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Wintertime air quality assessment in Sylhet city corporation, Bangladesh: Current status and implications

Ahmad Kamruzzaman Majumder[1*], Nasir Ahmmed Patoary[2], Rokib Uddin Bhuiyan[3], Rasheduzzaman Majumder[4], Kaspia Rahman Tanima[5]

[1] Professor, Department of Environmental Science, Center for Atmospheric Pollution Studie, Stamford University Bangladesh, Dhaka, Bangladesh
[2] Lecturer, Department of Environmental Science, Stamford University Bangladesh, Dhaka, Bangladesh
[3] Department of Environmental Science, Stamford University Bangladesh, Dhaka, Bangladesh
[4] Legal Director, Department of Environmental Science, Center for Atmospheric Pollution Studies, Stamford University Dhaka, Bangladesh
[5] Research Associate, Center for Atmospheric Pollution Studies, Dhaka, Bangladesh

Abstract
Particulate matter is a major pollutant in Sylhet, and it stems primarily from dust generated by construction sites, unpaved roads, and emissions from vehicles, especially those running on outdated engines. The objective of this study is to monitor the Particulate Matters (PM_1, $PM_{2.5}$, and PM_{10}) concentration based on different land use in Sylhet City Corporation. This study was conducted in 59 locations of Sylhet City Corporation, by using portable Air Quality Monitor. It is found that average concentrations of PM_1, $PM_{2.5}$, and PM_{10} in Sylhet City Corporation were 59.44, 97 and 124.91 µg/m^3 respectively. It is estimated that the average $PM_{2.5}/PM_{10}$ was 77.55%, $PM_1/PM_{2.5}$ was 63.36%. The average concentration of $PM_{2.5}$ (97 µg/m^3) of different land-use was found higher which 1.49 times higher than the NAAQS level. The concentration of PM in ambient air with respect to land use decreases as follows: mixed area> commercial area > road intersection area > residential area> sensitive area > village area > industrial area. As air pollution extent in Sylhet is relatively higher it is high time to take some mitigation measures to minimize this alarming environmental problem.

Keywords: Air pollution, particulate matter, concentration, Sylhet City corporation, Bangladesh

Introduction

Ambient air pollution is a major issue in urban areas of numerous developing nations, presenting grave risks to both public health and environmental integrity (Majumder *et al*., 2023a [7]; Harrison *et al*., 2014) [4]. It is a primary factor in causing death, accounting for one-third of fatalities related to stroke, heart disease, and lung cancer (WHO, 2018, Majumder *et al*., 2023b) [8]. Particulate matter (PM), namely fine particles ($PM_{2.5}$) and coarse particles (PM_{10}), is one of the most detrimental pollutants because of its significant influence on human health (Health Effects Institute, 2024). $PM_{2.5}$ is commonly emitted via biomass and fossil fuel burning, brick kilns, and motor vehicles (Begum *et al*., 2009) [2]. On the other hand, PM_{10} is primarily generated by mechanical processes including wind-blown dust, road dust, soil dust, and pollen (Majumder *et al*., 2020 [9]; Nayeem *et al*., 2020). Sylhet, a picturesque city located in the northeastern region of Bangladesh, renowned for its pristine surroundings, is currently grappling with a concerning surge in air pollution. According to the Sylhet City Corporation (SCC) website, the city had a population of 485,138 people as per the 2011 census, with an additional 200,000 people living in surrounding rural and semi-urban areas. This population surge occurred primarily after the 2000s, leaving the city unprepared to accommodate such rapid growth. The increase in population has led to a rise in household waste, vehicle numbers, and consequently, air pollution (Razib *et al*., 2020) [14]. In Sylhet, the two major contributors to air pollution are vehicular and industrial emissions. These pollutants are mainly concentrated in the city's core and nearby industrial areas. Zindabazar, Bandar Bazar, and Amberkhana are particularly affected by vehicular emissions, while Khadimpara, BISIC, Machimpur, Dhopagul, and the airport areas on the city's outskirts are primarily impacted by industrial emissions (Climate Sylhet, 2020) [3]. Additionally, numerous brick kilns operate seasonally, mainly during the dry season, further contributing to the city's air pollution problem (Majumder *et al*., 2024). This is especially true during dry seasons, when pollution levels increase due to emissions from brick kilns and traffic congestion (Nayeem *et al*., 2019; Hossain *et al*., 2019) [5]. Air pollution has a significant impact, since it is associated with elevated levels of particulate matter that are known to cause respiratory ailments, cardiovascular disorders, and other health conditions (Alam *et al*., 2018 [1], Hasan *et al*., 2019) [6]. Specific groups that are particularly susceptible, such as youngsters and the elderly, have a higher level of danger. In addition, the presence of low air quality is causing environmental deterioration, diminishing visibility, and causing harm to local ecosystems. To address these difficulties, it is crucial to thoroughly analyses the present condition of air pollution in Sylhet, including its origins and the health consequences it entails. The objectives of this study are to identify the status of air pollution in Sylhet Metropolitan, assess the relationship between land use and various air quality parameters and to determine the Air Quality Index (AQI) of Sylhet based on $PM_{2.5}$. Additionally, the study aims to create geospatial maps that visualize the concentration levels of PM_1, $PM_{2.5}$, and PM_{10}, across different areas.

