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Seasonal Variation of PM2.5 Concentration in the Air of Dhaka: An Analysis with Recommendations

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Abstract

Air pollution has been recognized as one of the most environmental hazards and public health concerns particularly for urban dwellers. On the basis of average annual PM2.5 concentration, IQ-Air in their 2021 World Air Quality Report ranked Dhaka as the second most polluted city in the world with an average PM2.5 concentration of 78.11µg/m3. This study analyzes monthly and seasonal variation of PM2.5 concentration in the air of Dhaka and its likely effects on human health based on a continuous air monitoring station (CAMS #3-Darus-salam) data of recent years (between 2013-2022). The CAMS data are extracted and statistical analysis of monthly and seasonally varying average concentrations of PM2.5 are performed and the mean values are compared with the local and international ambient air quality standards (i.e., DoE, US-EPA standards) to determine the effects of PM2.5 on public health in Dhaka city. Finally, based on a systematic review of literatures, major sources (i.e., road, motor vehicles and industry/brick kiln, and construction activities etc.) of PM2.5 in the air of Dhaka are identified and policy level recommendations are provided to improve the quality of air (i.e., to reduce the extent of PM2.5 pollutant) in Dhaka city.

Keywords: *PM2.5 Concentration; Air Quality; Dhaka City; Air Pollutant; Public Health*

1 Introduction

Dhaka is a densely populated unsustainable and unhealthy mega city with a poor track record of maintaining ambient air quality. Unplanned urbanization including poorly regulated industrialization, transportation and land developments (i.e., infrastructure and building construction activities)is primarily responsible for air pollution in Dhaka city. Bangladesh as a country and Dhaka as the capital of Bangladesh have been ranked consistently among the heavily air polluted countries and cities lists. For instance, in 2021, IQ-Air in their World Air Quality Report ranked Dhaka as the second most polluted city in the world with an average PM2.5 concentration of 78.11µg/m3 (IQ-Air, 2023). And most recently, in the list of countries based on 2022 global environmental performance index (EPI), Bangladesh has been ranked 177 among 180 countries with a score 23.1 (Wolf, et., al., 2022). EPI is a composite index that includes 11 broad issues including air quality. Furthermore, Randall et. al. (2011) found that Particulate Matter is the primary pollutant in the air of Dhaka during dry season (November-March) when PM2.5 concentration reaches at its peak (at a very dangerous level).

PM2.5 are fine particles (particulate matters) with an aerodynamic diameter of ≤2.5 milli-micron (µm) per cubic meter (m3) of air. They are inhalable droplets of solid and liquid mixtures of various substances such as dust and other particulate matter in the form of smoke, mist etc. They stay in the atmosphere as suspended substances for a long period of time and move a longer distance than other course particulate matters. The composition of PM2.5 (particulate matter) including physical and chemical properties depends on the source that generates such particles. Fine particles (PM2.5) if exists in the air at a high concentration for an extended period could be very harmful for human health. This is due to the fact that, if inhaled excessively, PM2.5 may penetrate deeply into the lung causing respiratory illness including lung cancer, cardiovascular disease and in some cases cardiac arrest and premature death (Pope et. al., 2002).

The purpose of this study is twofold: (1) to analyze monthly, and seasonal variation of PM2.5 concentration in the air of Dhaka and its likely effects on human health based on a continuous air monitoring station (i.e., CAMS #3-Darus-salam) data of recent years (between 2013-2022); (2) to identify major sources (i.e., road, motor vehicles and industry/brick kiln, and construction activities etc.) of PM2.5 in the air of Dhaka through literature review and provide general policy level recommendations to improve the quality of air (i.e., to reduce the concentration of PM2.5 pollutant) in Dhaka city.

1.1 Continuous Air Monitoring Station # 3 (CAMS #3; Darus-salam)

The Department of Environment (DoE) as part of its air quality monitoring network program operates 11 continuous air monitoring stations throughout Bangladesh. The continuous air quality monitoring station #3 (CAMS-3) is located at a close proximity of Mirpur road in Darus-salam, Mirpur (Fig. 1).A large number of Brick Kiln fields exist at some distance in the west and north-west direction from the Mirpur area (Rana, 2019). This station monitors and records PM2.5 concentration data continuously in real time with a satisfactory capturing rate.

