



Spatial distribution of atmospheric particulate matter (PM₁, PM_{2.5}, and PM₁₀) in the Dhaka Metropolitan area, Bangladesh

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Abstract

Particulate Matters (PM) is one of the serious problems in Dhaka metropolitan area. The main causes of particulate matter in Dhaka City include vehicle emissions, industrial activity, construction dust, continuous development projects, as well as biomass and garbage burning. In the Dhaka metropolitan area, the purpose of this study is to monitor the concentration of particulate matter (PM₁, PM_{2.5}, and PM₁₀) based on the different land uses that are there. Using a portable Air Quality Monitor this research was carried out in seventy different places within the metropolitan area of Dhaka. It is found that average concentrations of PM₁, PM_{2.5}, and PM₁₀ of 70 places in Dhaka metropolitan were 153.28, 252.96 and 326.93 µg/m³ respectively. The mean concentration of PM_{2.5} and PM₁₀ across all land use types was found to be 3.89 and 2.18 times greater than the National Ambient Air Quality Standards (NAAQS) limit. It is estimated that the average PM_{2.5}/PM₁₀ was 75.45%, PM₁/PM_{2.5} was 62.74%. The concentrations of all examined parameters within land uses did not change significantly. Additionally, it figured out that Suvastu Arcade, Elephant Road was most polluted place with the PM₁, PM_{2.5}, and PM₁₀ concentrations of 287.25, 300 and 605.33 µg/m³ respectively which is 4.61 and 4.03 folds higher than NAAQS level. At last, it has been found that the average concentration of PM₁, PM_{2.5}, and PM₁₀ becomes greater from commercial to residential to mixed to industrial to sensitive areas.

Keywords: Particulate matter, comparison, distribution, whisker, Dhaka metropolitan area

Introduction

One of the precious natural resources that is mandatory for every life and without which no one would be able to thrive is air. But this crucial element of nature getting polluted through our day-to-day life work. Now the air pollution is a worldwide concern threatening cities all around the entire globe and traverses' geographical borders^[1]. Based on data from the World Health Organization (WHO), approximately 99% of the global population inhales air that is highly polluted and beyond the guideline limits set by the WHO. This issue is particularly prevalent in low- and middle-income nations, where the levels of air pollution are the highest^[2]. Cities throughout the world have seen an upward trend in air pollution in recent decades due to factors like industrialization, urbanization, and increased vehicle traffic^[3]. In cities fossil fuel combustion, particularly the burning of coal, gasoline, and diesel contributes enormously to the global burden of disease and mortality by emitting fine particulate matter (PM_{2.5}) into the atmosphere^[4]. Bangladesh become the top polluted country in the world while Dhaka ranked as the 2nd most polluted city^[5]. Bangladesh and other countries in Southeast Asia have the third-highest risk of premature death due to air pollution^[6]. The number of deaths that can be attributed to air pollution in Bangladesh has increased from 123,000 in 2017 to 173,500 in 2019^[7]. Air pollution in Bangladesh has related to five out of the top 10 fatal diseases, especially lung cancer (13%), lower respiratory tract infection (7%), chronic obstructive pulmonary disorders (7%), ischemic heart disease (6%), and stroke (5%).^[8] In Bangladesh specially in Dhaka city, indoor

and ambient air pollution can be attributed to several factors, including fast urbanization, car emissions, industrialization, brick kilns, burning biomass, transboundary air pollution, etc.^[9]. According to IQAir report 2023^[5], the average PM_{2.5} concentration of Dhaka was recorded 80.2 µg/m³ that was 16.04 times higher than the World Health Organization (WHO) standards. The air pollution in Dhaka is mainly brought about by unplanned urbanization and pollutants from massive construction projects which are dealing with the needs of growing population^[10]. The number of automobiles in Dhaka has increased along with the city's population expansion during the last decade, which has increased air pollution^[11]. The seasonal variation is also responsible for this increasing amount of pollution. Winter had the highest concentrations of PM_{2.5} attributed to some activities like burning biomass and less rainfall while the monsoon had lower level of concentration in Dhaka^[12]. Rahman *et al.*, 2023 found that in Dhaka, sources of PM_{2.5-10} were primarily from dust, accounting for over 38% of the total^[13]. This increasing air pollution of Dhaka is continuously endangering public health and degrading the environment^[14]. Enhancing the environment should also be prioritized more in order to continue reaching both the sustainable development goals and the millennium development goals. An efficient environmental management system and implementable policies can be the only strategy obtainable for controlling and mitigating the degradation of environmental quality. The research aims to assess the present-day state of air pollution in the Dhaka Metropolitan area, analyze the statistical relationship between land use and several parameters (PM₁,

PM_{2.5}, and PM₁₀), and then generate geospatial maps illustrating the concentration of PM₁, PM_{2.5}, and PM₁₀.

Methodology

This study took place in Dhaka metropolitan area, which is located at 23.8103° N, 90.4125° E. For this study, 70 locations grouped under five types of land use namely, sensitive, residential, mixed, commercial and industrial had been selected (Figure 1). Four individuals' data of particulate matters (PM₁, PM_{2.5} and PM₁₀) were collected from each location of study area using Air Quality Monitor, Indoor Outdoor Formaldehyde (HCHO) Detector. After that IBM

SPSS V20 and MS Excel 2020 were used to process and analyze the data and ArcGIS version 10.8 was used to produce maps.

Table 1: Number of samples based on land use (study area)

S.N.	Land Use Types	Number of the Study
1.	Sensitive Areas	10
2.	Mixed Areas	20
3.	Residential Areas	20
4.	Commercial Areas	15
5.	Industrial Areas	5
	Total	70

