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Status of air quality in Rajshahi metropolitan area, Bangladesh

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Abstract

Rajshahi is well-known as a model city for clean air in Bangladesh but in recent time air pollution is increasing in metropolitan areas. This study aims to examine the concentration of Particulate Matters (PM_1, $PM_{2.5}$, and PM_{10}) in the Rajshahi metropolitan area during March 2021, with a focus on distinct land use categories. The research was carried out in 40 different sites within the Rajshahi metropolitan area, utilizing a portable device for measuring air quality. It was found that the average concentrations of $PM_{2.5}$ and PM_{10} were 56.41 and 72.63 μg/m^3 respectively, which is 2.25 and 1.45-fold than World Health Organizations (WHO) Standards. According to this study, the three locations with the highest levels of $PM_{2.5}$ pollution were the Mohanonda project gate (105.750 μg/m^3), Textile Mill (79.750 μg/m^3), and Sarkar Cold Storage (71.750 μg/m^3). The concentration of $PM_{2.5}$ in the most polluted location was found to be 1.63 times than the standard level set by Department of Environment (DoE) and 4.23 times higher than the WHO standard. Furthermore, it was calculated that the average $PM_{2.5}/PM_{10}$ ratio was 77.70% and the average $PM_1/PM_{2.5}$ ratio was 60.16%. It also revealed that temperature is negatively and humidity is positively correlated with PM_1, $PM_{2.5}$ and PM_{10}, which means any change in the concentration of PM_1, $PM_{2.5}$ and PM_{10} can cause a significant change in the percentage of humidity in the same direction, for humidity the change would be in opposite direction. The concentration of $PM_{2.5}$ in ambient air with respect to land use decreases as follows: industrial area > village area > road intersection area > sensitive area > mixed area > commercial area > residential area.

Keywords: Air Pollution; Particulate Matter; Meteorological Correlation; Rajshahi Metropolitan; Bangladesh.

1. Introduction

Air pollution is a combination of harmful pollutants originating from both anthropogenic and natural origins. It can be characterized as an atmospheric state when the concentrations of several compounds are significantly higher than their usual levels, resulting in a noticeable impact on humans, animals, plants, or materials. The term 'substances' encompasses both natural and synthetic chemical components or molecules that have the ability to exist in the air. [1]. Nowadays, Worldwide air quality become worse and worse due to increase of civilization, urbanization and modernization [2-4]. Air pollution is a prevalent global environmental health problem in the present era. As a result, several types of respiratory diseases have arisen [5]. This poses a significant menace to worldwide well-being and economic progress [6]. Global air pollution, in various manifestations, is accountable for about 6.5 million fatalities annually, a figure that has risen in the last twenty years. Air pollution has been a top concern in Asia and other regions worldwide. Most of the world's pollution, around 91% are being found in the most air polluted places like cities and towns in the world. Air pollution poses the primary environmental hazard to human health in numerous towns and cities [7-9]. Bangladesh ranks first in the Air Quality Report of 2019 and 2020, indicating the highest level of air pollution. Among the world's capital cities, Dhaka city holds the second position [10,11]. Particulate Matter (PM), specifically tiny particles (≤2.5 μm) that do not settle and can remain suspended in the air, are now widely

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acknowledged as a significant component of pollution in the air. Ambient PM_{10} refers to particles that have a size of 10 µm or smaller in terms of their aerodynamic diameter. $PM_{2.5}$ refers to particles that have a size of 2.5 µm or smaller [12,13]. Pollution encompasses the presence of harmful substances in the air, such as fine particulate matter (PM2·5) emitted by power plants, industrial processes, transportation, brick kilns, biomass burning, wind-blown dust, and sea spray. It also includes the presence of ozone, Sulfur and nitrogen oxides, as well as pollution of freshwater by nitrogen, phosphorus, plastic, and petroleum waste. Additionally, pollution involves the contamination of land by lead, mercury, pesticides, industrial chemicals, electronic waste, and radioactive waste [14-18]. The primary sources of $PM_{2.5}$ are particle transformations resulting from chemical reactions in the atmosphere, specifically from the combustion of biomass, gas, and fossil fuels [12,19] and coarse particles, known as PM_{10}, are generated by mechanical activity such as wind-blown dust, grinding, and resuspended road dust [20]. Rajshahi is known as cleaner city in Bangladesh, due to development activity air pollution level being increasing. Rahman et al., 2016 [21] found that $PM_{2.5}$ and PM_{10} concentration found being, 350.47 and 241.13 µg /m^3, surpassed the DoE Standard set for Bangladesh in 2005. The mean $PM_{2.5}$ level was calculated to be 149 µg/m^3 by Begum et al. in 2014. [22] Rajshahi tried to make things better and was able to bring about a change in 2016. Subsequently, Rajshahi provides its citizens with cleaner air and a predominantly dust-free atmosphere. Moreover, it has gained global acclaim for accomplishing the most significant decrease in levels of detrimental PM_{10} particles from 2014 to 2016. The Guardian study praised Rajshahi's effective measures in addressing urban air pollution [23]. Based on statistics provided by the WHO [24], Rajshahi had a significant reduction of 67.2% in the concentration of PM_{10} particles. The concentration decreased from 195 micrograms per cubic meter of air volume (µg/m^3) in 2014 to 64 µg/m^3 in 2016. This represents the most significant decline in PM_{10} concentration on a global scale. The $PM_{2.5}$ concentration decreased by about 50%, from 70 µg/m^3 to 37 µg/m^3. This was made feasible through the implementation of several targeted measures, including the elevation of chimneys in the brick fields adjacent to the city, the implementation of afforestation initiatives, the installation of concrete pavements along the roads, the introduction of battery-operated auto-rickshaws, the enforcement of stringent regulations on diesel-powered vehicles, and other measures [25]. Rajshahi has demonstrated to other towns that air pollution can be diminished with sincere endeavors and collaboration from every stakeholder involved. However, the industrialization in major cities continues to exacerbate air pollution. The primary aim of this study was to evaluate the current air quality in Rajshahi city, specifically focusing on the particulate matter (PM), following the involvement of government policies. Additionally, the study aimed to identify potential local and distant sources of PM in the atmospheric aerosol using particle data.