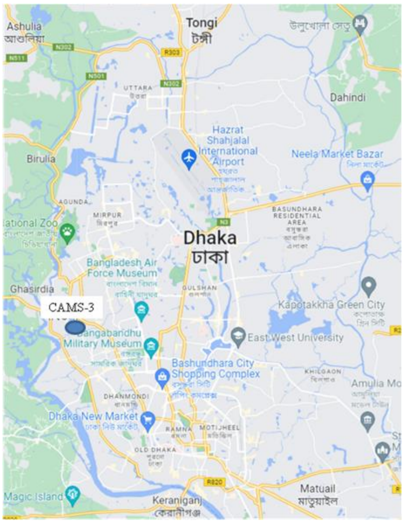

Figure 1. Approximate location of CAMS-3 (Darus-salam; Lat/Lon: 23.78N/90.36E) (Source: Google Map).

2 Methodology

The CAMS data are extracted and statistical analysis of monthly and seasonally varying average concentrations of PM2.5 are performed and the mean values are compared with the national and international ambient air quality (AAQ) standards (See Table 1) to determine the state of PM2.5 concentration and its effects on public health in Dhaka city.

Table 1. Ambient Air Quality Standardsand World Health Organization guideline values for PM2.5 (Source: Baldwin and Calkins, 2007; Randall et. al., 2011; APCR 2022).

Averaging Period	Bangladesh Standards		WHO Guideline Values	US EPA Standards
	(Until June 2022)	(Since July 2022)		
	µg/m3			
Annual	15	35	10	15
24-hour	65	65	25	35

Figure 2 shows the trends of PM2.5 concentration in the air of Dhaka for a period of ten years between 2013 and 2022. The u-shape nature of the plotted data indicates that the concentration of PM2.5 varies gradually between the wet and dry seasonswith a distinct and periodic patterns in each year. The data also showthat theconcentration ofPM2.5 in dry season is much higher than that in wet season. Furthermore, the post COVID period (i.e., in 2022)data show that the extreme (outlier) values of PM2.5 concentration reach as high as at 800 µg/m^3 indicating a deteriorating condition from all previous years.

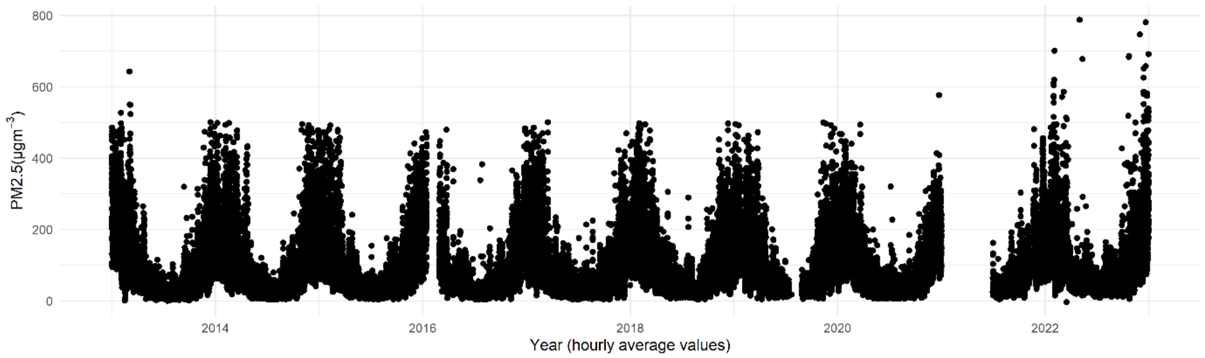

Figure 2. Trends in hourly PM2.5 concentration (time series plots from 2013 to 2022).

