5}$, and PM_{10} in Dhaka city.

Time Duration	Pollutants concentration (Monthly average)					
	SO_2 (ppb)	**NO_2 (ppb)**	**O_3 (ppb)**	**CO (ppm)**	**$PM_{2.5}$ (µg/m^3)**	**PM_{10} (µg/ m^3)**
October, 2016	5.41	34.1	5.44	1.98	44.1	91.7
November, 2016	12.1	81.5	8.1	3.0	105	188
December, 2016	23	66	5.12	4.0	169	272
January, 2017	30.93	61.18	13.8	4.96	183.87	300
February, 2017	37.1	63.3	26.7	5.82	160	303
March, 2017	32.2	27.4	7.87	1.53	92.7	167
April, 2017	17.2	15.2	4.88	1.23	55.9	105
May, 2017	13.9	16.5	2.55	1.68	48.8	87.3
June, 2017	11.2	12.6	1.65	1.5	29.6	56.6
July, 2017	10.8	17.8	1.81	1.25	30.2	61.1
August, 2017	7.26	17.64	1.53	0.85	33.16	72.66
September, 2017	1.2	18.9	2.02	0.92	40.8	76.9

3.3 Seasonal variation of NO_2 - Fig 1b shows dry (October-April) and wet season (May-September) variations of NO_2 concentration in the ambient environment of Dhaka city during October, 2016 to September, 2017. During the study period, high concentration of NO_2 (81.5 ppb) was measured in November, 2016 followed by February, 2017 (63.3 ppb). After the month of February NO_2 showed decreasing trends and reached to the lowest concentration (12.6 ppb) in June (**Fig 1b**). Azad and Kitada (1998) also reported a significant concentration of NO_2 over Bangladesh during dry season (November-March). NOx found high peak in winter and low peak in summer season (Sikder *et al.*, 2010).

As shown in **Table 1**, average concentration of NO_2 in winter (October-April) showed three times high values than those of the summer (May-September). High atmospheric concentration of NO_2 in winter may be associated with excessive level of coal burning in the brickfields adjacent to Dhaka city during the winter months. Moreover, positive correlation (r^2=0.68) was found between NO_2 and CO. This finding indicates that both of NO_2 and CO produces from similar pathways of photochemical oxidation of VOC.

3.4 Seasonal variation of O_3 - Fig 1c shows the winter and summer variations of O_3 concentrations in Dhaka city. O_3 concentration showed increasing trends in the beginning of winter and reached to the peak value (26.7 ppb) during February (**Fig 1c**), the coldest months of Bangladesh. Interestingly, the precursor of O_3 such and CO also showed peak concentrations during the February (**Fig 2c**). However, after the peak O_3 concentration in February it shows a decreasing trend and reached to the lowest value (1.53 ppb) in August. As reported by Sikder *et al.* (2010), they found that the maximal monthly O_3 concentrations during 2002, 2003, 2004 and 2005 were 41 ppb (December), 60 ppb (November), 60 ppb (February), and 59 ppb (March), respectively and also the largest diurnal amplitude of O_3 in winter (97 ppb). Higher level of O_3 in winter in our study area may happen due to the large-scale air transport from brick kiln situated in the immediate north side of Dhaka city and also associated with low atmospheric boundary heights during the winter months. Moreover, O_3 concentration showed 4 times higher values in winter (October-February) than that of the summer (March-September) (**Table 1**).

Winter high concentration of O_3 is due to brick kiln emission, which operated during winter season where northerly winds dominate over Dhaka. However, strong sunlight during winter together with excessive VOCs emission from coal burning in brick processing may be the dominant reason of high O_3 concentration in winter season. However, strong correlation (r^2=0.74) was observed between O_3, and CO. This result indicates that there was extensive oxidant production with increasing CO concentration during the study.

3.5 Seasonal variation of CO - Fig 2c shows the dry and wet season variations of CO concentrations in the Dhaka city. CO concentration shows a sharp increment from October, 16-September, 17 (**Fig 2c**). However, CO shows sudden decrement from March, 17 to September, 17 and showed the lowest value (0.85 ppm) during August, 17. During the observation, average CO concentrations in the winter months were almost more than double than those of the summer months. Sikder *et al.* (2010) have reported that the seasonal cycle of CO had high peak in winter and base in summer season.

