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Spatio-Temporal Variation of Urban Air Quality and Its Relation with Meteorological Variables in Bangladesh

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Abstract

Particulate Matter (PM) pollution is a major environmental concern in cities of Bangladesh due to its health impacts. The amount of pollution in the air is steadily becoming worse in district level. The study aims to examine the relationship between air quality and meteorological factors in Dhaka and Rajshahi, two major cities in Bangladesh. By analyzing the concentration of PM over the land uses, the research seeks to provide valuable insights into the urban air pollution dynamics of these rapidly growing metropolises. Three sets of 15 minutes data (PM_1, $PM_{2.5}$ and PM_{10}) were collected from ground level of each location. $PM_{2.5}$ and PM_{10} measurements were conducted using automated portable air quality monitor called "Aeroqual S500" and for PM_1, handheld air quality monitor "DM106A" has been deployed. The findings reveal that Dhaka consistently experiences higher levels of PM pollution compared to Rajshahi, indicating poorer air quality. Comparing the land uses in both the cities the mixed areas of Dhaka exhibit the highest concentration of all types of PM though the concentrations in all the land uses in this city cross the standard limit while in Rajshahi the highest concentration is found in industrial areas. The variations in PM concentrations can be attributed to factors such as industrial activities, vehicular emissions, population density, and local meteorological conditions (Humidity and Temperature). Additionally, the analysis of $PM_{2.5}$ to PM_{10} ratio provides insights into the composition of particulate matter in the air, highlighting the importance of understanding pollution sources and atmospheric conditions. The study also investigates the correlation between atmospheric parameters (humidity and temperature) and PM concentrations in both cities, revealing a negative relationship. As humidity and temperature increases, PM_1, $PM_{2.5}$ and PM_{10} concentrations tend to decrease. This underscores the influence of meteorological conditions on air pollution levels and emphasizes the need to consider local climatic factors when designing pollution control measures. Furthermore, the study highlights the issue of transboundary air pollution, particularly concerning Aerosol Optical Depth (AOD). Rajshahi, situated near the West Bengal region of India, exhibits higher AOD levels compared to Dhaka, indicating the influence of transboundary pollution sources. Addressing this issue requires regional cooperation, including the establishment of air quality monitoring networks, data sharing, and coordinated strategies with neighboring countries.

Keywords: *Air Pollution, Seasonal Variation, Transboundary, AOD, PM*

Intoduction

Climate change was proclaimed as "the single biggest health threat facing humanity" by the World Health Organization report 2021 and air pollution is also considered to be a serious threat to human health in the environment (Keswani *et al.*, 2022). Globally within five leading risk factors for death, air pollution ranked fifth position (GBD, 2017).

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Ambient air pollution, a complex mixture of both local and distant pollutants changes over time (Rahman *et al.,* 2020). Among all the pollutants, particulate matters (PM_1, $PM_{2.5}$ and PM_{10}) are the major contributor of human health hazard (Wang *et al*., 2021). Particulate Matter (PM), particles of varying but extremely small in diameters that enter the respiratory system through inhalation and can lead to cancer, reproductive, cardiovascular, and central nervous system disorders, as well as respiratory and other diseases (Manisalidis *et al*., 2020). The major PM sources that created naturally include dust (airborne soil, also called crustal material), secondary sulphate, pollen, black carbon from wildfires, and volcanic ash and dust from construction or unsealed roads, traffic movements, cooking, fossil fuel combustion activities, smoking, machine operation, and residential hobbies are the main PM sources of human activity (Tran *et al.,* 2020). Air pollution is more severe due to overpopulation and unplanned urbanization along with the excessive industrialization in developing nations (Manucci *et al*., 2017) like Bangladesh. Increased concentrations of particulate matter and airborne gaseous pollutants have been linked to hypertension and elevated systolic and diastolic blood pressure (Yang *et al.*, 2018). In terms of poor urban air quality, Dhaka currently ranks highly among the major cities in the world (Alam *et al.,* 2018). Dhaka, the capital of Bangladesh, is the hub of all political, economic, and cultural activity and has been expanding quickly in tandem with the worldwide urbanization and technological advancement trend. It is also the fourth most overpopulated city in the world (BBS 2014). World Bank report 2022 declared that the major construction sites and perdurable traffic in Dhaka City were responsible for the highest level of air pollution. On the other hand, Rajshahi city bears more pollutants free air than Dhaka (Graham-Harrison & Doshi, 2016). Compared to Dhaka, Rajshahi had never been as densely inhabited and didn't have a large industrial zone (Archi *et al.,* 2021). Several steps were taken to reduce air pollution such as a campaign to make the city more environmentally friendly and to clean up the brick kilns etc. (Graham-Harrison and Doshi, 2016). The main focus of this research is to determine the statistical relationship between meteorological data and air quality, to observe parameter concentrations, and to evaluate the variation of PM in Dhaka and Rajshahi cities. Additionally, the study aims to evaluate the relationship between land uses and observed parameter concentrations in both cities.

Methods

In this study three significant parameters, PM_1, $PM_{2.5}$ and PM_{10} were considered. Particulate matters were selected because of their capability to enter deep into the respiratory system which is linked to substantial health such as cardiovascular and respiratory disorders (Arias-Pérez *et al.,* 2020; Thangavel *et al.*, 2022).