2. Material and methods

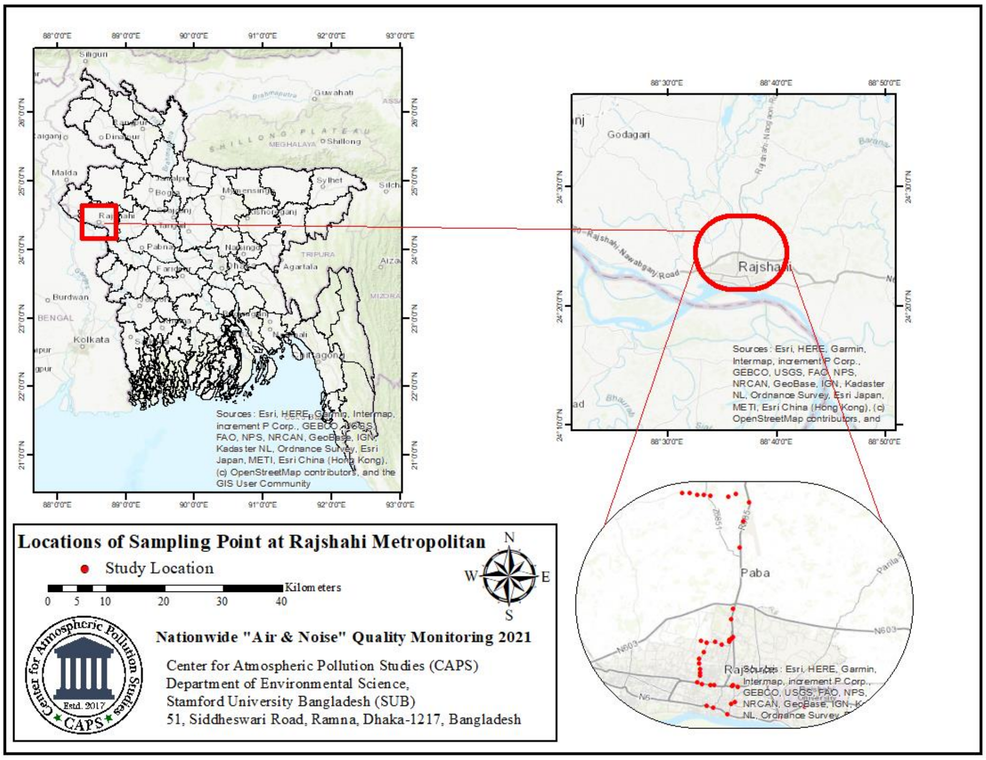

Figure 1 Study Area (Rajshahi Metropolitan area and Data Collection Locations Point)

Rajshahi is located at 24.3746° N, 88.6004° E. In this study, 40 locations were selected on basis of the use of land. After that, all locations were divided according to the use of land into Seven types, which are sensitive (6 locations), residential (5 locations), mixed (5 locations), road intersection (6 locations), commercial (7 locations), industrial (5 locations) and village area (6 locations).

2.1. Data Collection & Analysis

The all-samples sites have been pointed into the study area map. Particulate Matter (PM_1, $PM_{2.5}$ and PM_{10}) were measured for seven days from each location of study area using Air Quality Monitor. After that, collected data were input in an IBM SPSS V26 and MS Excel 2020. Multiple graphs, tables, diagrams, box-whiskers were generated for understating the data nature. Descriptive statistics was also done to know the data nature, done ANOVA for significance test. The results are displayed with various graphs, charts and maps. In the study used ArcGIS 10.7.1. version for preparing our concentration maps and AQI map of Rajshahi Metropolitan area. Different projected locations were used for making concentration maps and AQI map in the GIS. Used different color for understanding the concentration of Map. The equation employed to convert concentration to AQI is as follows:

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low}$$

The highest value obtained from the aforementioned equation for each pollutant is used to determine the AQI when several contaminants are assessed. (EPA, 2018).

Where:
I = the (Air Quality) index
C = the pollutant concentration
C_{low} = the concentration breakpoint that is ≤ C
C_{high} = the concentration breakpoint that is ≥ C
I_{low} = the index breakpoint corresponding to C_{low}
I_{high} = the index breakpoint corresponding to C_{high}