Materials and Methodology

Sylhet City Corporation uses as study area in this study. Sylhet City Corporation is a part of Sylhet district in the Division of Sylhet, Bangladesh. Sylhet City Corporation is located at 24.8917°N 91.8833°E (Fig 1). It has 86074 units of household and its total area is 323.17 km^2. In this Study, 59 locations were select 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, residential, mixed, commercial, road intersection, industrial and village Area. The all-samples sites have been pointed into the map.

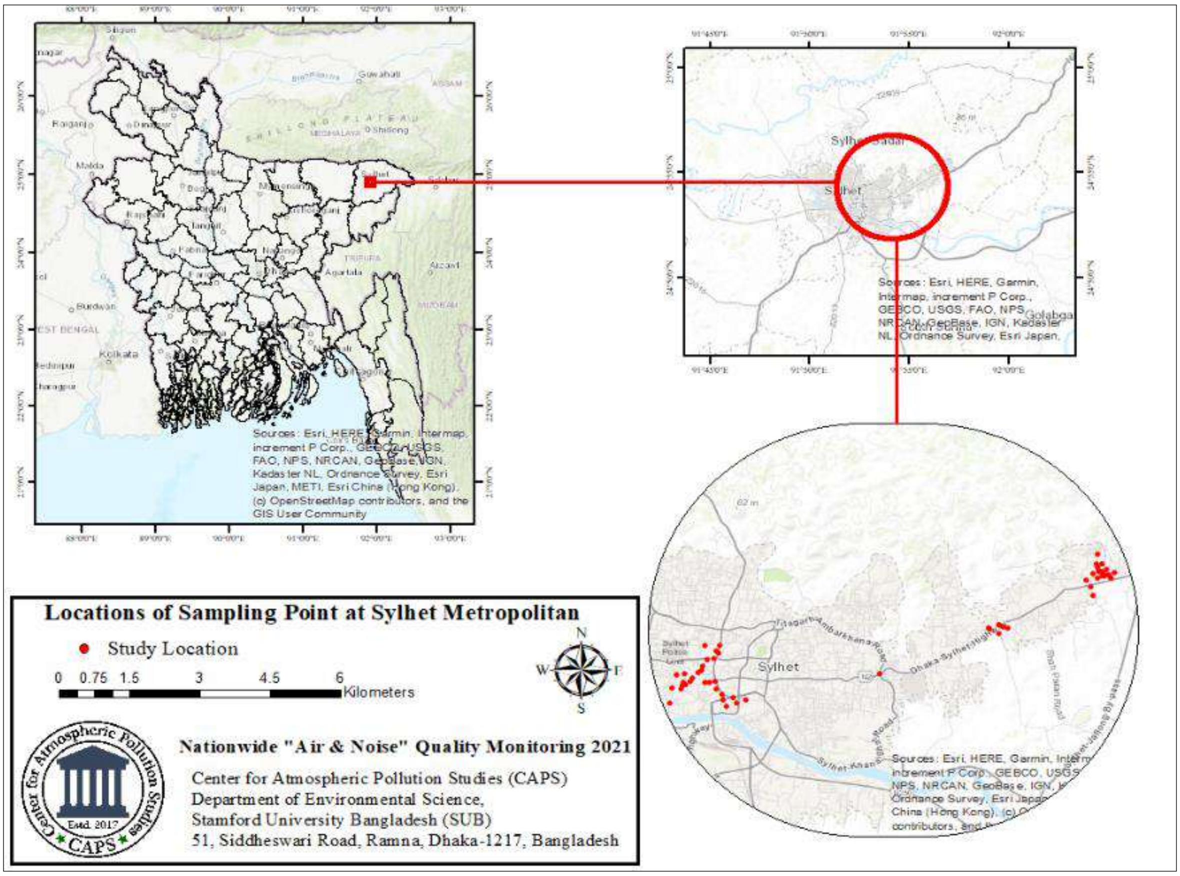

Fig 1: Study Area (Sylhet City Corporation Area and Data Collection Locations Point)

Particulate Matter (PM_1, $PM_{2.5}$, and PM_{10}) were measured for two days from each location of study area using Air Quality Monitor, Indoor Outdoor Formaldehyde (HCHO) Detector. Collected data were input in an IBM SPSS V20 and MS Excel 2020. Following formula was used for converting the concentration of $PM_{2.5}$ to AQI.

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

If multiple pollutants are measured, the AQI is calculated from the above equation applied for each pollutant. 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}.