Fig. 3 showsBox and Whisker plots(time series analysis) of PM2.5 concentration. The figure shows that the mean yearly values range between 70.63μg/m^3 in 2016 and 97.8 μg/m^{3}in 2019. The mean values of PM2.5 concentration in year 2020 and 2021 (i.e., during the COVID-19 lockdown period) are 83.9 μg/m^{3}and 72.2μg/m^3 respectively. Given the mean, median (box), and whisker (outlier) values, the finding is that the concentration of PM2.5 increases slightlyin the post-COVID period (2022) from that of pre-COVID period (2013-2019). Furthermore, a slight reduction of PM2.5 concentration is observed during the COVID-19 lockdown and school closure periods (i.e., 2020 and 2021). These findingsare consistent with other internationalfindings. For instance, Venter et.al. (2020) in a study based on 10,000air quality station data in 34 countries found that the COVID-19 lockdown reduces the air pollution in general and PM2.5 concentration in particular.

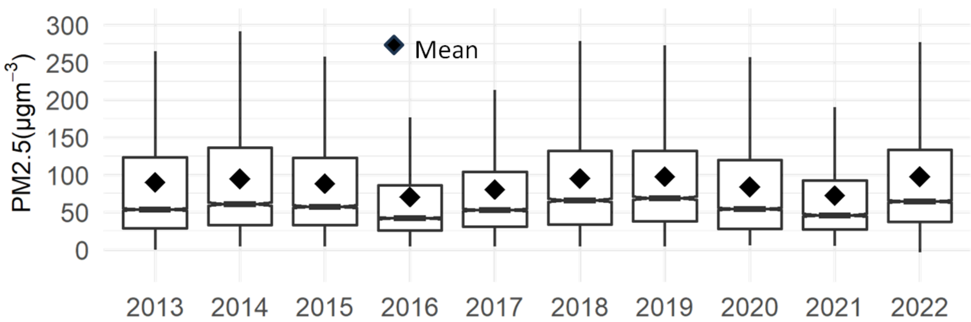

Figure 3. Box-whisker (time series) plots and yearly mean values of PM2.5 concentration.

To better understand the seasonal influence on the concentration of PM2.5, seasonal analysis considering two separate seasons (i.e., wet and dry seasons) has been performed. The dry season (November-March) is generally characterized by dryness of soil with low to moderate relative humidity while the wet season (May-October) is characterized by wetness of soil caused by frequent rainfalls with moderate to high wind speed and humid conditions.As shown in Fig. 4, it is found that the mean values of PM2.5 concentration (ranges approximately between 35 - 50 μg/m3) in wet season (May-October) are lower than the corresponding values (ranges approximately between 116 -165 μg/m3) in dry season (Nov-March).

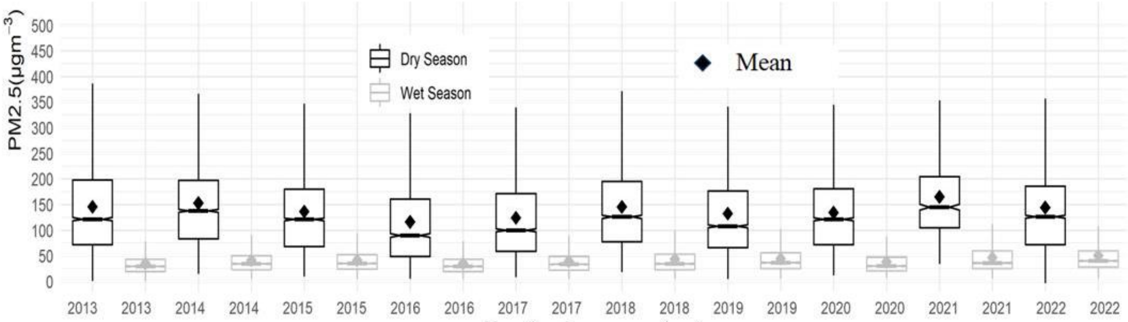

Figure 4. Box-whisker (time series) plots with mean values of PM2.5 concentrations (dry and wet seasons).

Comparing the PM2.5 values presented in Fig. 3 and Fig. 4, and the AAQ standard values presented in Table 1, it is found that the annual average PM2.5 concentration is 2.33 to 11 times higher than the Bangladesh national ambient air quality standard value (i.e., pre-July 2022 value of 15μg/m^3) for PM2.5. Furthermore, the lowest concentration of 27.65μg/m^3 (mean value) is found in July and the highest concentration of 197.56μg/m^3 (mean value) in January (Fig. 5). The reason for lower concentration of PM2.5 in the wet season is that the Monsoon rainfall washes away PM2.5 particles and settled them down on ground at a frequent interval. Furthermore, Brick Kiln fields remain closed in the wet season.