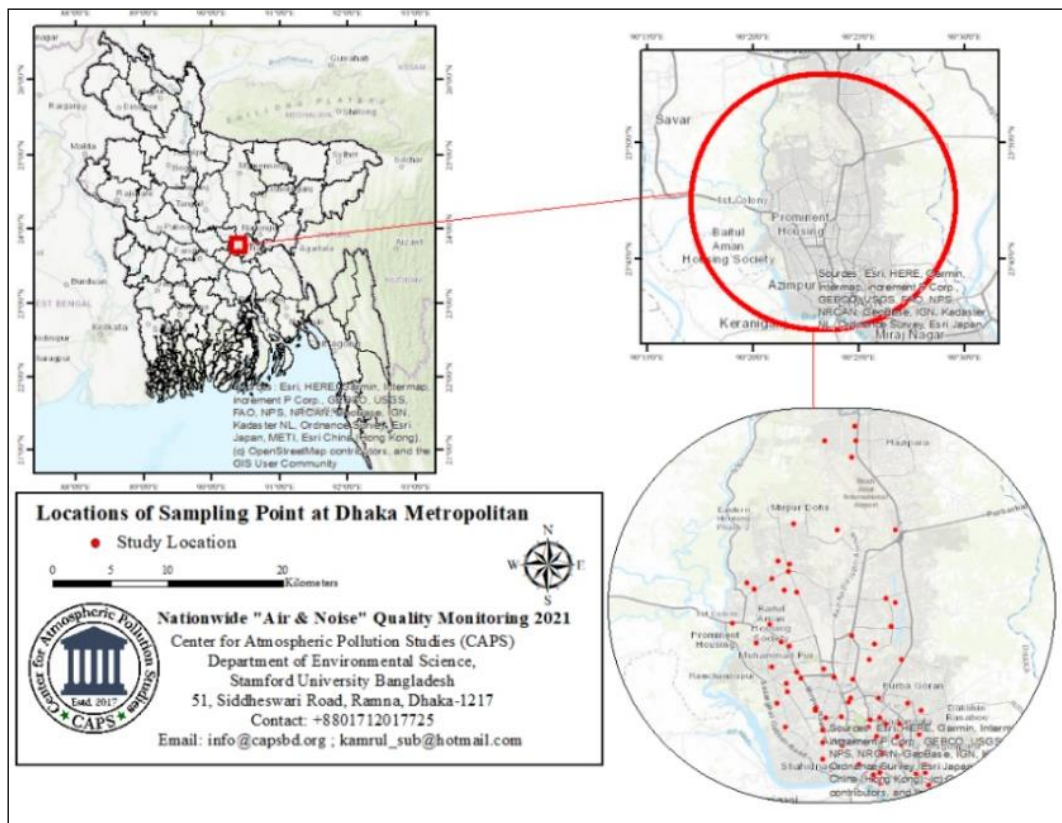


Fig 1: Study Area (Dhaka Metropolitan Area and Data Collection Locations Point)

Result and Interpretation

2.1 Statistical analysis of PM₁, PM_{2.5}, and PM₁₀ values among 5 distinct land use categories

The levels of particulate matter (PM) in the Dhaka metropolitan region are depicted in Figure 2 (a), (b), (c), (d), (e), and (f) in terms of micrograms per cubic meter. The values displayed were measured in sensitive, mixed, residential, commercial, and industrial areas. The sensitive area encompasses offices, educational establishments, religious organizations, and hospitals, among others. As we could see, among these 10 sensitive locations, three highly polluted places were 5 no. gate of Bangabandhu Sheikh Mujib Medical University Hospital (BSMMU), main gate of Mugda Medical College and Hospital and adjacent area of Dhaka Shishu Hospital with PM₁, PM_{2.5} and PM₁₀ concentration of 121.50, 206.75 and 265.25 µg/m³, 109.75, 175.50 and 230.25 µg/m³ and 104.25, 175.75 and 224.75 µg/m³ respectively and comparatively less polluted places were ICDDR'B of Mohakhali (70.50, 115.50 and 149.50 µg/m³), in front of Kallyanpur Girls' High School (75.25, 123.75 and 159.75 µg/m³) and main gate of Shahjalal avenue (77.00, 127.50 and 164.25 µg/m³). Therefore, the most

polluted location was 5 no. gate of Bangabandhu Sheikh Mujib Medical University Hospital (BSMMU) and the less polluted was ICDDR'B of Mohakhali. However, the concentrations of PM_{2.5} found in the polluted location were 1.78 to 3.18 times higher than the NAAQS limit which is 65 µg/m³ set by the Department of Environment (DoE). The concentration of PM₁₀ of the most polluted place was also 1.77 times higher than NAAQS which is 150 µg/m³. In mixed area, out of 20 location, three most polluted places based on PM₁₀ concentration were Gulshan 2 circle (531.25 µg/m³), Gulistan bus stop (492.25 µg/m³) and Sayedabad circle (477.50 µg/m³) and three most polluted locations based on PM_{2.5} were Shanti Nagar (346.00 µg/m³), English road (335.50 µg/m³) and Jatra Bari (319.75 µg/m³) respectively. Comparatively less polluted places were BGB Cinema Hall (120.50, 206.75 and 262.00 µg/m³), main gate of Mascot Plaza (130.00, 209.50 and 273.25 µg/m³) and Farmgate Police Box (131.75, 210.00 and 275.25 µg/m³). However, the concentrations of PM_{2.5} and PM₁₀ found in the polluted location were respectively 3.18 to 5.32 and 1.75 to 3.54 times higher than that of NAAQS level.