3. Results and discussion

3.1. Concentration of PM_1, $PM_{2.5}$ & PM_{10} in 7 different land use

Figure 2 (a), (b), (c), (d), (e) shows the concentration (µg/m^3) of PM_1, $PM_{2.5}$ and PM_{10} of locations in sensitive, residential, mixed, road intersection and commercial areas in the Rajshahi Metropolitan area. Sensitive areas include administrative office, schools, colleges, mosques and universities. It can be seen that out of six sensitive locations, three highly contaminated places were Rajshahi Development Authorities, Rajshahi University and Rajshahi Women Technical Training Center with $PM_{2.5}$ concentration of 60, 55.5 and 53.75 µg/m^3 respectively and comparatively less contaminated places were Engineer's Institution Bangladesh, Masjid-e Noor Complex and Nahar Academy School & College with the $PM_{2.5}$ concentration of 46.25, 50.75, 52.25 µg/m^3. In all the levels of $PM_{2.5}$ and PM_{10} were remain within the permissible limit (65 µg/m^3 and 150 µg/m^3) set by Department of Environment (DoE) except WHO standard level. However, the concentrations of $PM_{2.5}$ and PM_{10} found in the most contaminated location were 2.4 and 1.58 times higher than WHO standard level which is 25 and 50 µg/m^3. Study also found that among 5 residential locations, three highly contaminated places were Christian Para, Thanar moor and Tanzimul Ummah Hafez Madrasa with the $PM_{2.5}$ concentration of 61.25, 51.75, 51.50 µg/m^3 respectively and least contaminated places were Cantonment and Uposhohor 2 no. sector with the $PM_{2.5}$ concentration of 45.50 and 46.50 µg/m^3 respectively. Noted that in the residential areas, concentrations of $PM_{2.5}$ and PM_{10} found to be 2.45 and 1.59 times higher than WHO standard level in the most contaminated location. The residential area values are less than DoE Standard due to implementation of initiative to reduce air pollution. A plan called 'zero soil' initiated by Rajshahi Metropolitan area planted a lot of greenery with some other management activities might have contributed to relatively clean air of Rajshahi [25]. It is shown that among five mixed locations, two highly contaminated places was Police Commissioner Office and Bowlia with the $PM_{2.5}$ concentration of 57 and 52.25 µg/m^3 respectively. Relatively less contaminated places among mixed areas were Sona Deghi, Maida Colony and Agriculture Development Corporation with the $PM_{2.5}$ concentration of 51.50, 50.75 and 43 µg/m^3 respectively.

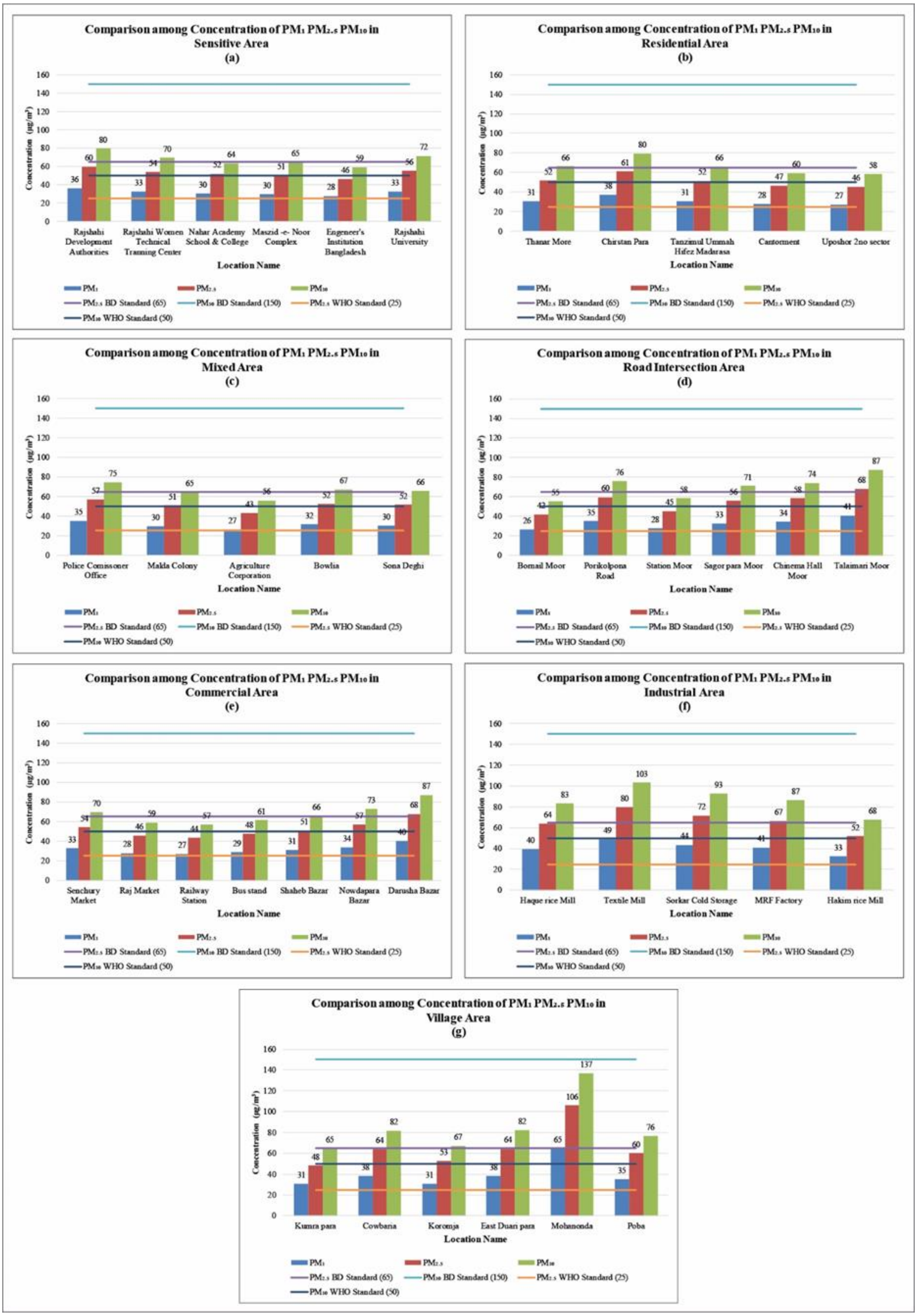

Figure 2 Comparison among PM_1, $PM_{2.5}$ and PM_{10} in Seven Land use of Rajshahi Metropolitan area