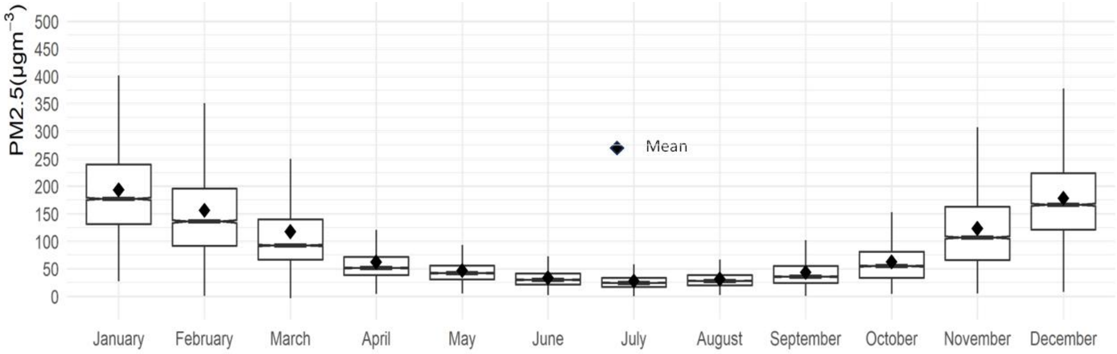

Figure 5. Box-whisker plots and monthly mean values of PM2.5 concentration.

To understand the daily (24 hr average values) variation of PM2.5 concentrations during the wet and dry seasons, January (as the month of highest concentration in wet season) and July (as the month of lowest concentration in dry season) month’s data are analyzed further. Fig. 6 shows daily (24-hr) PM2.5 concentration values in January and July months for a period of four years (2019 as pre-COVID, 2020 and 2021 as COVID period and 2022 as post-COVID period).Further, the figure shows that the mean values of PM2.5 concentration during the COVID period are slightly lower than the pre-and-post COVID period values and the averaging 24-hr PM2.5 concentration values in January range between 180 – 200 μg/m^{3}and the same in July range between 26 – 33.5 μg/m^3. Comparing the AAQ standard values presented in Table-1, the finding is that none of the averaging 24-hr PM2.5 concentration values in January satisfy the 24-hour National Ambient Air Quality Standard (i.e., 65 μg/m^3) while all the July concentration values satisfy the standard.

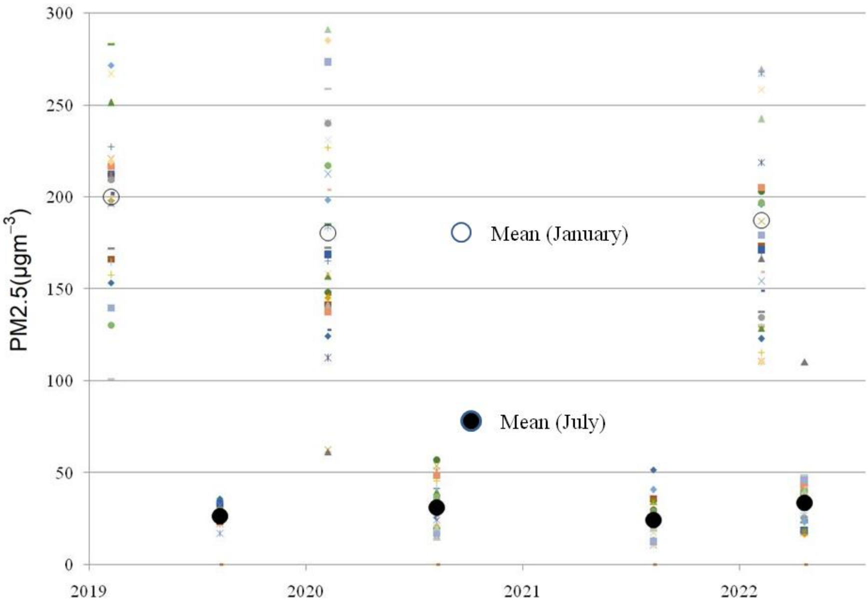

Figure 6. PM2.5 concentration in the months of January and July (mean and 24-hr variation).