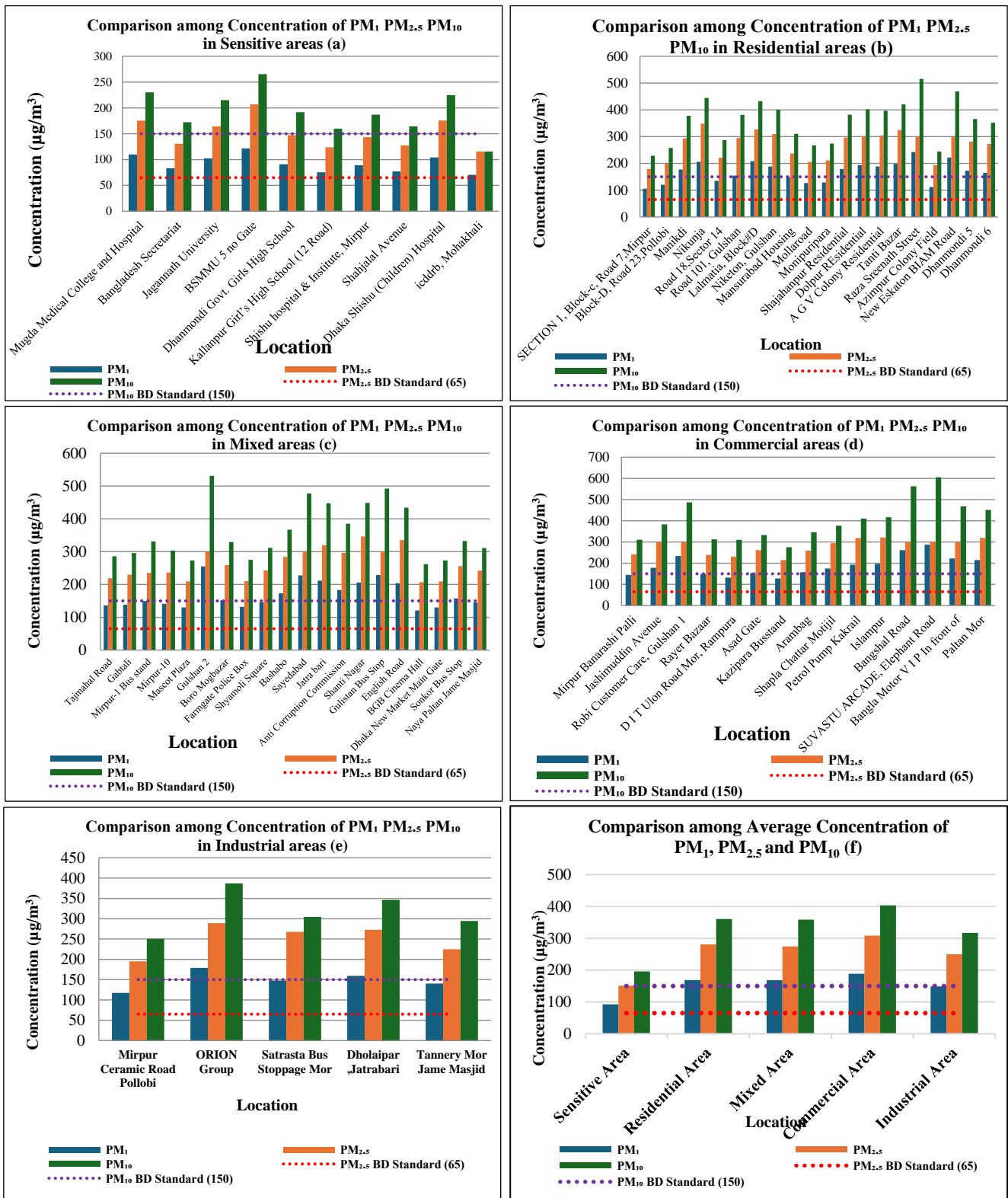


Fig 2: Comparison among Concentration of PM₁, PM_{2.5} and PM₁₀ in Sensitive, Mixed Area, Residential area, Commercial area and Industrial area

Among selected 20 residential places, three most polluted places according to PM₁₀ concentration were Raza Sreenath street (with the PM₁, PM_{2.5}, and PM₁₀ concentration of 242.25, 300 and 515.50 µg/m³), New Eskaton BIAM road (with the PM₁, PM_{2.5}, and PM₁₀ concentration of 222, 300 and 468.50 µg/m³) and Nikunja (with the PM₁, PM_{2.5}, and PM₁₀ concentration of 205.75, 348.50 and 444.25 µg/m³) respectively and three highly polluted places according to PM_{2.5} were Nikunja (with the PM₁, PM_{2.5}, and PM₁₀

concentration of 205.75, 348.50 and 444.25 µg/m³), Lalmatia, Block #D (with the PM₁, PM_{2.5}, and PM₁₀ concentration of 208.25, 327.00 and 432.25 µg/m³) and Tanti bazar (with the PM₁, PM_{2.5}, and PM₁₀ concentration of 198.25, 324.00 and 420.25 µg/m³) comparatively less polluted places were Section-1, Block-C, Road-7, Mirpur (with the PM₁, PM_{2.5}, and PM₁₀ concentration of 105.75, 179.00 and 228.75 µg/m³), Azimpur Colony Field (with the PM₁, PM_{2.5}, and PM₁₀ concentration of 111.75, 193.00 and

244.00 $\mu\text{g}/\text{m}^3$) and Block-D, Road-23, Pollobi (with the PM_{10} , $\text{PM}_{2.5}$, and PM_{10} concentration of 120.25, 200.75 and 257.75 $\mu\text{g}/\text{m}^3$) respectively. However, the concentrations of $\text{PM}_{2.5}$ and PM_{10} found in the polluted location were 2.75 to 5.36 and 1.53 to 3.44 times higher than NAAQS level which is 150 $\mu\text{g}/\text{m}^3$. In this study, out of 15 commercial places, three most polluted places according to $\text{PM}_{2.5}$ were Islampur (197.00, 321.00 and 416.75 $\mu\text{g}/\text{m}^3$), Paltan circle (214.75, 319.50 and 451.25 $\mu\text{g}/\text{m}^3$) and Petrol Pump Kakrail (192.75, 318.00 and 410.50 $\mu\text{g}/\text{m}^3$) where comparatively less polluted places were Kazipara bus stand DIT Ulon Road circle, Rampura and Mirpur Banarashi Palli with the PM_{10} , $\text{PM}_{2.5}$, and PM_{10} concentration of 127.75, 214.50 and 275.25 $\mu\text{g}/\text{m}^3$, 132.00, 231.00 and 310.00 $\mu\text{g}/\text{m}^3$ and 144.75, 242.00 and 310.50 $\mu\text{g}/\text{m}^3$ respectively. However, the concentrations of $\text{PM}_{2.5}$ found in the polluted location were 3.3 to 4.94 times and PM_{10} found were 1.84 to 4.04 times higher than NAAQS level. Growth in the population comes with an increase in larger demand for earnings as well as a boom across all industries. The high levels of pollution in Dhaka can be explained by the rapid, unplanned and environmentally unfriendly industries, with thousands of harmful air pollutants. The ORION Group, along with the PM_{10} , $\text{PM}_{2.5}$, and PM_{10} concentrations of 179.00, 289.00, and 387.00 $\mu\text{g}/\text{m}^3$, was found to be highly polluted in 5 selected industrial places. Dholaipar and Jatra Bari MOR, with the PM_{10} , $\text{PM}_{2.5}$, and PM_{10} concentrations of 159.50, 272.75, and 346.50 $\mu\text{g}/\text{m}^3$, respectively, ranked