However, the concentrations of $PM_{2.5}$ was 2.28 times and PM_{10} was1.49 times higher than WHO standard level, found in the most contaminated location. It has been collected that out of six road intersection locations, most polluted place was Talaimari moor (67.75 μg/m^3) on the basis of $PM_{2.5}$ concentration followed by two more contaminated places were Porikolpona road mor and Chinema hall moor with the $PM_{2.5}$ values of 59.50 and 58.25 μg/m^3 accordingly. Where comparatively less contaminated places were Sagor para moor, Station moor area and Bornali moor with $PM_{2.5}$ concentration of 56, 45.25 and 42 μg/m^3 accordingly. The concentration of $PM_{2.5}$ and PM_{10} were found lower in all study area where the concentration did not exceed the DoE standard level except in Talaimari moor, where the concentration of $PM_{2.5}$ was just above the DoE standard which is 65 μg/m^3. Local sources dominate coarse particles, according to the Begum study [26]. Nevertheless, the levels of $PM_{2.5}$ and PM_{10} detected in the most contaminated area exceeded the WHO standard 2.71 and 1.75 times, respectively. The municipal authorities-imposed restrictions on the use of diesel and petrol vehicles on the roadways due to their contribution to air pollution. [25]. The city introduced battery-powered rickshaws and prohibited heavy vehicles from operating in the city center during the day. These methods lowered petrol and diesel fumes emitted by older, more polluting automobiles, as well as carbon emissions. In cities, mixed-use zones with motorized traffic exhibited higher $PM_{2.5}$ concentrations than regions without motorized traffic. [4]. Air pollution was subdued because many electric and gas-powered vehicles have replaced in the city. It is found that out of seven commercial locations, Darusha Bazar where the $PM_{2.5}$ was above the DoE standard level where other places (Nowdapara bazar, Century market area, Railway station and Raj market & Bus stand) less than DoE standard level but higher than WHO standard level.

In studied areas, selected five industrial locations demonstrate in figure 2 (f), three polluted places were Textile Mill, Sarkar cold storage and MRF Factory with $PM_{2.5}$ concentration of 79.75, 71.75 and 66.75 μg/m^3 respectively and relatively less contaminated places were Hakim Rice Mill and Haque Rice Mill. The levels of $PM_{2.5}$ and PM_{10} concentrations were measured in two study locations and determined to be below the standard threshold. On the other side in Textile Mill, besides Sarkar cold storage and MRF Factory where the concentration of $PM_{2.5}$ was above the standard which is 1.22. Even so, the levels of $PM_{2.5}$ and PM_{10} detected in the most polluted area exceeded the WHO limit by about three and two times, respectively. In order to mitigate pollution, the brick kilns and heavy industries were strategically located at a considerable distance from Rajshahi City. Additionally, the existing brick kilns were enhanced with improved chimneys [27]. These types of management might have made some places pollution free but not all of them. Figure 2 (g) illustrates the concentration (μg/m^3) of PM_1, $PM_{2.5}$ and PM_{10} of some locations in village areas in the Rajshahi Metropolitan area. It has been found that out of 6 village locations, polluted place was Mohanonda area (64.50, 105.75 and 136.75 μg/m^3) and the least contaminated place was Kumra para-area (30.50, 48 and 64.5 μg/m^3). It was also mentioned that the concentration of $PM_{2.5}$ found in most polluted location was 1.62 times higher than DoE level. Moreover, $PM_{2.5}$ and PM_{10} concentrations in the highest polluted place were approximately four and three times higher than WHO standard level. Study found the average concentration of PM_1, $PM_{2.5}$ and PM_{10} were found higher in industrial and village area with the values of 41.05, 66.75 and 86.60 μg/m^3 and 39.46, 65.75 and 84.71 μg/m^3 where highest in industrial area. Nevertheless, the concentration was found comparatively less high in position in mixed, residential and sensitive area. Moreover, the average concentration of PM_1 (30.65 μg/m^3), $PM_{2.5}$ (50.90 μg/m^3) and PM_{10} (65.65 μg/m^3) were found to be least in mixed area.

3.2. Dispersion of PM_1, $PM_{2.5}$ & PM_{10}

Table 1 Descriptive Statistics for PM_1, $PM_{2.5}$ and PM_{10}

S. N.	Land Use	Number of Locations	PM_1				$PM_{2.5}$				PM_{10}			
			Range (μg/m^3) (Min-max)	Mean (μg/m^3)	Std. Deviation (μg/m^3)	Coefficient of Variation (%)	Range (μg/m^3) (Min-max)	Mean (μg/m^3)	Std. Deviation (μg/m^3)	Coefficient of Variation (%)	Range (μg/m^3) (Min-max)	Mean (μg/m^3)	Std. Deviation (μg/m^3)	Coefficient of Variation (%)
1	SA	6	8.5	31.5	3.0	9.4	13.8	53.1	4.6	8.7	20.3	68.0	7.2	10.5
2	MA	5	8.8	30.7	3.2	10.3	14.0	50.9	5.0	9.9	18.5	65.7	6.6	10.1
3	RA	5	10.3	30.8	4.1	13.3	15.8	51.3	6.2	12.2	21.3	65.9	8.4	12.8
4	RIA	6	14.5	32.8	5.3	16.2	25.8	54.8	9.6	17.5	32.3	70.2	11.9	17.0
5	CA	7	13.5	31.5	4.6	14.7	24.0	52.3	8.2	15.7	30.3	67.4	10.4	15.4
6	IA	5	16.3	41.1	5.9	14.5	28.0	66.8	10.3	15.5	35.8	86.6	13.1	15.1
7	VA	6	34.0	39.5	12.7	32.2	57.8	65.8	20.6	31.3	72.3	84.7	26.5	31.3

SA-Sensitive area, MA-Mixed area, RA-Residential area, RIA- Road Intersection Area, CA-commercial area, IA-Industrial area and VA-Village Area

The above table 1 shows the descriptive statistics for PM_1, $PM_{2.5}$ & PM_{10} of the studied seven land uses. The highest ranges were found for PM_1, $PM_{2.5}$ and PM_{10} in village area (34, 57.75 and 72.25 μg/m^3) however lower ranges were found in sensitive area (8.5 and 13.8 μg/m^3) for PM_1 and $PM_{2.5}$ but for PM_{10} lower range found in mixed area (18.5 μg/m^3).