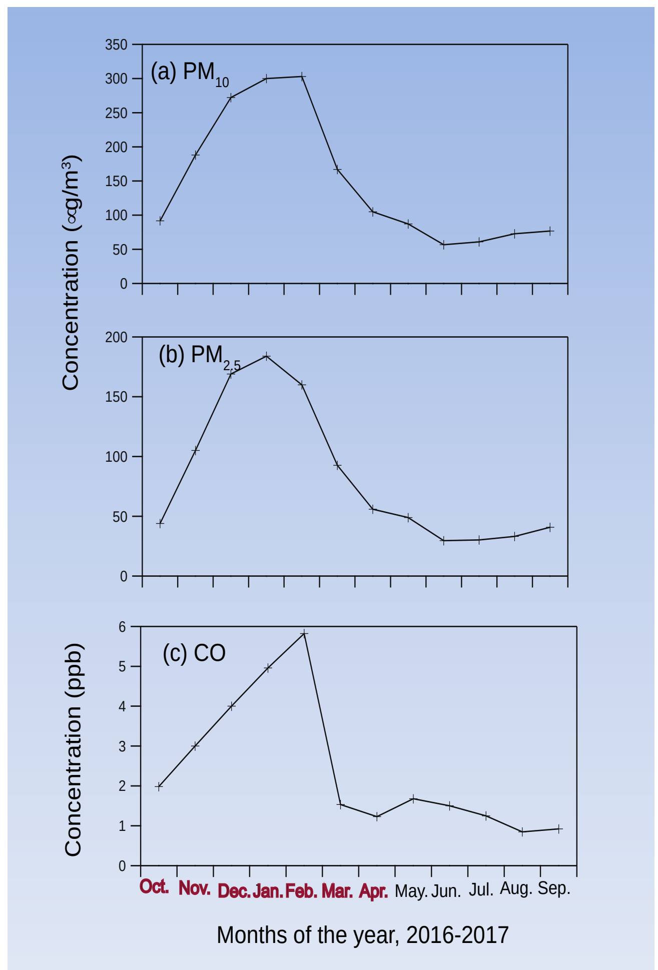

Fig 2: Seasonal variations in the atmospheric concentration of (a) PM10; (b) PM2.5, and (c) CO in Dhaka city.

Seasonal variations with maximum concentrations of CO in the winter period and minimum concentrations in the summer period are also observed in Kuwait (Abdul-Wahab and Bouhamra, 2016) and in Indian and Japanese cities (Morikawa, 1998; and Sahu and Lal, 2006).

3.6 Seasonal variation of $PM_{2.5}$ and PM_{10} - Fig 2b shows the dry and wet months' variations of $PM_{2.5}$ and PM_{10} concentrations in the Dhaka city. Concentrations of $PM_{2.5}$ and PM_{10} shows increasing trends from October 2016 to February 2017 and after that it shows decreasing trends up to September, 2017 (**Fig 2b**). During the observations, highest peaks ($PM_{2.5}$=183.87µg/m^3, PM_{10}=303 µg/m^3) were in January and February, respectively. However, background concentrations ($PM_{2.5}$=29.6µg/m^3 and PM_{10}=56.6µg/m^3) were detected during June, 2017 (**Fig 2b**).

Islam *et al.* (2015) have reported that concentration of particulates ($PM_{2.5}$ and PM_{10}) had exceeded the ideal level during the dry season while remaining as bellow from the standards during the rainy season. Highest concentrations of particulates in Dhaka city were observed in January (Islam *et al.*, 2015). Highest concentrations of particulates in winter may be associated with enhanced atmospheric emissions from fossil fuels combustion, biomass burning and unfavorable meteorological conditions for pollution dispersion.

3.7 Relationship between $PM_{2.5}$ and PM_{10} with rainfall - Precipitation can effectively reduce atmospheric $PM_{2.5}$ and PM_{10} load through wet deposition (**Fig 3a**, **Fig 3b**, and **Fig 3c**). **Fig 3** shows the relationship between atmospheric particulates concentrations with rainfall. Interestingly, during dry season (October-March) when rainfall amount is low then particulates loads are high (**Fig 3a**, **Fig 3b**, and **Fig 3c**). On the contrary, during wet season (April-September) rainfall showed higher values at the same time $PM_{2.5}$ and PM_{10} load showed lower values. These findings may specify that atmospheric wet deposition of PM_{10} accelerated with rainfall (Giri *et al.*, 2008).