Results and Discussion

1. Comparison among Different Land Use

The Status of Air Pollution in Sylhet area was studied by comparing the PM_1, $PM_{2.5}$, and PM_{10} in 59 location of 7 area (sensitive, residential, mixed, commercial, road intersection, industrial and village area) which are presented in Fig 2 (a-g). Fig 2 (a) illustrates the concentration (µg/m^3) of PM_1, $PM_{2.5}$, and PM_{10} of some polluted locations in sensitive areas in Sylhet City Corporation area. These areas include administrative offices, educational institutes and mosques. As we could see, among these 10 sensitive places, three highly polluted places were Sha Gohor Jame Mosjid, Shohid Shamsuddin Ahmed Hospital and Sylhet Medical College with $PM_{2.5}$ concentration of 107, 105.75, and 101 µg/m^3 respectively and comparatively less polluted places were Govt. Agragami Girls' High School & College, Basic Mosque and Moricha Govt. Primary School. It has been observed that concentration of PM_1, $PM_{2.5}$, and PM_{10} of Shohid Shamsuddin Ahmed Hospital and Govt. Agragami Girls' High School & College were 65.00, 107 and 135.50 µg/m^3 and 49.25, 80.25 and 103 µg/m^3 respectively. It was also noted that the concentrations of $PM_{2.5}$ found in the most polluted place was 1.62 times higher than NAAQS level which is 65 µg/m^3 set by the Department of Environment (DoE). Moreover, the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted location were 4.23 and 2.77 times higher than World Health Organization (WHO) standard levels respectively. The Air Quality Standard (24-hour) set by the WHO for $PM_{2.5}$ and PM_{10} are 25 and 50 µg/m^3 respectively. The study estimated that in all sensitive areas, 77.55% of $PM_{2.5}$ was present in PM_{10} and 60.43% of the PM_1 was present in $PM_{2.5}$. Fig 2 (b) demonstrates the concentration (µg/m^3) of PM_1, $PM_{2.5}$, and PM_{10} of some polluted locations in mixed areas in Sylhet City Corporation area. It has been found that out of 6 mixed places three highly polluted places were Sadipur, Bangladesh Medical Association bhobon, and Kuyarpar and comparatively less polluted places were Jitu miyar point, Court point and Jallar par road. It has been observed that concentrations of PM_1, $PM_{2.5}$, and PM_{10} of Sadipur and Jitu Miyar Point were 109, 185.5 and 221.25 $\mu g/m^3$ and 56, 85 and 109.25 $\mu g/m^3$ respectively. It was also noted that the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted place were 2.85 and 1.48 times higher than NAAQS levels. The concentrations of $PM_{2.5}$ of Sadipur, Bangladesh Medical Association bhobon and Kuyarpar were 185.5, 98.75 and 92.75 $\mu g/m^3$. The study estimated that the ratio of $PM_{2.5}$ /PM_{10} was 77.06%. It was also found that 61.08% of PM_1 mass was present in $PM_{2.5}$. Fig 2 (c) despricts the concentration ($\mu g/m^3$) of PM_1, $PM_{2.5}$, and PM_{10} of some polluted locations in residential areas in Sylhet City Corporation area. It has been found that out of 10 residential places, three highly polluted places were Dariya para, Monipuri rajbari and Dariya para a block and comparatively less polluted places were Rustampur, Digonto and Mirza jangal. It has been observed that concentrations of PM_1, $PM_{2.5}$, and PM_{10} of Dariya para and Rustampur were 69.75, 109 and 142 $\mu g/m^3$ and 47.25, 81.25 and 103.25 $\mu g/m^3$ respectively. It was also noted that the concentration of $PM_{2.5}$ found in the most polluted place was 1.68 times higher than NAAQS level. However, the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted location were 4.36 and 2.84 times higher than WHO standard level respectively. The concentrations of $PM_{2.5}$ of Dariya para, Monipuri rajbari and Dariya para a block was found 109, 109 and 98 $\mu g/m^3$. The study estimated that