Study area

The study areas of Dhaka and Rajshahi were selected considering their different urban features and contrasting levels of industrial activity. Ranking first for worst air quality, Dhaka has been identified as the most polluted city worldwide, according to IQAir AirVisual (2023). On the other hand, Rajshahi has received recognition for its notable reduction of PM_{10} and $PM_{2.5}$, winning the National Environmental Award in 2013, the WHO's designation as the most successful city in Bangladesh from 2014 to 2016, and multiple tree-planting accolades (Kawser, 2020).

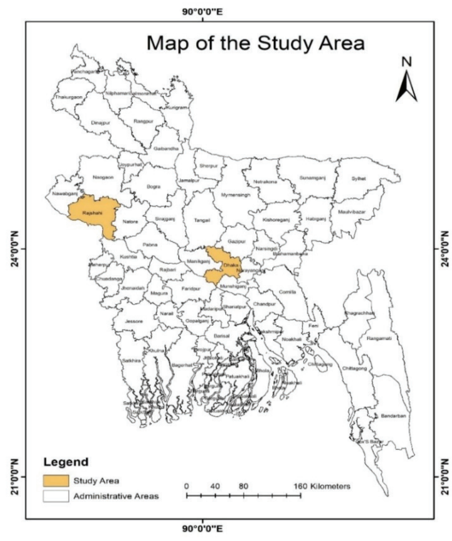

Figure 1. Study area Map (Dhaka and Rajshahi city

Data collection, result interpretation and data visualization

To compare air quality in different land use, the study followed the land use classification mentioned in Environment Conservation Rules 1997, Schedule 2; namely 1) Sensitive are 2) Residential area 3) Mixed area 4) Commercial area and 5) Industrial area (Rules, E. C., 1997). Among two districts total 60 locations were surveyed (30 in Rajshahi and 30 in Dhaka) under 5 different land use categories. $PM_{2.5}$ and PM_{10} measurements were conducted using automated portable air quality monitor called "Aeroqual S500" and for PM_1, handheld air quality monitor "DM106A" has been deployed. The technology used in these instruments is laser scattering. Additionally, Garmin ETrex 10 was employed for precise GPS data analysis. Three sets of 15 minutes data (PM_1, $PM_{2.5}$ and PM_{10}) were collected from ground level of each location. Besides, the ground-level $PM_{2.5}$ data has been retrieved from global annual $PM_{2.5}$ grids, which was produced from MODIS, Multiangle Imaging Spectroradiometer (MISR) and Sea-Viewing Wide Field-of-View Sensor (SeaWiFS), Aerosol Optical Depth (AOD) with Geographically Weighted Regression (GWR).

Sampling season

The PM concentration remains much higher than the Bangladesh National Ambient Air Quality Standard due to combined meteorological factors and long-range transport during the winter along with local emissions (Begum *et al.,* 2012). The stable meteorological conditions in post monsoon and winter, biomass and agriculture burning and domestic heating during winters are the main causes for increased air pollution during the dry season (Jain *et al*., 2020).

Results and Discussion

PM_1 concentration

The Figure 2 presents the mean PM_1 (particulate matter with a diameter of 1.0 micrometer or smaller) concentrations in various land use areas in Dhaka and Rajshahi. It is obvious from the figure that Dhaka generally shows higher levels of PM_1 concentration in comparison to Rajshahi and the average concentration of this pollutant in Dhaka (153.80 μg/m³) is nearly 5 times higher than the average concentration of PM_1 in Rajshahi (32.75 μg/m³). The relatively higher PM_1 concentration in Dhaka can be attributed to several factors, including industrial activities, vehicular emissions, population density, and local meteorological conditions. Among the five land uses in Rajshai, the commercial area shows the least concentration of PM_1 with 20.84 μg/m³ whereas the industrial area has the highest concentration of 41.05 μg/m³. In Dhaka the least PM_1 concentration of 101.55 μg/m³ has been seen in the sensitive area and the highest concentration (179.72 μg/m³) is found in the mixed area. It is to be noted that no standard limit is set for PM_1 concentration for the ambient air quality of Bangladesh. Later Table 1 is added to show the descriptive statistics of the PM concentrations in Dhaka and Rajshahi.