The study indicated that the industrial region had the highest mean values for particulate matter concentration, with values of 41.05, 66.75, and 86.60 μg/m^3. The village area had slightly lower mean values of 39.5, 65.8, and 84.7 μg/m^3. The sensitive and mixed areas had even lower mean values. Among all those land uses, though the PM_1, $PM_{2.5}$ and PM_{10} the minimum concentration (26.25, 42 and 55 μg/m^3) was found in road intersection area but the maximum value was found in the village area. Again, highest coefficient of variation was seen in village area which were 32.2%, 31.3% and 31.3% for PM_1, $PM_{2.5}$ and PM_{10} respectively and the lowest was seen in sensitive area which were 9.4%, 8.7% and 10.5%. Nevertheless, the variation found in village area more and less in the sensitive area.

3.3. Whisker box plot of concentration for PM_1, $PM_{2.5}$ and PM_{10} in Different Land use

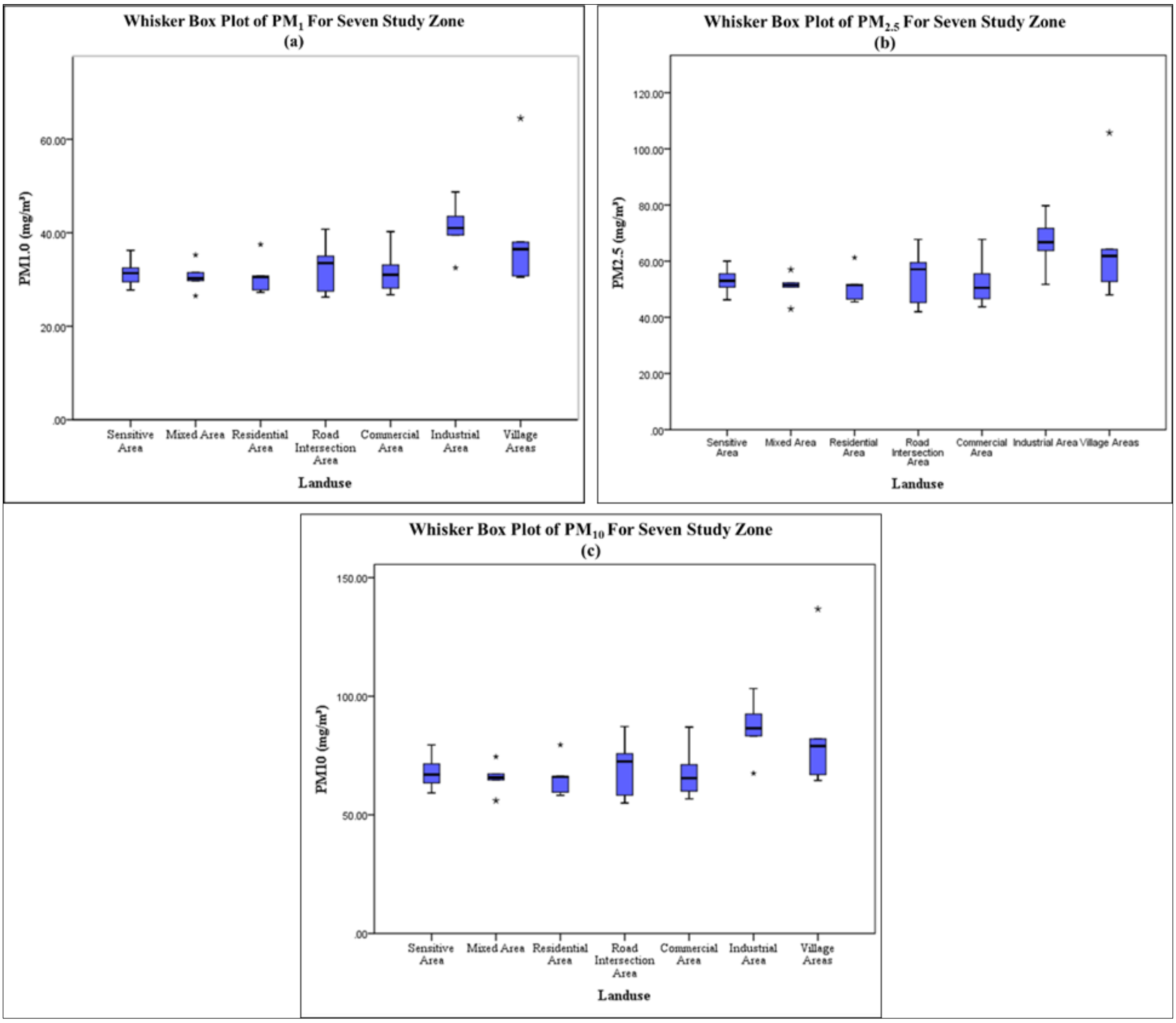

Figure 3 Whisker box plot showing the concentration of PM_1, $PM_{2.5}$ & PM_{10} in Different Land use

Figures 3 (a), (b), and (c) illustrate the average concentrations of PM_1, $PM_{2.5}$ and PM_{10} in seven different land uses using a whisker box plot. The median is shown by a horizontal black line inside the box. The bottom limit of the box represents the 25th percentile, while the top boundary represents the 75th percentile. The whisker represents the maximum (upper whisker) and minimum value (lower whisker) for each land use. Whisker box plot revealed that road intersections had most dispersed concentration with negative skewness. The later dispersed concentration was found in village area and commercial area in contrast to the findings form descriptive analysis. The coefficient of variation was found high due to the presence of one distant outlier. Industrial area has medium dispersion with one outlier. The values of mixed area are tightly clustered with two outliers in both sides. This outcome is also different from descriptive analysis due to the presence of outlier in missed area where sensitive area had the least variation. Meanwhile the later higher dispersion was found in village area with one distant outlier and commercial area respectively. Due to that outlier the variation was found high and the reason behind this outlier might be burning of homestead and agricultural wastages.