3 Major Sources of PM2.5 in the air of Dhaka

A number of sources that are responsible for releasing PM2.5 in the air of Dhaka have been identified by others (Begum et. al., 2008; Randall et. al., 2011; Rouf et. al., 2011, and Rana2019). The anthropogenic sources of PM2.5 concentration in Dhaka city include both mobile (road traffic- fossil fuel, tire-road friction etc) and point (Brick Kilns, infrastructure and building construction sites, development sites, diesel powered generators, irrigation and agricultural equipments, miscellaneous industries/factories, open refuse/solid waste/wood fire etc) sources. Open burning of solid waste, particularly plastic waste in landfills, slums, and residential areas further contributes to elevated PM2.5 concentration (ESDO, 2020). Studies (Randall et. al., 2011; Rana2019) also identified motor vehicles (combustion of fossil fuel and road dust mainly generated by road-tire frictions) and Brick Kilns (with energy source coal and wood) as two major sources of air pollution in Dhaka city. The Norwegian Institute for Air Research (NILU) under the project titled “the Clean Air and Sustainability Project-CASE” found that vehicular emission and road dust contribute to 10.4% and 7.7% of fine particles (PM2.5) in Dhaka city (Randall et. al., 2011). Others (Randall et al. 2014; and Begum and Hopke 2019) indicated that Brick Kiln industry alone contributes as high as 58% of PM2.5 concentration in the air of Dhaka during the dry season.

4 Conclusions and Recommendations

This study examines monthly, and seasonal variation of PM2.5 concentration in the air of Dhaka and its likely effects on human health based on a continuous air monitoring station (i.e., CAMS #3-Darus-salam) data of recent years (between 2013-2022). Major sources (i.e., road, motor vehicles and industry/brick kiln, and construction activities etc.) of PM2.5 concentration in the air of Dhaka are also identified. It is found that PM2.5 concentrations (annual averaging values) throughout the year and continuously in the last ten years (2013-2022) have been much higher than the National and International AAQStandards and the current state of PM2.5 concentrations is very alarming and detrimental for public health, particularly the dry season is very dangerous. Alimited study (i.e., only for the months of January and July between 2019 and 2022) has been performed on the averaging 24-hr PM2.5 concentration valuesand it is found that the averaging 24-hr PM2.5 concentration values in the month of July satisfy the National Ambient Air Quality Standard (i.e., 65 $\mu g/m^3$). The findings of this study indicate that the existing policies and strategies are substantially inadequateto control/maintain the national ambient air quality standards for PM2.5in Dhaka city. Therefore, Dhaka needs to re-examine the existing policies and develop/redevelop more effective policies and strategies to control and maintain PM2.5 concentration in the air of Dhaka for dwellers healthy life. In particular, the following source specific policy actions are desirable.

- The current and foreseeable futureactivities in the infrastructure (such as BRT, Airport 3rd terminal and multimodal hubs, Metro rail, Elevated expressway etc.) and housing development sectorswould continue to contribute in the increment of PM2.5 concentrationin the air of Dhaka. Therefore, development of a new robust PM2.5 pollution control policyand/or updating of existing air pollution control related policies (acts/laws, rules, regulations, inspection, enforcement etc) is needed.
- Modal shift from auto to mass/public transportation through appropriate transportation policy, planning, operations and management strategies as well as investment in the low emission vehicle technology (i.e., sulfur-and-lead-free fossil fuel; battery-electric vehicles etc.) are desirable to reduce PM2.5 concentration from transportationsources. In this regard, further expansion and all-dayoperations of Metro rail and BRT services in the upcoming days would be helpful inreducing the concentration of PM2.5 in the air.
- Pollution control policymust also address on how to regulate major point and moving sources that generate PM2.5 (i.e., construction and demolition activities; road cutting and other infrastructure operations and maintenance activities; Brick Kiln operations activities etc.).

AUTHOR CONTRIBUTIONS

The first author (Md. Shoaib Chowdhury) has planned, conceived (scope, objective, & methodology), & prepared/written the manuscript. The co-authors have compiled PM2.5 data and prepared numerous tables/figures/graphs under the supervision/ direction of first author.

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