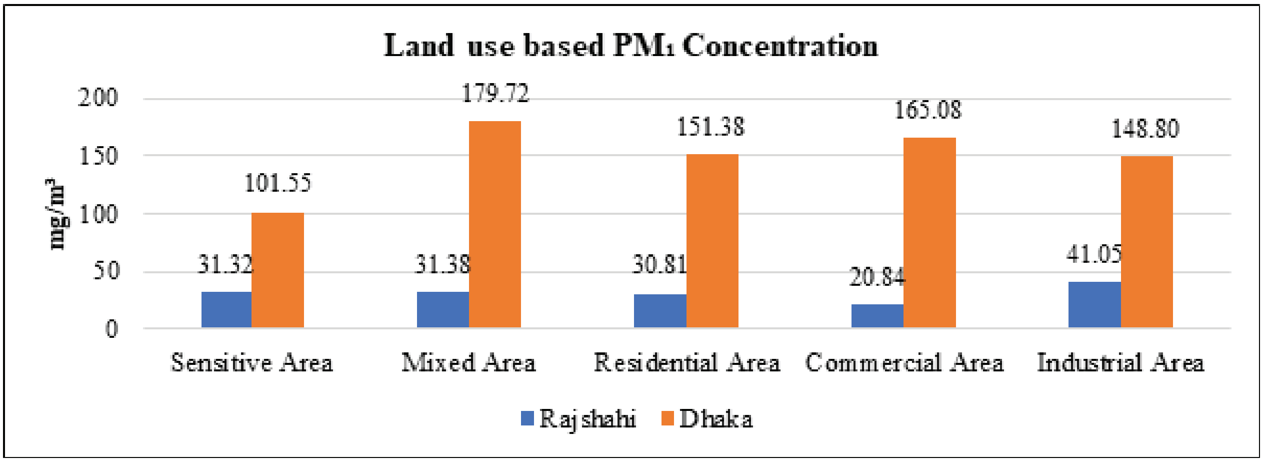

Figure 2. Land use based PM_1 concentration

This table shows the relatively lower standard deviation and variance in PM_1 concentration in Rajshahi and higher standard deviation and variance in Dhaka which implies less variation in PM_1 pollutant concentration among the land uses in Rajshahi whereas very high variation in the concentration in Dhaka. Since Dhaka is a crowded and industry surrounded the sources of PM_1 emission varies among the land uses.

Concentration of $PM_{2.5}$

The dataset provides insights into the mean $PM_{2.5}$ (particulate matter with a diameter of 2.5 micrometers or smaller) concentrations across various land use areas, shedding light on the comparison between cities and the daily limit of 65 micrograms per cubic meter for ambient air in Bangladesh set by Air Pollution (Control) Rule -2022, Schedule-1 (Rules, A. P. C. 2022). Figure 3 shows that the industrial area in Rajshahi has the highest concentration of $PM_{2.5}$ with 66.75 µg/m³ which is just beyond the standard limit. Whereas all the other land use zones' concentrations are within standard limit and the lowest (51.25 µg/m³) is found in the commercial area though the concentrations over the land uses are closer to each other. On contrarily the $PM_{2.5}$ concentrations in all the land use zones in Dhaka cross the standard limit of 65 µg/m³ with the highest in the mixed area (267.11 µg/m³) and the lowest (164.85 µg/m³) in the sensitive area.

This scenario is corresponding to the concentration level of PM_1 in both cities. In previous studies highest level of concentration had been noticed in industrial areas (Islam et al., 2023; Mahmud and Rahman, 2022) while this study shows that though in Rajshahi the highest concentration is found in the industrial area, in Dhaka, it is the mixed area may be due to several kinds of mixed economic activities, crowd and vehicular emission. Comparing the

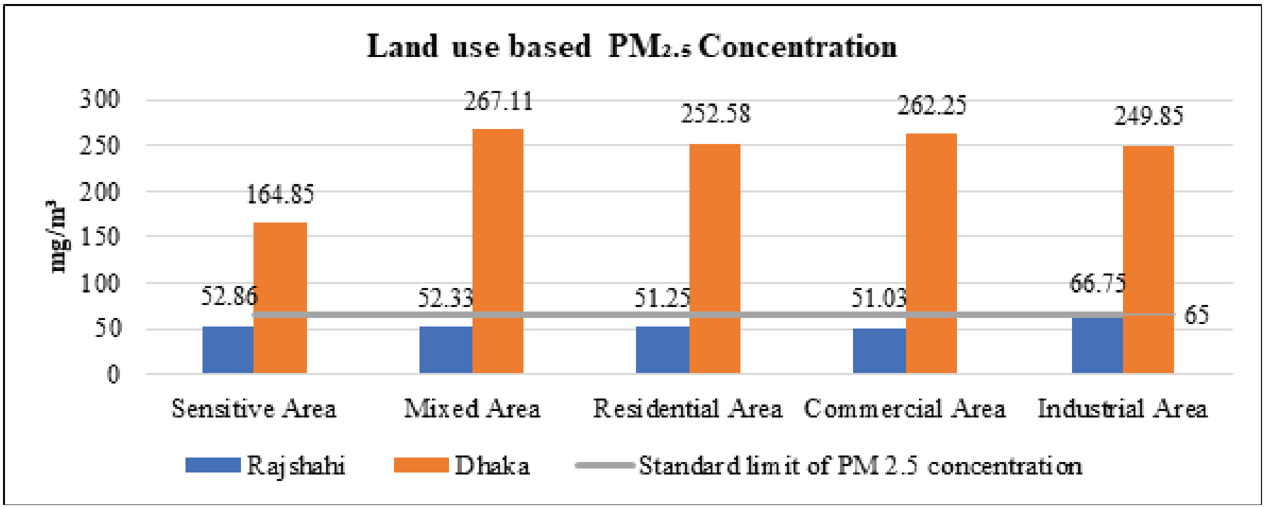

Figure 3. Land use based $PM_{2.5}$ concentration

Table 1. Descriptive statistics of PMs in two cities

District		Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Rajshahi	PM_1	22.50	26.25	48.75	32.75	5.49	30.17
	$PM_{2.5}$	37.75	42.00	79.75	54.36	8.88	78.99
	PM_{10}	48.25	55.00	103.25	70.02	11.65	135.81
Dhaka	PM_1	171.75	83.25	255.00	153.80	43.74	1913.29
	$PM_{2.5}$	218.00	130.50	348.50	242.33	53.41	2852.31
	PM_{10}	359.00	172.25	531.25	328.31	92.03	8470.21

mean $PM_{2.5}$ concentrations between Rajshahi and Dhaka, it is evident that Dhaka is again nearly 5 folds contaminated than Rajshahi. Additionally, Dhaka shows very high variation in concentration level of $PM_{2.5}$ than Rajshahi (Table 1).