3.4. Significance Test

Table 2 represents the analysis of variance (ANOVA) results for the significance test. An ANOVA analysis is conducted to determine the significance of the concentration variations in all parameters, both between and within different land uses. The F values obtained were 2.521 for PM_1, 2.239 for $PM_{2.5}$, and 2.349 for PM_{10}. The p-values for the PM_1, $PM_{2.5}$ and PM_{10} were 0.040, 0.064, and 0.053. The following table shows that the concentrations of PM_1 changes significantly as the p value are less than 0.05. Therefore, the concentration of PM_1 might change significantly between and within in the land uses. $PM_{2.5}$ and PM_{10} do not changes significantly as the p value are greater than 0.05.

Table 2 Significance Test by ANOVA

ANOVA of PM_1					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	627.394	6	104.566	2.521	0.040
Within Groups	1368.854	33	41.480		
Total	1996.248	39			
ANOVA of $PM_{2.5}$					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1539.149	6	256.525	2.239	0.064
Within Groups	3780.225	33	114.552		
Total	5319.373	39			
ANOVA of PM_{10}					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2681.130	6	446.855	2.349	0.053
Within Groups	6278.488	33	190.257		
Total	8959.619	39			

3.5. Land Use Based Cluster Analysis

Figures 4 (a), (b), and (c) illustrate the dendrogram plot resulting from cluster analysis using Z-score normalization for the Particulate Matters. In this analysis, the average connectivity between groups has been taken into account. Three clusters have been found from for PM_1, $PM_{2.5}$ and PM_{10} Graph. Here, for PM_1 first cluster is consisted of sensitive, commercial, mixed and residential area, second cluster consisted of road intersection alone and; third cluster includes industrial and village area. The first and second clusters converge at a distance of approximately 5 unit. This larger cluster merges with the third cluster at a distance of around 25 unit. On the other hand, for $PM_{2.5}$ first cluster is consisted of mixed, residential, sensitive and commercial area, second cluster consisted of road intersection alone and third cluster includes industrial and village area. First and second clusters join at the approximate distance of 5. This broader cluster joins with third cluster at the approximate distance of 25. And for PM_{10} first cluster is consisted of mixed, residential, sensitive and commercial area, second cluster consisted of road intersection alone and third cluster includes industrial and village area. The first and second clusters converge at a distance of approximately 5 unit. These broader cluster joins with third cluster at the approximate distance of 25.