in all residential areas, 77.26% of $PM_{2.5}$ was present in PM_{10} and 61.34% of the PM_1 was present in $PM_{2.5}$. Fig 2 (d) shows the concentration ($\mu g/m^3$) of PM_1, $PM_{2.5}$, and PM_{10} of polluted some locations in road intersection areas in Sylhet City Corporation area. It has been found that out of 6 road intersection places, three highly polluted places were Jindabazar point, West Shah Jalal Dargah gate and East Shah Jalal Dargah gate and comparatively less polluted places were Lamabazar point, Bondor bazar and Sylhet City Corporation (Nogor Bhobon). It has been observed that concentration of PM_1, $PM_{2.5}$, and PM_{10} of Jindabazar point and Lamabazer point were 66, 107.25 and 139.75 $\mu g/m^3$ and 54, 89.5 and 115.25 $\mu g/m^3$ respectively. It was also noted that the concentrations of $PM_{2.5}$ found in the most polluted place was 1.65 times higher than level. On the other hand, the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted location were 4.31 and 2.79 times higher than WHO standard level respectively. The concentrations of $PM_{2.5}$ of Jindabazar point, West Shah Jalal Dargah gate and East Shah Jalal Dargah gate were found 107.75, 103 and 97.75 $\mu g/m^3$ respectively. The study estimated that in all road intersection areas, 78.41% of $PM_{2.5}$ was present in PM_{10} and 59.83% of the PM_1 was present in $PM_{2.5}$. Fig 2 (e) explain the concentration ($\mu g/m^3$) of PM_1, $PM_{2.5}$, and PM_{10} of some polluted locations in commercial areas in Sylhet City Corporation area. It has been found that out of 7 commercial places, three highly polluted places were Darga gate, Kastoghar road and Laldighir par and relatively less polluted places were Bicik mor, Farid Plaza and Hill view tower. It has been observed that concentrations of PM_1, $PM_{2.5}$, and PM_{10} of Darga get and Bicik mor were 75.5, 122.75 and 160 $\mu g/m^3$ and 52.5, 83.75 and 109.75 $\mu g/m^3$ respectively. It was also noted that the concentration of $PM_{2.5}$ and PM_{10} found in the most polluted place were 1.89 and 1.06 times higher than NAAQS levels. The concentrations of $PM_{2.5}$ of Darga gate, Kastoghar road and Laldighir par were found 122.75, 120.75 and 109.75 $\mu g/m^3$ respectively. The study estimated that in all commercial areas, 79.59% of $PM_{2.5}$ was present in PM_{10} and 60.56% of the PM_1 was present in $PM_{2.5}$. Fig 2 (f) shows the concentration ($\mu g/m^3$) of PM_1, $PM_{2.5}$, and PM_{10} of some polluted locations in industrial areas in Sylhet City Corporation area. It has been found that out of 10 industrial places, three highly polluted places were Peoria Food Industry, Mr. Plastic Industry and Jest Food & Beverages Ltd. and relatively less polluted places were Fulkoli, Dunlop Foam Industry and Royel Food Industry. It has been observed that concentrations of PM_1, $PM_{2.5}$, and PM_{10} of Peoria Food Industry and Fulkoli Industry were 67.25, 104.25 and 135.75 $\mu g/m^3$ and 52, 86 and 110.75 $\mu g/m^3$ respectively. It was also noted that the concentrations of $PM_{2.5}$ found in the most polluted area was 1.60 times higher than NAAQS level. Nevertheless, the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted location were 4.17 and 2.71 times higher than WHO standard level respectively. The study estimated that in Industrial areas, 80.39% of $PM_{2.5}$ was present in PM_{10} and 60.93% of the PM_1 was present in $PM_{2.5}$. Fig 2 (g) illustrates the concentration ($\mu g/m^3$) of PM_1, $PM_{2.5}$, and PM_{10} of some polluted locations in village areas in Sylhet City Corporation area. It has been found that out of 10 village places, three highly polluted places were the Khadimnagor-1, Khadimpara-3 and Khadimnagor-2 and the less polluted places were Kollogram, Khadimnagor-3 and Kadimpara-1.