PM_{10} concentration

The following diagram (Figure 4) presents the mean PM_{10} (particulate matter with a diameter of 10 micrometers or smaller) concentrations in different land use areas for a comparison between Rajshahi and Dhaka. The daily limit of PM_{10} for ambient air quality in Bangladesh is 150 μg/m³. Comparing to that limit none of the land use areas in Rajshahi do not cross the pollution level. Among the studied land uses in Rajshahi, the industrial area shows the highest concentration of 86.6 μg/m³ while the lowest concentration is seen in the commercial area with 85.88 μg/m³ like PM_1 and $PM_{2.5}$ concentration level observed in this study. In Dhaka the concentration exceeds the daily limit of 150 μg/m³ in all the land uses.

Dhaka's significantly higher value suggests severe pollution in this land use area (Islam *et al*., 2023). Like the previous scenarios of PM_1 and $PM_{2.5}$ concentration, the mixed area is showing the highest concentration with 381.94 μg/m³ and the sensitive area has the lowest concentration of 214.9 μg/m³. Dhaka is again experiencing nearly 5-fold more PM_{10} concentration compared to Rajshahi with mean concentration of 70.02 μg/m³ and 328.31 μg/m³ respectively, and the standard deviation and variance of the PM_{10} concentration of these cities suggests that Dhaka's concentration is highly variable among the land uses than Rajshahi.

Comparison between cities

The below Figure 5 has been constructed to compare the pollution level among PMs in Dhaka and Rajshahi. This figure indicates that the mean concentrations of $PM_{2.5}$ and PM_{10} in Rajshahi are within daily limit of these two pollutants. Hence from the observation of this study it can be said that Rajshahi is pollution free city in the aspect of $PM_{2.5}$ and PM_{10} concentration. On the other hand, the mean concentrations of $PM_{2.5}$ and PM_{10} in Dhaka noticeably exceed the daily limit of these two pollutants. Therefore, Dhaka can be considered as polluted city in the aspect of $PM_{2.5}$ and PM_{10} concentration and the concentration level of these pollutants in average 5 times higher than Rajshahi.

Even the PM_1 concentration of Dhaka 5-fold higher that the Rajshahi though there is no daily limit of this pollutant to compare the pollution level. Various factors, including higher population density, industrial activities, vehicular emissions,