Similar observation also found by Islam *et al.* (2015), where they reported that trends in air quality over the past decade had large seasonal variations in $PM_{2.5}$ and PM_{10} concentrations during winter due to wind direction which suggested that brick-kilns were major contributors to $PM_{2.5}$ and PM_{10} concentrations in Dhaka air during dry season and their concentrations reduced through wet deposition, since the number of rainy days have increased in the onset of monsoon.

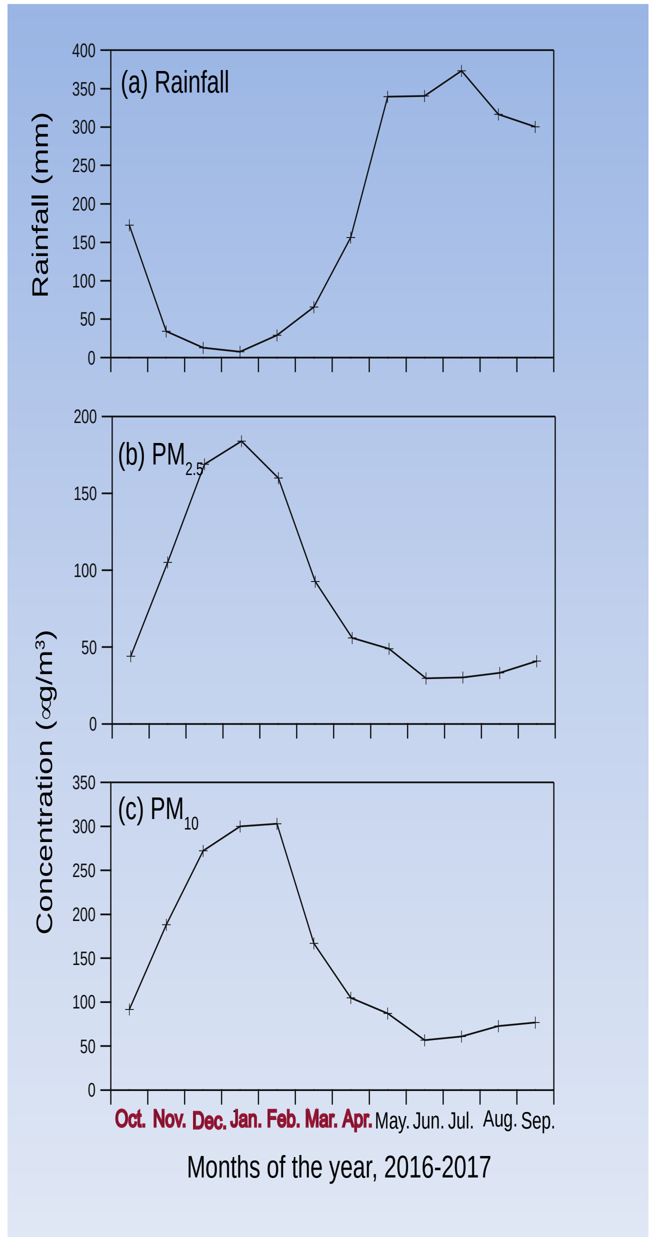

Fig 3: Seasonal variations of (a) Rainfall; (b) PM2.5 and (c) PM10 in Dhaka city.

3.8 Relationship between $PM_{2.5}$ and PM_{10} with ambient Temperature - Fig 4a, **Fig 4b**, and **Fig 4c** represent the relation between $PM_{2.5}$ and PM_{10} with ambient temperature.