It has been observed that concentrations of PM_1, $PM_{2.5}$, and PM_{10} of the Khadimnagor-1 and Kollogram were 68.5, 112.25 and 145.25 $\mu g/m^3$ and 49.25, 81 and 104.25 $\mu g/m^3$ respectively. It was also noted that the concentrations of $PM_{2.5}$ found in most polluted places were 1.73 times higher than NAAQS level. Despite that, the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted location were 4.49 and 2.90 times higher than WHO standard level respectively. The study estimated that in village areas, 78.42% of $PM_{2.5}$ was present in PM_{10} and 59.34% of the PM_1 was present in $PM_{2.5}$.

2. Descriptive Statistics of PM_1, $PM_{2.5}$, and PM_{10}

The following table 1 demonstrates the descriptive statistics for PM_1 of the studied seven land uses. The higher ranges were found in mixed area (57.50, 100.50 and 135.88 $\mu g/m^3$) followed by commercial area and residential area (22.50, 28.50 and 38.75 $\mu g/m^3$) and lower ranges were found in road intersection area (12, 18.25 and 24.50 $\mu g/m^3$) and industrial area. The highest mean value of PM_1, $PM_{2.5}$, and PM_{10} was found in mixed area (66.21, 106.54 and 135.88 $\mu g/m^3$) followed by commercial area (62.61 $\mu g/m^3$) and the lowest mean was found in village area (56.05 $\mu g/m^3$). The highest standard deviation was seen in mixed area (21.62 $\mu g/m^3$) and the lowest was seen in road intersection area (3.92 $\mu g/m^3$). Table also shows that; the highest coefficient of variation was seen in mixed area which was 32.65% and lowest was seen in road intersection area which was 6.60 %. It is observed that the highest variation in the concentration of the PM_1 was in mixed area followed by commercial area and residential area. The less variation was found in road intersection and industrial area apart from this village has less variation too.