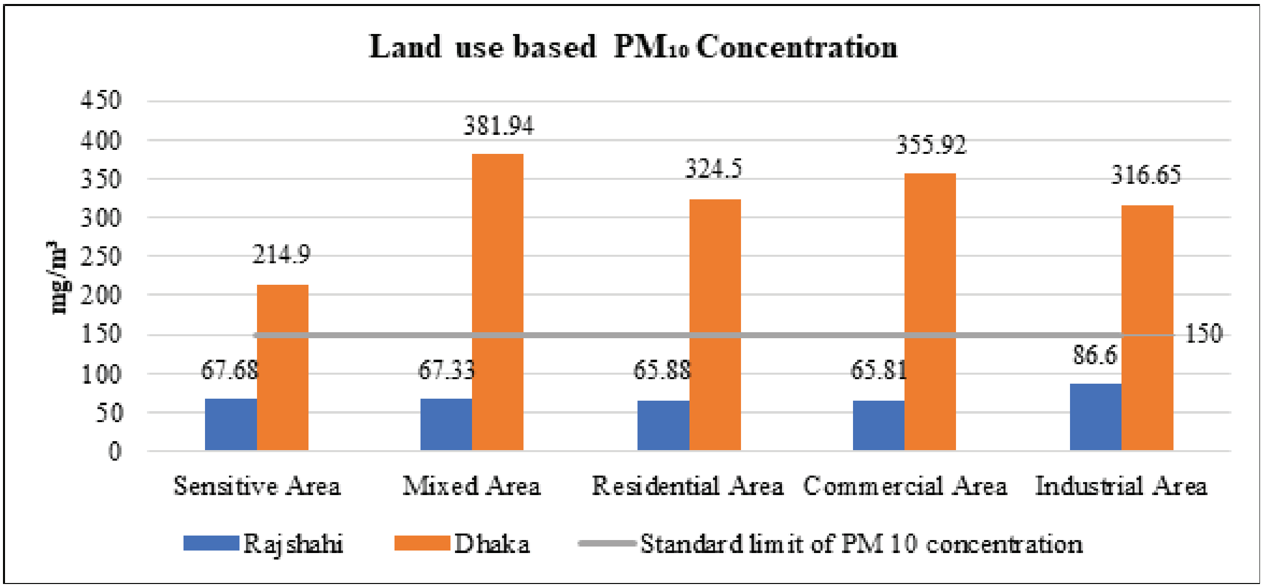

Figure 4. Land use based PM_{10} concentration

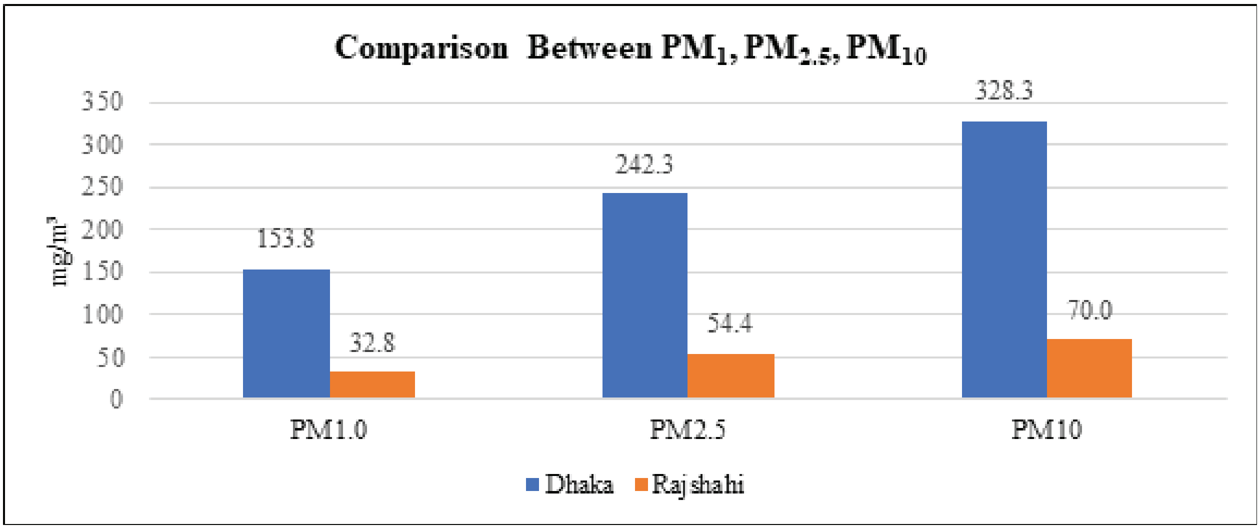

Figure 5. Comparison between cities and particulate matter

and urbanization (Islam *et al*., 2023; Mahmud and Rahman 2022; Majumder *et al.,* 2021) influence the air quality of Dhaka and make it contaminated than Rajshahi. The meteorological parameters might also play a significant role in determining the quality of air in both cities which is explored in the later part of this paper.

Ratio between $PM_{2.5}$ and PM_{10}

The ratio between $PM_{2.5}$ and PM_{10} refers to the proportion of fine particulate matter (PM) with a diameter of 2.5 micrometers or less ($PM_{2.5}$) compared to the total suspended particulate matter with a diameter of 10 micrometers or less (PM_{10}). $PM_{2.5}$ and PM_{10} are two sized categories of particulate matter that have different implications for air quality and human health. particles are smaller in size and can penetrate deep into the respiratory system, reaching the lungs and even entering the bloodstream. These fine particles are known to have adverse health effects and are associated with respiratory and cardiovascular diseases. On the other hand, PM_{10} particles include both $PM_{2.5}$ and larger particles up to 10 micrometers in size. These particles are generally coarser and are more likely to be trapped in the upper respiratory tract or the nose and throat when inhaled.

While PM_{10} particles can still cause health issues, the smaller $PM_{2.5}$ particles are considered more hazardous due to their ability to penetrate deeper into the lungs. The ratio $PM_{2.5}$ to PM_{10} provides insights into the composition of particulate matter in the air. A higher ratio indicates a larger proportion of fine particles ($PM_{2.5}$) relative to coarse particles (larger than $PM_{2.5}$ but smaller than PM_{10}) in the overall particulate matter. This can be indicative of different pollution sources or atmospheric conditions. Figure 6 depicts $PM_{2.5}$ as well as PM_{10} dispersion levels in Rajshahi and Dhaka which are marked in green and orange dots respectively. The results reveal that there is a positive relationship between $PM_{2.5}$ and PM_{10} values in both

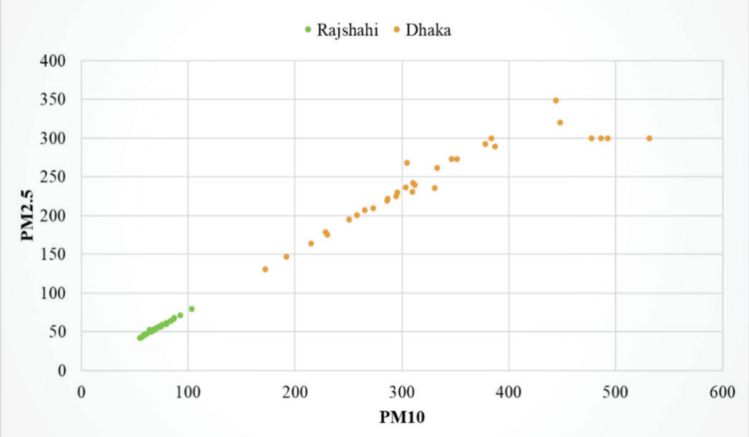

Figure 6. Ratio between $PM_{2.5}$ and PM_{10}

cities, which means that an increase in values will also lead to an increase in values. Rajshahi average $PM_{2.5}$ is about 40-60% of the average PM_{10} levels, implying a uniform ratio. On the contrary for Dhaka, ratio of $PM_{2.5}$ to PM_{10} was less stable, fluctuating around 60-70% at deterioration levels of pollution. Therefore, while Rajshahi records low levels of $PM_{2.5}$ and PM_{10} but with a consistent ratio, pollution levels in Dhaka are extremely high recorded together with a higher and inconsistent $PM_{2.5}$ to PM_{10} ratio.