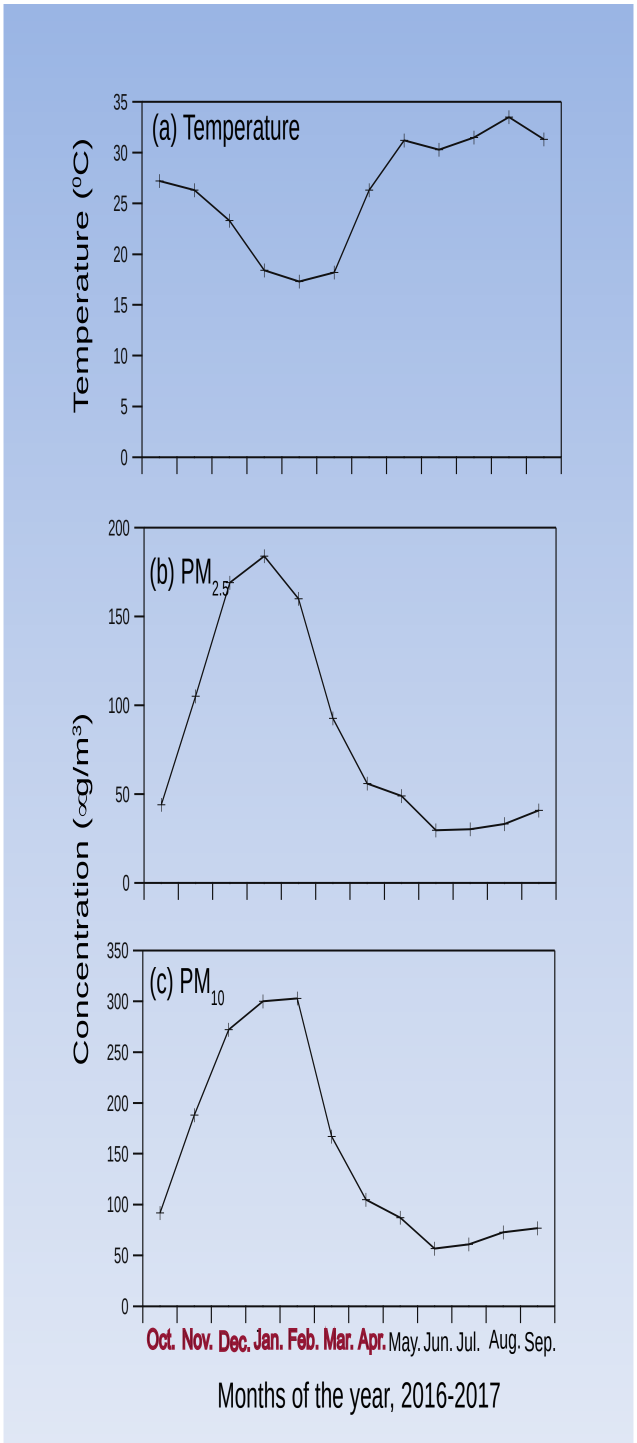

Fig 4: Seasonal variations of (a) Temperature; (b) PM2.5, and (c) PM10 in Dhaka city.

As shown in Fig. 4a, b and c, both of the $PM_{2.5}$ and PM_{10} shows high values when atmospheric temperature remains as low, indicating that during winter (average low temperature) a high pressure exist in the atmosphere as a result particulates ($PM_{2.5}$ and PM_{10}) cannot disperse over the long area and concentrated in a local vicinity, which finally contribute to high atmospheric particulate loads.

However, when ambient temperature is high then $PM_{2.5}$ and PM_{10} pollution loads remains as lower level. These results indicate that during high temperature (summer months) a low pressure exist in the atmosphere and an atmospheric instability is existed, which helps for pollutants dispersion over the large area (Nam *et al.*, 2010).

4 CONCLUSIONS:

In this study concentration of major air pollutants (SO_2, NO_2, O_3, CO, $PM_{2.5}$ and PM_{10}) was determined with Darus-salam CAMS of DoE to find their seasonal variability. Average concentration of SO_2 showed high value (21.7 ppb) in dry season (October-February) and low value (13.4 ppb) in wet season (March-September). This may happen, because of low temperature in dry season together with high emissions of sulphur from brick kilns, where coal used as the major fuel for burning. In addition, SO_2 cannot spread out through the atmosphere and exist in lower atmosphere level during winter season due to difference in atmospheric pressure. Moreover, average concentration of NO_2 in winter (October-February) showed three times high values than the summer (March-September). High atmospheric concentration of NO_2 in winter may be associated with excessive level of coal burning in the brickfields adjacent to Dhaka city during the winter months. Similarly, O_3 showed 4 times higher values in winter (October-February) than that of the summer (March-September). Winter high concentration of O_3 is due to brick kiln emission, which operated during winter season where northerly winds dominate over Dhaka. However, favorable sunlight during winter together with excessive VOCs emission from coal burning for brick processing may be the dominant reason of high O_3 concentration in winter season. During the observations, highest peaks ($PM_{2.5}$=183.87 µg/m^3, PM_{10}=303 µg/m^3) were observed in January and February, respectively. However, background concentrations (PM=29.6 µg/m^3 and PM_{10}=56.6 µg/m^3) were detected during June. Winter time highest concentrations of $PM_{2.5}$ and PM10 may be associated with enhanced atmospheric emissions from fossil fuels combustion, biomass burning and unfavorable meteorological conditions for pollution dispersion.

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CONFLICTS OF INTEREST:

All the authors of this manuscript agreed that they have no confliction to make the manuscript publishable.

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