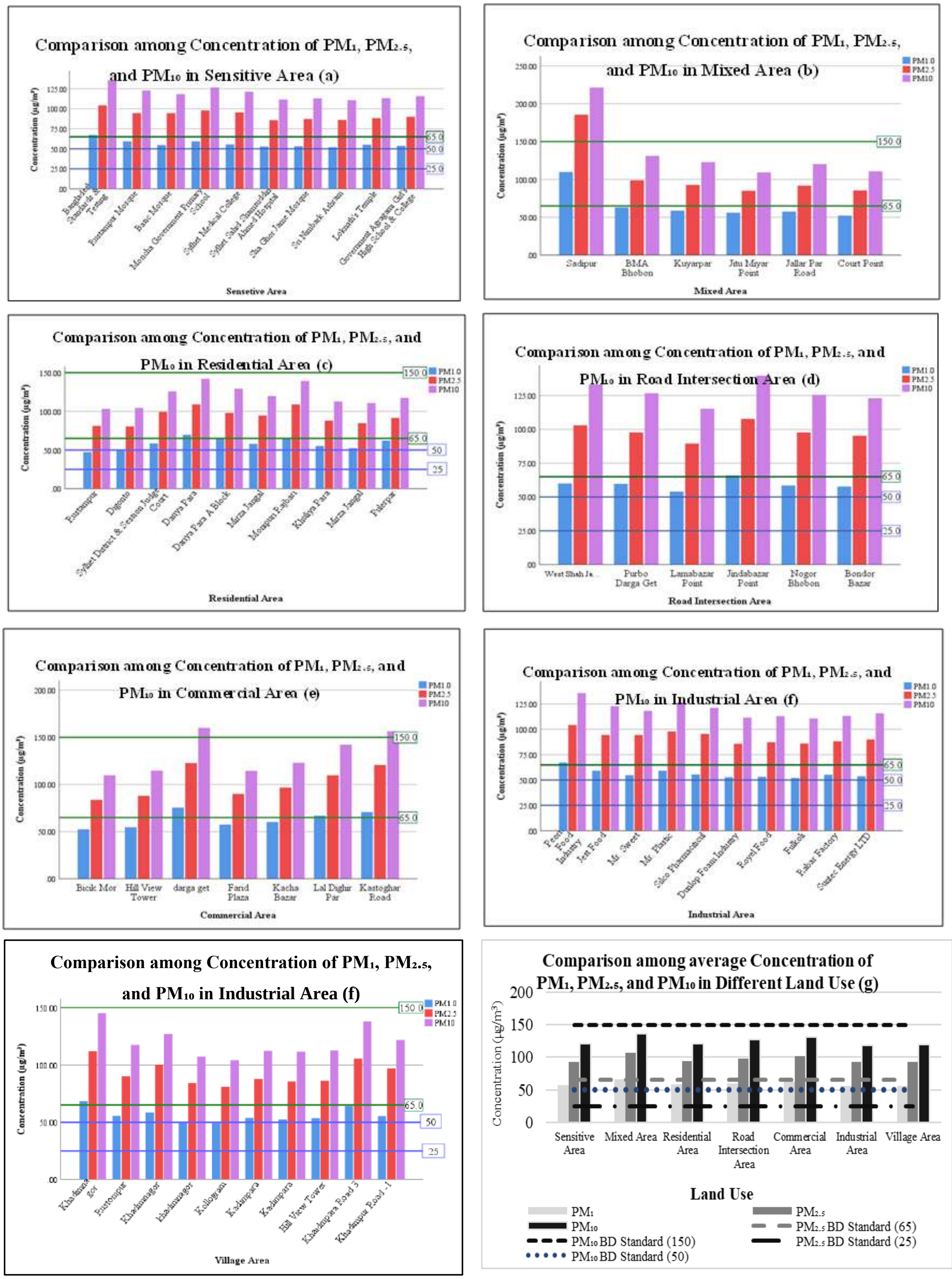

Fig 2: Comparison among Concentration of PM_1, $PM_{2.5}$, and PM_{10}

The highest mean value of $PM_{2.5}$ was found in mixed area (106.54 µg/m^3) and then in commercial area (101.68 µg/m^3) and lowest mean was found in industrial area (92.40 µg/m^3). The highest standard deviation was seen in mixed area (39.02 µg/m^3) and lowest was seen in industrial area (6.01 µg/m^3). Table 1 also describe that; the highest coefficient of variation was seen in mixed area which is 32.65% and lowest was seen in industrial area which is 8.13%. It was observed that the highest coefficient of variation in the concentration of the $PM_{2.5}$ was in mixed area followed by commercial area and residential area. The reasons behind the higher dispersion in concentration in mixed and commercial area are various economic activities. The less variation was found in industrial area and road intersection area. For PM_{10} ranges were found in mixed area (112.00 µg/m^3), commercial area (50.25 µg/m^3) and village area (41.00 µg/m^3) and lower ranges were found in road intersection area (24.50 µg/m^3) and industrial area (25.00 µg/m^3). The highest mean value of PM_{10} was found in mixed area (µg/m^3) and followed by commercial area (131.54 µg/m^3) and the lowest mean was found in industrial area (118.88 µg/m^3). The highest standard deviation was seen in sensitive area (42.59 µg/m^3) and the lowest was seen in industrial area (7.89 µg/m^3). Table also shows that; the highest coefficient of variation was seen in mixed area which is 31.34% and lowest was seen in industrial area which is 