Meteorology and PMs

Table 2 shows that in Dhaka, a moderate to relatively strong negative correlation exists between the PMs (PM_1, $PM_{2.5}$, PM_{10}) and humidity and the strength has been increased (-0.577 to -0.797) with the increasing size of the particulate diameter (Islam *et al.*, 2022). These correlations are statistically significant at a 95% confidence level (p-values of 0.011, 0.014, and 0.002, respectively). Similar trend is also found in Rajshahi at a 95% confidence level (p-values of 0.001, 0.008, and 0.05, respectively), though the correlation between PM_{10} and humidity is negatively moderate (-0.438) instead of being relatively stronger like Dhaka. Therefore, in general, as humidity increases, the concentrations of PM_1, $PM_{2.5}$, and PM_{10} tend to decrease in both Dhaka and Rajshahi (Islam *et al.,* 2022) and in Dhaka PM_{10} is more susceptible to the change of humidity whereas in Rajshahi it is $PM_{2.5}$. In case of temperature, the relationship is also negative and strong for PM_1 and PM_{10} (-.811 and -.848) but very strong for $PM_{2.5}$ (-.921) in Dhaka while in Rajshahi this relationship between PM_1 and temperature is moderate (-.634) and between other two PMs ($PM_{2.5}$ and PM_{10}) and temperature is strong (-.834 and -.792) and all are negatively correlated (in both cities) at a 95% confidence level. Hence, in both cities $PM_{2.5}$ is more susceptible to the change of temperature. The overall statistical analysis is portraying that the meteorological parameter like humidity and temperature are more influential in Dhaka than Rajshahi and in between two studied parameters, change in PMs is more susceptible to change in the temperature compared to humidity. Some other studies revealed that not only PMs other air pollutants also have significant relationship with meteorological parameters (Haque *et al.,* 2022; Zaman *et al.,* 2021).

Table 2. Correlation between meteorology and PMs

Year			Humidity	Temperature
Dhaka	PM_1	Pearson Correlation	-.577	-.811
		Sig.	.011	.000
	$PM_{2.5}$	Pearson Correlation	-.687	-.921
		Sig.	.014	.000
	PM_{10}	Pearson Correlation	-.797	-.848
		Sig.	.002	.000
Rajshahi	PM_1	Pearson Correlation	-.489	-.634
		Sig.	.001	.003
	$PM_{2.5}$	Pearson Correlation	-.679	-.834
		Sig.	.008	.003
	PM_{10}	Pearson Correlation	-.438	-.792
		Sig.	.05	.006
Significant Level at 95% (.05)				

Spatial distribution of $PM_{2.5}$ and PM_{10}

The $PM_{2.5}$ and PM_{10} concentration data of Dhaka and Rajshahi cities are interpolated on map to observe the spatial distribution of these two pollutants over the cities (Figure 7 and 8). Both the maps of Dhaka city show that the pollutants were mostly concentrated in the north-eastern area, south-eastern tip and some areas of the central city. These are the mainly mixed and residential areas.

The development associated construction activities were ongoing near the 300 feet road during the studied period at the north-eastern part of the city as well as some industry inside the residential area were also noticed in the lower part of this area. The south-eastern part is dominated by residential, industrial, commercial area and intercity bus terminal, all of them are contributing to account it as a mixed area.