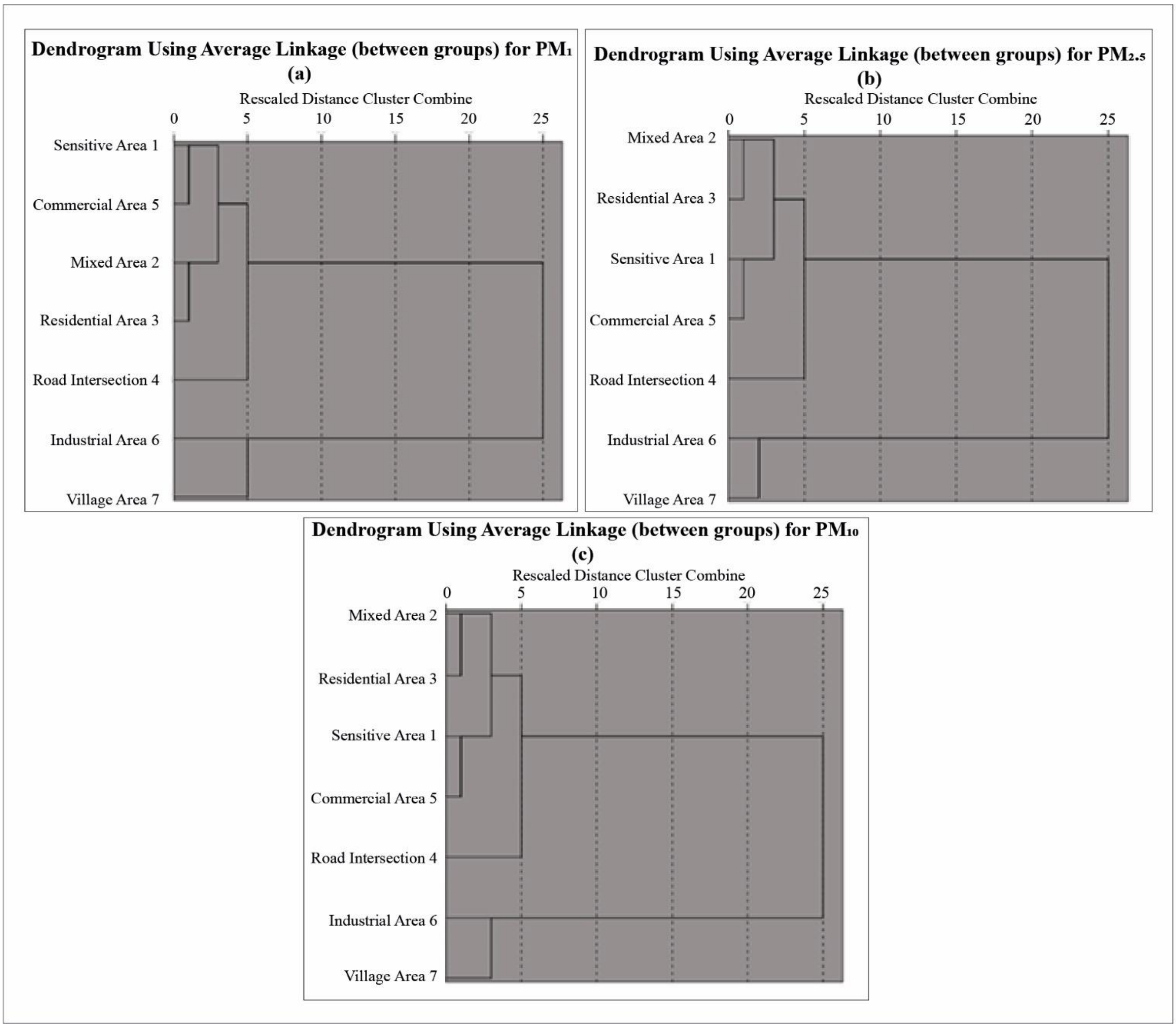

Figure 4 Land Use Based Cluster Analysis for PM_1, $PM_{2.5}$ and PM_{10}

3.6. Correlation between Particulate Matters (PM_1, $PM_{2.5}$ and PM_{10}) and Meteorological Parameter

Pearson correlation coefficient in table 3 shows that there are weak and insignificant relationships existing between all three PM_1, $PM_{2.5}$ and PM_{10}. On the other hand, the two environmental parameters' temperature and humidity significantly (alpha level 0.01) correlated with all the PM_1, $PM_{2.5}$ and PM_{10}. However, the strength of the both relations is moderate; temperature is negatively and humidity is positively correlated with PM_1, $PM_{2.5}$ and PM_{10}, which means any change in the concentration of PM_1, $PM_{2.5}$ and PM_{10} can cause significant change in the percentage of humidity in same direction, for temperature the change would be in opposite direction. Razib et al., 2020 [28] found relationship between $PM_{2.5}$ and Meteorological parameters at Dhaka city. Study found that, $PM_{2.5}$ had weak relationship with humidity and temperature. Here, two environmental parameters' temperature and humidity are found to be significantly (alpha level 0.01) negatively correlated and the strength of correlation is very strong. It means that if temperature fluctuates humidity will be decreased or increased significantly. At the end, it can be said that these studied air pollutants can significantly change the two important environmental parameters.

Table 3 Correlation among PM_1, $PM_{2.5}$ and PM_{10} and Selected Meteorological Parameters

		PM_1	**$PM_{2.5}$**	**PM_{10}**	**Temperature**	**Humidity**
PM_1	Pearson Correlation	1	0.995**	0.998**	-0.532**	0.572**
	Sig. (2-tailed)		0	0	0	0
	N	40	40	40	40	40
$PM_{2.5}$	Pearson Correlation	0.995**	1	0.998**	-0.534**	0.576**
	Sig. (2-tailed)	0		0	0	0
	N	40	40	40	40	40
PM_{10}	Pearson Correlation	0.998**	0.998**	1	-0.539**	0.580**
	Sig. (2-tailed)	0	0		0	0
	N	40	40	40	40	40
Temperature	Pearson Correlation	-0.532**	-0.534**	-0.539**	1	-0.954**
	Sig. (2-tailed)	0	0	0		0
	N	40	40	40	40	40
Humidity	Pearson Correlation	0.572**	0.576**	0.580**	-0.954**	1
	Sig. (2-tailed)	0	0	0	0	
	N	40	40	40	40	40

** Correlation is significant at the 0.01 level (2-tailed).

3.7. Concentration Map on PM_1, $PM_{2.5}$, PM_{10} and AQI map of Rajshahi Metropolitan area in 2021

Figure 5 (a, b and c) show the concentration of Particulate Matter (PM_1, $PM_{2.5}$ and PM_{10}) at various location of Rajshahi Metropolitan area in the year of 2021. Concentrations of Particulate Matter (PM_1, $PM_{2.5}$ and PM_{10}) are expressed in $\mu g/m^3$. The concentration of $\mu g/m^3$ mean one millionth of gram of PM_1, $PM_{2.5}$ and PM_{10} per cubic meter air. Yellow areas have less, while progressively higher concentrations are shown in orange and red. Concentration of PM_1, $PM_{2.5}$ and PM_{10} was found to higher in Noahata Pourashava, some part of 17, 24, 25 no ward. Also shows that PM_1, $PM_{2.5}$ and PM_{10} Concentrations were found lower in 4, 5, 6, 7, 15, 16 and 17 no ward of Rajshahi Metropolitan area.

Figure 5 (d) shows the Rajshahi Metropolitan area based on $PM_{2.5}$ concentration. In this map different color represent the category of AQI according to Bangladesh National Ambient Air Pollution Standard. Map shows that AQI was high which is indicating in orange color and caution conditions were shown in yellow color except center part of 17, east part of 25 no

Ward and some part of Noahata Pourashava are; all the area was found in caution condition where the AQI was (101-150) which indicated by yellow colour. Caution conditions means people who are vulnerable due to air pollution need to take some prevention when they are going outside from the home.