second. Satrasta bus stoppage mor had PM_{10} , $\text{PM}_{2.5}$, and PM_{10} concentrations of 147.75, 267.75, and 304.5 $\mu\text{g}/\text{m}^3$, respectively. The places with slightly lower pollution levels were Mirpur Ceramic Road Pollobi and Ternary mor Jame Mosque, with PM_{10} , $\text{PM}_{2.5}$, and PM_{10} levels reaching 117.25, 195.00, and 250.75 $\mu\text{g}/\text{m}^3$, and 140.5, 224.75, and 294.50 $\mu\text{g}/\text{m}^3$, respectively. However, the concentrations of $\text{PM}_{2.5}$ found in the polluted location were 3 to 4.45 times and PM_{10} found were 1.67 to 2.58 times higher than Bangladesh NAAQS level. However, the study estimated that in Industrial places, 79.08% of $\text{PM}_{2.5}$ was present in PM_{10} and 59.65% of the PM_{10} was present in $\text{PM}_{2.5}$. The figure 2 (f) shows the comparison of the average concentration of PM_{10} , $\text{PM}_{2.5}$, and PM_{10} of five lands uses in Dhaka metropolitan. Study found that the average concentration of PM_{10} , $\text{PM}_{2.5}$ and PM_{10} was higher in commercial area, residential area and mixed area with the values of 188.38, 308.53 and 403.26 $\mu\text{g}/\text{m}^3$, 168.58, 280.95 and 360.39 $\mu\text{g}/\text{m}^3$ and 168.26, 274.48 and 358.39 $\mu\text{g}/\text{m}^3$ respectively. The average concentration of $\text{PM}_{2.5}$ and PM_{10} found in the most polluted area were 4.75 and 2.69 times higher than NAAQS level. Moreover, the concentration was found relatively lower in sensitive areas and industrial areas. It was further found that the average concentration of PM_{10} (92.38 $\mu\text{g}/\text{m}^3$), $\text{PM}_{2.5}$ (151 $\mu\text{g}/\text{m}^3$) and PM_{10} (195.98 $\mu\text{g}/\text{m}^3$) were the least in sensitive area. Most surprised part was in least polluted areas, $\text{PM}_{2.5}$ and PM_{10} were found 2.32 and 1.30 times higher than NAAQS level.

Table 2: Descriptive statistics for PM_{10} , $\text{PM}_{2.5}$ & PM_{10} in seven Land Use

S. N.	Land Use	Number of Locations	PM_{10}				$\text{PM}_{2.5}$				PM_{10}			
			Range ($\mu\text{g}/\text{m}^3$) (Min-max)	Mean ($\mu\text{g}/\text{m}^3$)	Std. Deviation ($\mu\text{g}/\text{m}^3$)	Coefficient of Variation (%)	Range ($\mu\text{g}/\text{m}^3$) (Min-max)	Mean ($\mu\text{g}/\text{m}^3$)	Std. Deviation ($\mu\text{g}/\text{m}^3$)	Coefficient of Variation (%)	Range ($\mu\text{g}/\text{m}^3$) (Min-max)	Mean ($\mu\text{g}/\text{m}^3$)	Std. Deviation ($\mu\text{g}/\text{m}^3$)	Coefficient of Variation (%)
1.	SA	10	51.00	92.38	16.64	18.02	91.25	151.00	28.96	19.18	115.75	195.98	36.97	18.87
2.	RA	20	134.50	168.26	40.09	23.82	139.25	261.90	44.78	17.10	269.25	358.39	84.08	23.46
3.	MA	20	136.50	168.58	38.63	22.91	169.50	269.98	51.19	18.96	286.75	360.39	80.44	22.32
4.	CA	15	159.50	188.38	47.69	25.31	106.50	280.00	35.36	12.63	330.08	403.26	96.84	24.01
5.	IA	5	61.75	148.80	22.87	15.37	94.00	249.85	38.78	15.52	136.25	316.65	52.01	16.43

SA-Sensitive area, MA-Mixed area, RA-Residential area, CA-commercial area and Industrial area

The following table 2 demonstrate the descriptive statistics for PM_{10} , $\text{PM}_{2.5}$ & PM_{10} of the studied five land uses. The highest ranges for PM_{10} and PM_{10} were found in commercial area (159.50 and 330.08 $\mu\text{g}/\text{m}^3$) while $\text{PM}_{2.5}$ had the highest range in residential area (169.50 $\mu\text{g}/\text{m}^3$) whereas the lowest range for all three PM_{10} , $\text{PM}_{2.5}$, and PM_{10} was seen in sensitive area (51, 91.25 and 115.75 $\mu\text{g}/\text{m}^3$). The highest mean value of all PM_{10} , $\text{PM}_{2.5}$, and PM_{10} concentration was also found in commercial area (159.50, 280 and 403.26 $\mu\text{g}/\text{m}^3$) while the lowest was in sensitive area (92.38, 151.00 and 195.98 $\mu\text{g}/\text{m}^3$). Hence it can be said that mean values were corresponding to ranges which led to other findings of observing maximum concentration (287.50, 214.50 and 605.33 $\mu\text{g}/\text{m}^3$) in commercial area and the minimum (70.50, 115.50 and 149.50 $\mu\text{g}/\text{m}^3$) in sensitive area. Again, the highest coefficient of variation was seen in commercial area which was 25.31% and 24.01% for PM_{10} & PM_{10} and the lowest was seen in industrial area which was 15.37% and 16.43%. However, for $\text{PM}_{2.5}$ the highest, 18.96 $\mu\text{g}/\text{m}^3$ was

found in residential area and the lowest, 12.63% was in commercial area.

The whisker box plot in figure 3 (a), (b) and (c) depicts the average concentrations of particulate matter (PM) in five different land uses. There is a black line that runs horizontally across the middle of the box, and it represents the median. The bottom boundary of the box represents the 25th percentile, while the upper boundary of the box represents the 75th percentile. Both the highest possible value (upper whisker) and the lowest possible value (lower whisker) for each land use are represented by the whisker. Outliers are shown by points raised above the whiskers. Whisker box plot of PM_{10} revealed that commercial area had highest dispersion with positively skewed distribution followed by residential area and mixed area though the IQR was quite similar for these three land uses. However, the industrial area had most concentrated concentration prior to sensitive area in which the values were normally distributed. Whisker box plot of $\text{PM}_{2.5}$ showed that residential area had the highest dispersion with negatively skewed distribution followed by mixed area.

It is contradicting to the outcomes of descriptive statistics though the CV values were very closer while the sensitive area had most concentrated concentration with positively skewed distribution prior to industrial area. PM₁₀'s whisker box plot was close to that of PM₁, with the most significant variations in the commercial area and a compacted concentration in the industrial and sensitive areas. In all of three cases the range of the concentration and found highest and lowest value of sensitive area were notably less than all other land uses. Moreover, in most of the land uses for all

three PM₁, PM_{2.5}, and PM₁₀, the values were more scattered beyond 3rd quartile indicating erratic changes in external sources. Another worth finding was that in residential area 50 percent data at the lower end were dispersed while the other 50 percent at the upper end concentrated. The distribution of sensitive area showed the opposite scenario. Besides, the location of median in the boxes had been suggesting that changes in the concentration of PM₁, PM_{2.5}, and PM₁₀ according to land uses was significant. Hence to get clearer view on that an ANOVA test was conducted in next segment.