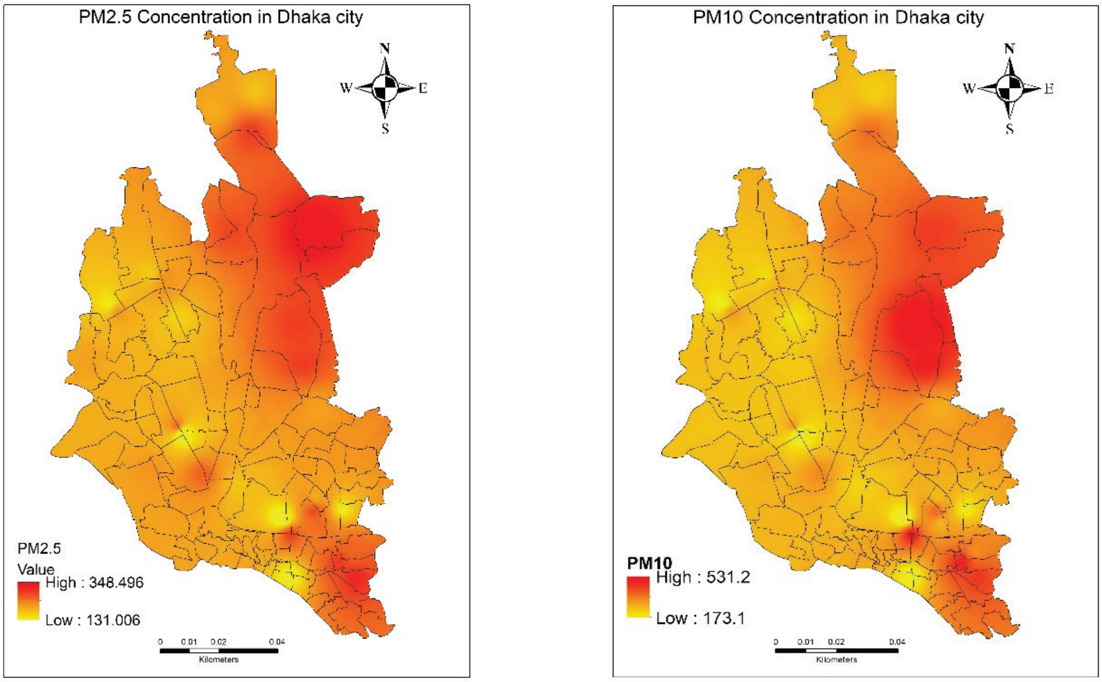

Figure 7. Spatial distribution of $PM_{2.5}$ and PM_{10} in Dhaka city

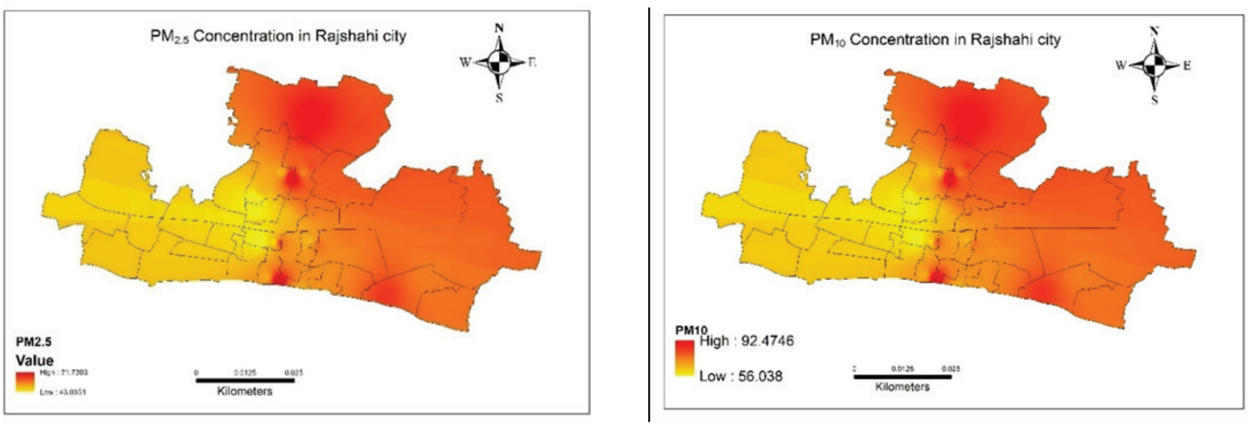

Figure 8. Spatial distribution of $PM_{2.5}$ and PM_{10} in Rajshahi city

Here the industrial activities, vehicular emission and population density are the contributing factor to the higher concentration of $PM_{2.5}$ and PM_{10}. The central part of Dhaka is representing the Dhahmondi and the surrounding area, which is also a mixed area with high population and traffic conveyance. The sensitive areas with least $PM_{2.5}$ and PM_{10} concentration are scattered over the city. The spatial distribution of $PM_{2.5}$ and PM_{10} concentration maps of Rajshahi show a clear distinction between the western and eastern part of the city suggesting the urbanization trend towards the eastern side. Less concentration of the two pollutants is seen at the western part of the city where some areas are still in rural set up and free from any development activities. On the other hand, the northern tip of the city is dominated by industry, therefore industrial activities are the main cause of higher concentration in this part. The economic hub, educational institutions and universities, government offices and workplaces of several organizations are situated at the western part of the city. Hence, different economic activities, vehicular emission, crowd and construction activities are providing this area with high $PM_{2.5}$ and PM_{10} concentration. Though the government offices, educational institutions, hospitals should be the part of sensitive area, due to the crowd and associated vehicular emission the higher concentration level of $PM_{2.5}$ and PM_{10} are noticed in this area.

AOD level over two cities

Transboundary air pollution, specifically concerning Aerosol Optical Depth (AOD), is a significant environmental issue in Bangladesh, and a comparison between Dhaka and Rajshahi reveals interesting dynamics. It is worth noting that Rajshahi is situated near the West Bengal region of India, which can influence its air quality. Satellite images have indicated that Rajshahi generally exhibits higher AOD levels compared to Dhaka (Figure 9). AOD is a parameter that quantifies the amount of aerosol particles suspended in the atmosphere.