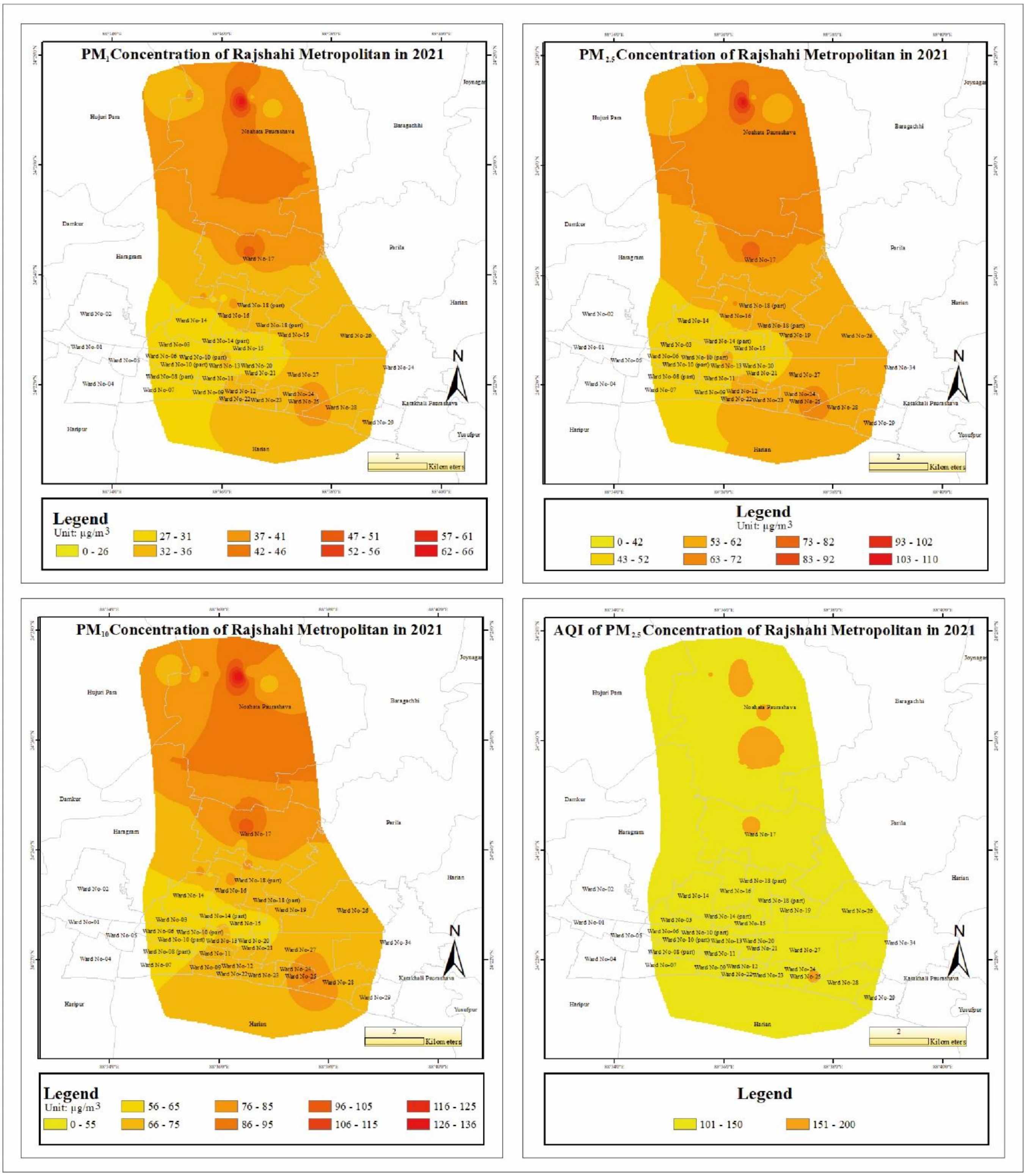

Figure 5 Concentration Map of PM_1, $PM_{2.5}$, PM_{10} and AQI map on $PM_{2.5}$ Concentration of Rajshahi Metropolitan area in 2021

4. Conclusion

Air pollution in Rajshahi city hasn't reached on alarming level but in concerning level. Spatial pattern analysis of PM data is important for source identification. This study found that the average concentration of PM_1, $PM_{2.5}$ and PM_{10} of selected place in Rajshahi Metropolitan area found to be 33.95, 56.41 and 72.63 µg/m^3 respectively which was 2.25 and

1.45 times higher than WHO standard level respectively. The land uses evaluated in this research are ranked in descending order according to their average concentration of $PM_{2.5}$. The ranking are as follows: industrial area > village area > road intersection area > sensitive area > mixed area > commercial area > residential area. There are three highly polluted areas in the Rajshahi Metropolitan region in terms of $PM_{2.5}$ levels. These areas are Mohanonda (105.750 μg/m^3), Textile Mill (79.750 μg/m^3), and Sorkar Cold Storage (71.750 μg/m^3). The concentrations of $PM_{2.5}$ in the most polluted area were found to be 1.63 times higher than the Bangladesh National Ambient Air Quality Standards (BNAAQS) established at 65 by the Department of Environment (DoE). The dispersion of PM_1, $PM_{2.5}$, and PM_{10} varied significantly across different land uses. The highest range was seen in village, industrial, road intersection, and commercial areas, while the lowest range was identified in sensitive areas, mixed areas, and residential areas. It was discovered that the standard deviation and coefficient of variation are larger in the village area when examining the dispersion of particulate matter among different land uses. The dendrogram plot for PM_1, $PM_{2.5}$, and PM_{10} reveals that each plot has a minimum of 3 clusters, and these two clusters merge at an estimated distance of 25. In order to mitigate air pollution in the Rajshahi Metropolitan region, it is advised that the pertinent authority prioritize the dissemination of information to the public regarding the detrimental impacts of air pollution. Additionally, prompt measures should be taken to minimize the health hazards associated with air pollution. In addition, enhancing traditional cooking stoves, employing chimneys to mitigate industrial emissions, and shielding construction materials while in use.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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