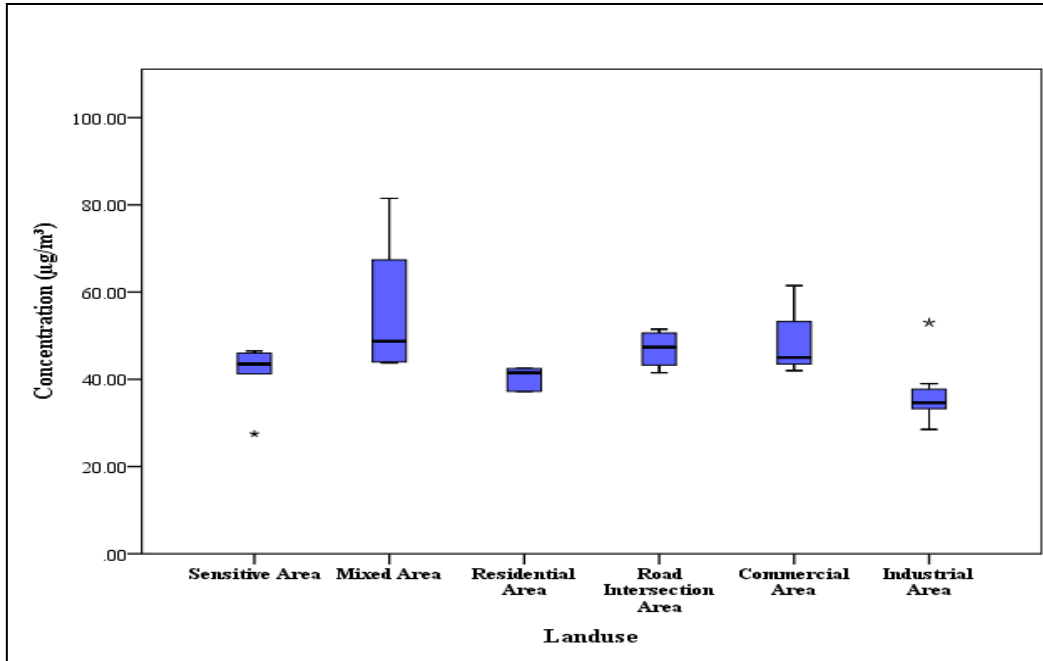


Fig 3 (a): Whisker box plot showing the concentration of PM₁ in Different Land use

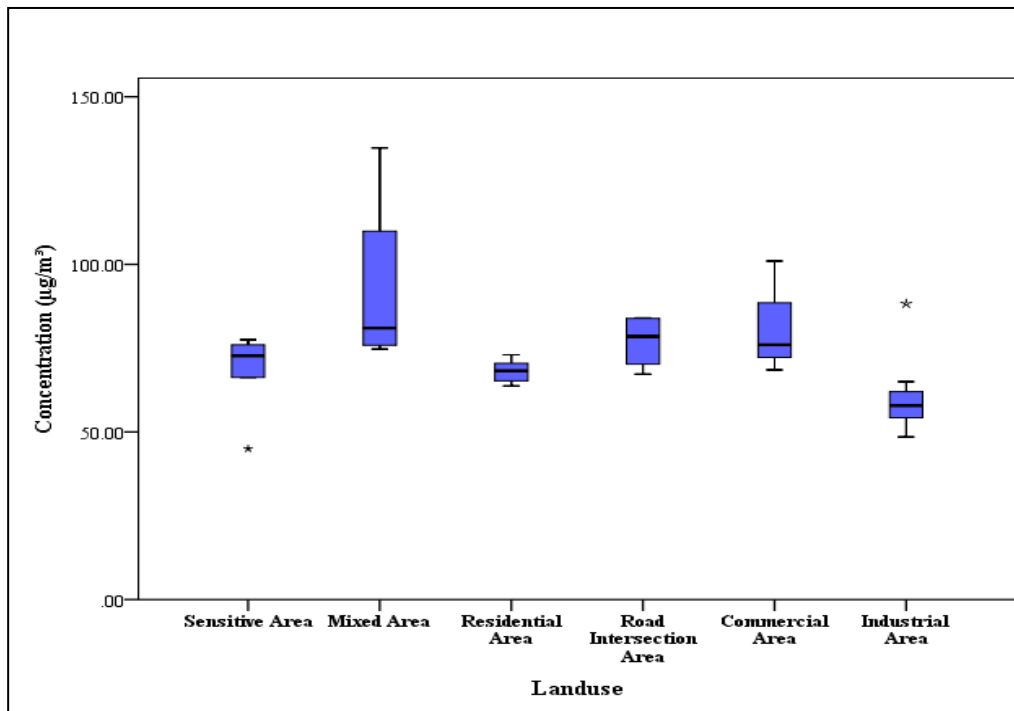


Fig 3 (b): Whisker box plot showing the concentration of PM_{2.5} in Different Land use

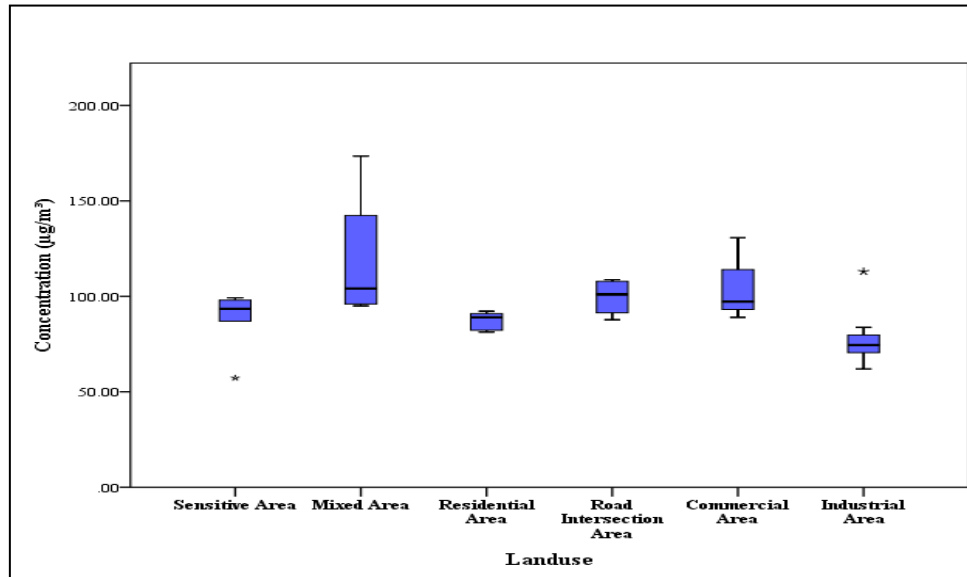


Fig 3 (c): Whisker box plot showing the concentration of PM₁₀ in Different Land use

Table 3 shows Analysis of variance, performed to find whether the changes in the concentration of all the parameters between and within land uses are significant. The F values were calculated to be 10.446 for PM₁, 16.691 for PM_{2.5}, 11.244 for PM₁₀. The table shows that the concentrations of PM₁, PM_{2.5}, and PM₁₀ change significantly between and

within in the land uses as the p values are less than 0.05. These finding indicated that the sources of PM₁, PM_{2.5}, and PM₁₀ were not similar in all the studied land uses and these sources and concentration also varied greatly according to location in an individual land use. Hence further study on individual land uses could draw clearer scenarios.