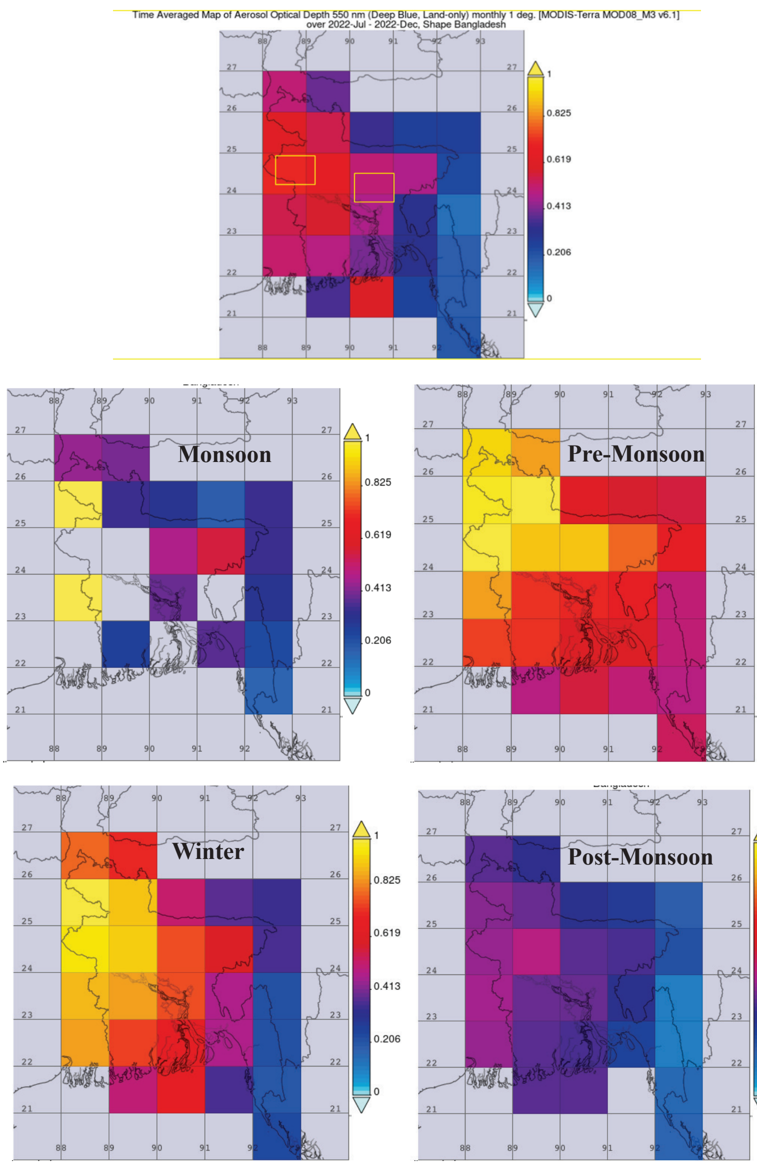

Figure 9. Average and seasonal variation of AOD over Dhaka and Rajshahi cities

It plays a crucial role in determining atmospheric visibility and can have significant implications for climate and human health. In Bangladesh, AOD levels show distinct seasonal variations.

During the winter season, both Dhaka and Rajshahi experience elevated AOD levels. This can be attributed to several factors, including increased emissions from residential heating, agricultural burning, and industrial activities. These emissions, coupled with meteorological conditions such as stable atmospheric conditions and lower mixing heights, contribute to the accumulation of aerosol particles and higher AOD values. As the winter season transitions into the pre-monsoon period, AOD levels remain relatively high in both cities. The pre-monsoon season is characterized by increased dust transport from neighboring regions, biomass burning, and the onset of thunderstorms. These factors result in enhanced aerosol loading in the atmosphere, leading to elevated AOD. Interestingly, during the monsoon season, both Dhaka and Rajshahi exhibit lower AOD levels compared to the winter and pre-monsoon seasons (Haque *et al*., 2022; Zaman *et al.,* 2021). The monsoon brings increased precipitation, higher atmospheric moisture content, and enhanced vertical mixing, which helps to cleanse the atmosphere and reduce aerosol concentrations. Additionally, the washout effect of rainfall plays a significant role in removing aerosol particles from the atmosphere, leading to lower AOD values (Haque *et al.,* 2022; Zaman *et al.,* 2021). Scientific observations indicate that various sources contribute to the higher AOD levels in Rajshahi compared to Dhaka. While both cities face challenges associated with local emissions from vehicular traffic, industrial activities, and biomass burning, Rajshahi's proximity to West Bengal introduces additional sources of transboundary pollution. Agricultural burning, industrial emissions, and other anthropogenic activities in the West Bengal region can transport aerosol particles across the border, thereby influencing Rajshahi's air quality and contributing to higher AOD levels. Addressing transboundary air pollution and reducing AOD levels in Bangladesh require collaborative efforts between neighboring countries. It is crucial to enhance regional cooperation, establish robust air quality monitoring networks, share data and information, and develop coordinated strategies to mitigate emissions and improve air quality. Additionally, promoting cleaner technologies, adopting sustainable practices, and implementing effective policies are key to reducing AOD and mitigating the impacts of transboundary air pollution.

Conclusions

This study underscores the critical disparities in PM pollution levels between Dhaka and Rajshahi, emphasizing the urgent need for targeted air quality interventions. Dhaka's PM levels consistently exceed those of Rajshahi across all particulate sizes (PM_1, $PM_{2.5}$, and PM_{10}) and land use types. Specifically, Dhaka's mean $PM_{2.5}$ concentration in the mixed land use area reaches 267.11 μg/m³, well above Bangladesh's daily limit of 65 μg/m³. Conversely, Rajshahi's $PM_{2.5}$ levels remain relatively controlled, with the highest concentration found in industrial areas at 66.75 μg/m³, close to the permissible limit. These findings point to significant health risks associated with Dhaka's air quality, where $PM_{2.5}$ and PM_{10} levels are nearly five times higher than in Rajshahi.

Meteorological factors such as humidity and temperature further reveal a negative correlation with PM concentrations in both cities, suggesting that higher humidity and temperature generally reduces PM levels. For instance, Dhaka shows a strong inverse relationship between temperature and $PM_{2.5}$ ($r = -0.921$), indicating that temperature variability could be leveraged in pollution control strategies. Additionally, transboundary pollution appears to impact Rajshahi's AOD, suggesting that regional cooperation is vital for comprehensive air quality improvement. Establishing a collaborative air quality monitoring network and sharing data across borders will be crucial to mitigating PM pollution. In conclusion, effective air quality management in Dhaka requires not only local mitigation measures but also regional coordination to address transboundary pollution sources. The implementation of stringent air quality standards and policy enforcement particularly in densely populated and industrialized areas will be essential to reducing health risks and achieving sustainable urban growth in Bangladesh.

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