Table 3: Significance Test by Analysis of variance (ANOVA)

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
PM ₁	Between Groups	61265.729	4	15316.432	10.446	0.000
	Within Groups	95303.761	65	1466.212		
	Total	156569.490	69			
PM _{2.5}	Between Groups	122188.603	4	30547.151	16.691	0.000
	Within Groups	118962.737	65	1830.196		
	Total	241151.340	69			
PM ₁₀	Between Groups	284852.098	4	71213.025	11.244	0.000
	Within Groups	411686.173	65	6333.633		
	Total	696538.271	69			

Figure 4 (a), (b) and (c) demonstrates the dendrogram plot resulting from cluster analysis, specifically focusing on PM₁, PM_{2.5}, and PM₁₀ with Z-score normalization. In this analysis, the average connections between groups have been adjusted to take into respect. At very primary level one cluster has been found for PM₁, consisting of residential area and mixed area. This grouping joined with industrial area at the approximate distance of 7 which again joined with commercial area at the approximate distance of 9. This cluster joins with sensitive area at the approximate distance of 25. Therefore, the found concentration of PM₁ in sensitive area was very different from all the other land uses. For PM_{2.5} only one cluster has been found at very early stage consisting of residential area and mixed area which joined shortly with industrial area at the distance of 5. This grouping and commercial area joined at the approximate distance of 7 which finally joined with sensitive area at the approximate distance of 25. The dendrogram for PM₁₀ was very similar to PM_{2.5}. Hence comparing the all three diagrams it can be said like previous that the found concentration of PM₁,

PM_{2.5}, and PM₁₀ in sensitive area was very different from all the other land uses. For that the controlling measures in sensitive areas should be different from other land uses. In the following table 4 is showing the top three most polluted locations regarding to PM₁, PM_{2.5}, and PM₁₀ in Dhaka Metropolitan area. The highly polluted location was Suvastu Arcade, Elephant Road followed by Bangshal Road and Gulshan 2 circle respectively while comparatively 3 less polluted places were ICDDR'B Dhaka hospital, Mohakhali; Kallanpur Girl's High School (12 Road) and Shahjalal Avenue. It was also noted that top polluted two places were from commercial area and one from mixed area and all the three less polluted places were from same land use; sensitive area. In SUVASTU ARCADE, Elephant Road the concentrations of PM₁, PM_{2.5}, and PM₁₀ were 4.61 and 4.03 times higher than NAAQS level. However, the concentrations PM_{2.5} of International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR) Mohakhali is also 1.77 times higher than NAAQS limit.

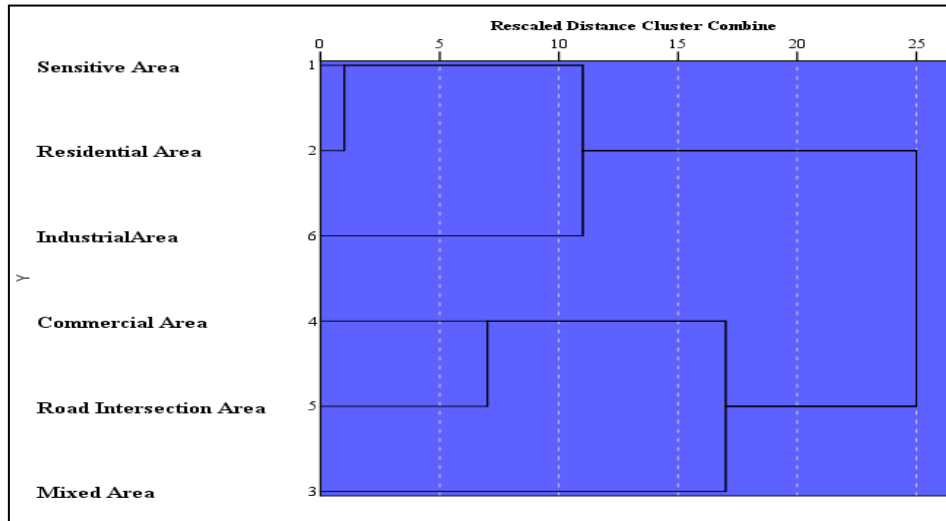


Fig 4 (a): Land Use Based Cluster Analysis for PM₁

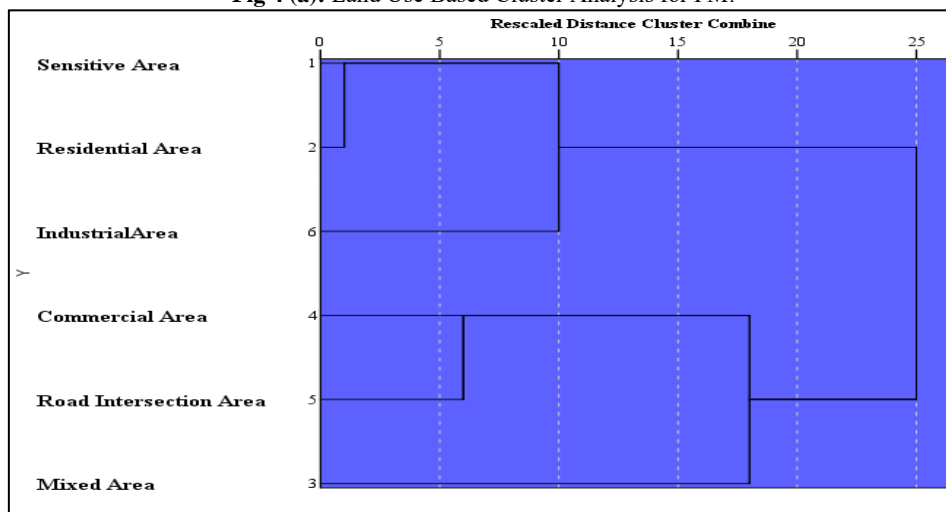


Fig 4 (b): Land Use Based Cluster Analysis for PM_{2.5}

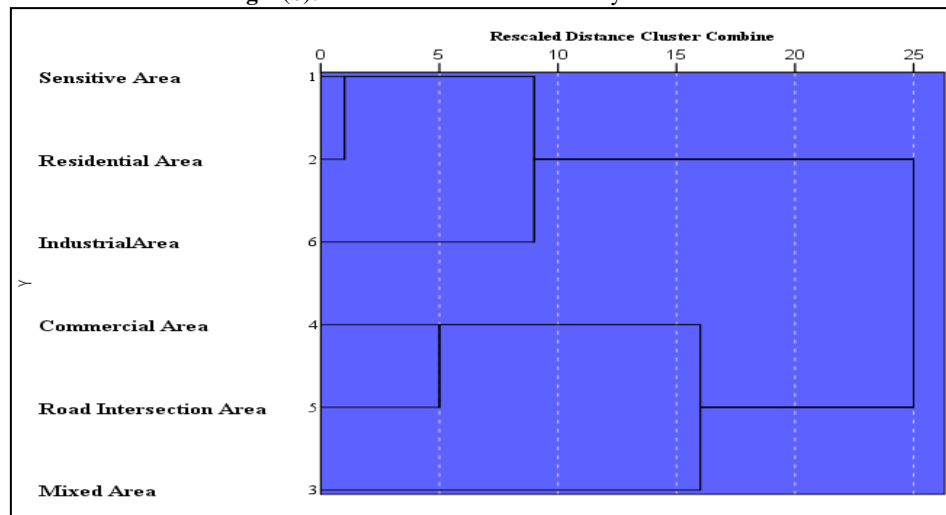


Fig 4 (c): Land Use Based Cluster Analysis for PM₁₀

Table 4: The following are the three most polluted locations and three least polluted sites

Rank	Land use Type	Land Use	PM ₁	PM _{2.5}	PM ₁₀	PM _{2.5} higher than	PM ₁₀ higher than
1.	Commercial Area	Suvastu arcade, Elephant Road	287.25	300.00	605.33	4.16	4.05
2.	Commercial Area	Bangshal Road	261.25	300.00	562.75	4.16	3.75
3.	Mixed Area	Gulshan 2	255.00	300.00	531.25	4.16	3.54
Rank	Land use Type	Land Use	PM ₁	PM _{2.5}	PM ₁₀	PM _{2.5} higher than	PM ₁₀ higher than
1.	Sensitive Area	ICDDRDB Dhaka hospital, Mohakhali	70.50	115.50	149.50	1.77	-
2.	Sensitive Area	Kallanpur Girl's High School (12 Road)	75.25	123.75	159.75	1.90	1.065
3.	Sensitive Area	Shahjalal Avenue	77.00	127.50	164.25	1.96	1.095

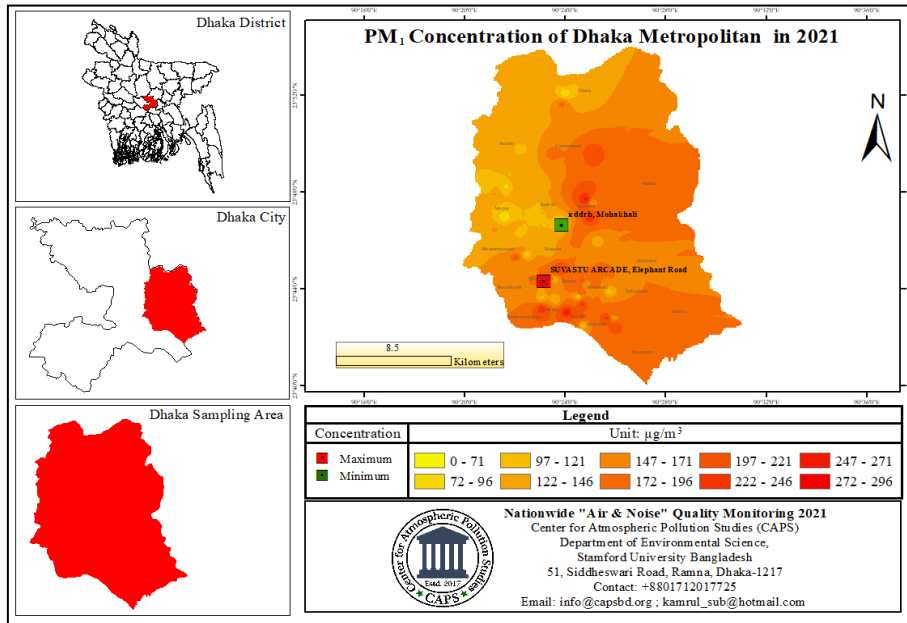


Fig 5 (a): PM₁ Concentration of Dhaka metropolitan area in 2021

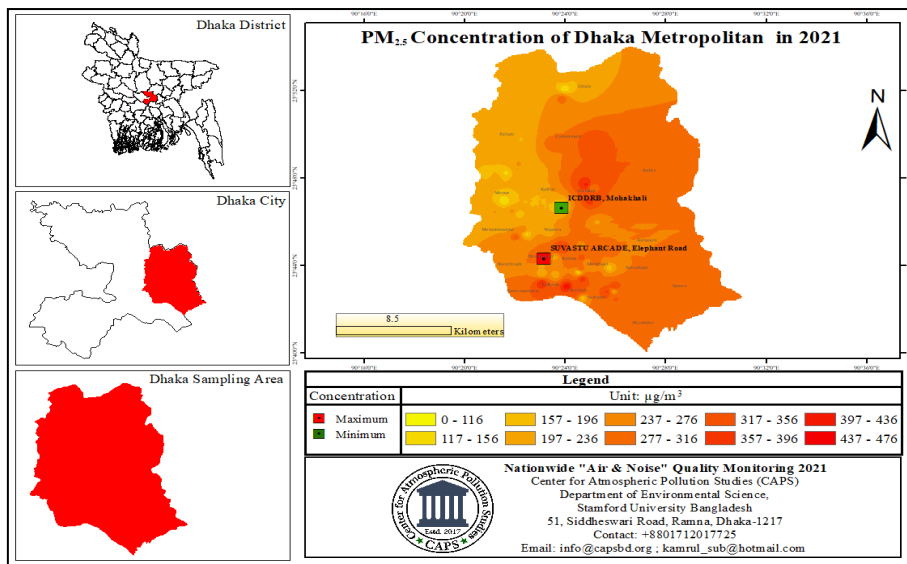


Fig 5 (b): PM_{2.5} Concentration of Dhaka metropolitan area in 2021

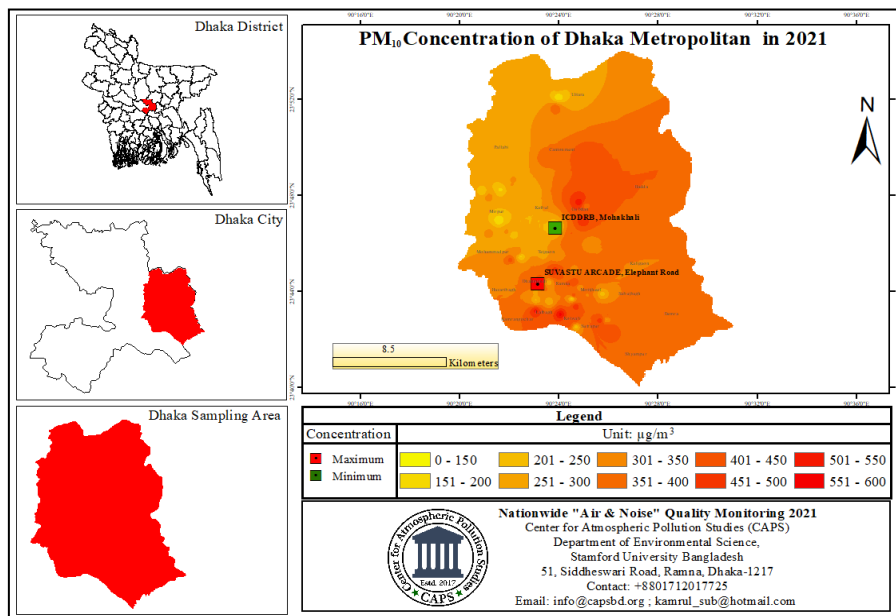


Fig 5 (c): PM₁₀ Concentration of Dhaka metropolitan area in 2021

2.2 Concentration Map on PM₁, PM_{2.5} and PM₁₀

Figure 5 (a), (b) and (c) illustrate the concentration of particulate matter (PM₁, PM_{2.5} and PM₁₀) at various locations of Dhaka metropolitan area in the year of 2021. Yellow areas in the maps had less concentration, while progressively higher concentrations were shown in orange and red. The concentration of PM₁ (197-296 µg/m³), PM_{2.5} (317-476 µg/m³) and PM₁₀ (301-600 µg/m³) was found to be higher in the center point of Gulshan-2 circle, Gulistan bus stop, Sayedabad, Raza Sreenath Street, New Eskaton BIAM road, Nikunja, SUVASTU ARCADE, Elephant Road, Bangshal road, Robi Customer Care, Gulshan-1, ORION Group, Dholaipar, Jatra Bari and Starasta bus stop mor. Also shows that PM_{2.5} concentrations were found lower than 236 µg/m³ in, Dhanmondi Govt. Girls High School, Kallanpur Girl's High School (12 Road), Shishu hospital & Institute, Mirpur, Shahjalal Avenue, Dhaka Shishu (Children) Hospital, ICDDR, Mohakhali, Block-c, road-7, Mirpur, Block-D, Road 23, Pollobi, Azimpur Colony Field, Tajmahal Road, Gabtali, Mirpur-1 Bus stand, Mirpur-10 and Mirpur Ceramic Road Pollobi. Also shows that PM₁₀ concentrations were found lower than 300 µg/m³ in Mugda Medical College and Hospital, Bangladesh Secretariat, Jagannath University, BSMMU 5 no gate, Dhanmondi Govt. Girls High School, Kallanpur Girl's High School (12 Road), Shishu hospital & Institute, Mirpur, Shahjalal Avenue, Dhaka Shishu (Children) Hospital, ICDDR, Mohakhali, Kazipara Busstand, Tajmahal road, Gabtali, Farmgate Police Box, English road, BGB Cinema Hall, Tannery Mor Jame Masjid and Mirpur Ceramic road Pollobi.

Conclusion and Recommendations

The study revealed that the mean levels of PM₁, PM_{2.5}, and PM₁₀ at 70 locations within the Dhaka metropolitan region were measured at 153.28, 252.96, and 326.93 µg/m³, respectively. The land uses were classified in descending order according to the average concentrations of PM₁, PM_{2.5}, and PM₁₀. The commercial area had the highest average concentrations, followed by the residential area, the mixed area, the industrial area, and finally, the sensitive region. In addition, the study revealed that the levels of PM_{2.5} and PM₁₀ in various land use areas were significantly elevated, measuring 3.89 and 2.18 times higher than the National Ambient Air Quality Standards (NAAQS) limits of 65 and 150 µg/m³, respectively. Additionally, calculations indicated that the average PM_{2.5}/PM₁₀ ratio was 75.45%, meaning that the mass of PM_{2.5} accounted for 75.45% of the PM₁₀ mass. Similarly, the average PM₁/PM_{2.5} ratio was 62.74%, indicating that the mass of PM₁ made up 62.74% of the PM_{2.5} mass. According to the dispersion of PM₁, PM_{2.5}, and PM₁₀, the commercial and residential areas have the widest range of pollution levels, while the sensitive area has the narrowest range. It was discovered that the dispersion coefficient of variation for PM₁, PM_{2.5}, and PM₁₀ is higher in the commercial and residential areas, and lower in the sensitive and industrial areas. Furthermore, the whisker box graph depicting PM₁, PM_{2.5}, and PM₁₀ reveals that the values are widely spread in the commercial region, while the sensitive area has a more concentrated value. Furthermore, the study demonstrated that the concentrations of the parameters exhibit substantial variations depending on land use, as indicated by p values below 0.05. The dendrogram plot of PM₁, PM_{2.5}, PM₁₀ revealed that each analysis consisted of a minimum of four clusters in the initial phase. To address the

issue of particulate matter in Dhaka Metropolitan area, it is crucial to enforce more stringent emissions regulations for automobiles and encourage the adoption of public transit. These actions may successfully reduce pollution caused by traffic. It is essential to improve industrial rules to ensure that enterprises adopt cleaner technology and implement adequate waste management methods. Expanding the presence of green spaces and urban forests can effectively mitigate the impact of pollutants and enhance the overall air quality. In addition, improving public consciousness regarding the health consequences of air pollution and fostering community participation in monitoring and reporting air quality may encourage collective efforts towards achieving cleaner air.

Acknowledgements

The authors are thankful to Center for Atmospheric Pollution Studies (CAPS) and Department of Environment Science, Stamford University Bangladesh.

Author contributions

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