6.64%. It is observed that the highest variation in the concentration of the PM_{10} was in mixed area followed by commercial area and residential area. The less variation was found in industrial area and road intersection area. As demonstrated by a whisker box plot of PM_1, $PM_{2.5}$, and PM_{10} shown in Fig 3 (a, b, c), the highest dispersion is seen in commercial area where the values are positively skewed. Three land use values are normally distributed, with one outlier in a mixed area. The concentration was moderately spread at the sensitive area, residential area and village area. In these three-land use two where normally distribution was seen and in village area values were positively skewed. All the road intersections and industrial areas featured a compacted distribution were seen positive.

Table 1: Descriptive Statistics of 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	10	16.50	57.20	6.17	10.79	26.75	93.25	9.34	10.79	35.25	120.55	12.17	10.09
2	MA	6	57.50	66.21	21.62	32.65	100.50	106.54	39.02	32.65	112.00	135.88	42.59	31.34
3	RA	10	22.50	58.35	7.06	12.10	28.50	93.58	10.35	12.10	38.75	120.48	13.48	11.19
4	RIA	6	12.00	59.33	3.92	6.60	18.25	98.50	6.30	6.60	24.50	127.25	8.46	6.65
5	CA	7	23.00	62.61	8.63	13.79	39.00	101.68	16.03	13.79	50.25	131.54	21.09	16.03
6	IA	10	15.25	56.30	4.57	8.13	18.50	92.40	6.01	8.13	25.00	118.88	7.89	6.64
7	VA	10	19.25	56.05	6.15	10.97	31.25	93.03	10.27	10.97	41.00	119.80	13.36	11.15
SA-Sensitive area, MA-Mixed area, RA-Residential area, RIA- Road Intersection Area, CA-commercial area and IA-Industrial area, VA-Village Area, NoL-Number of Locations														

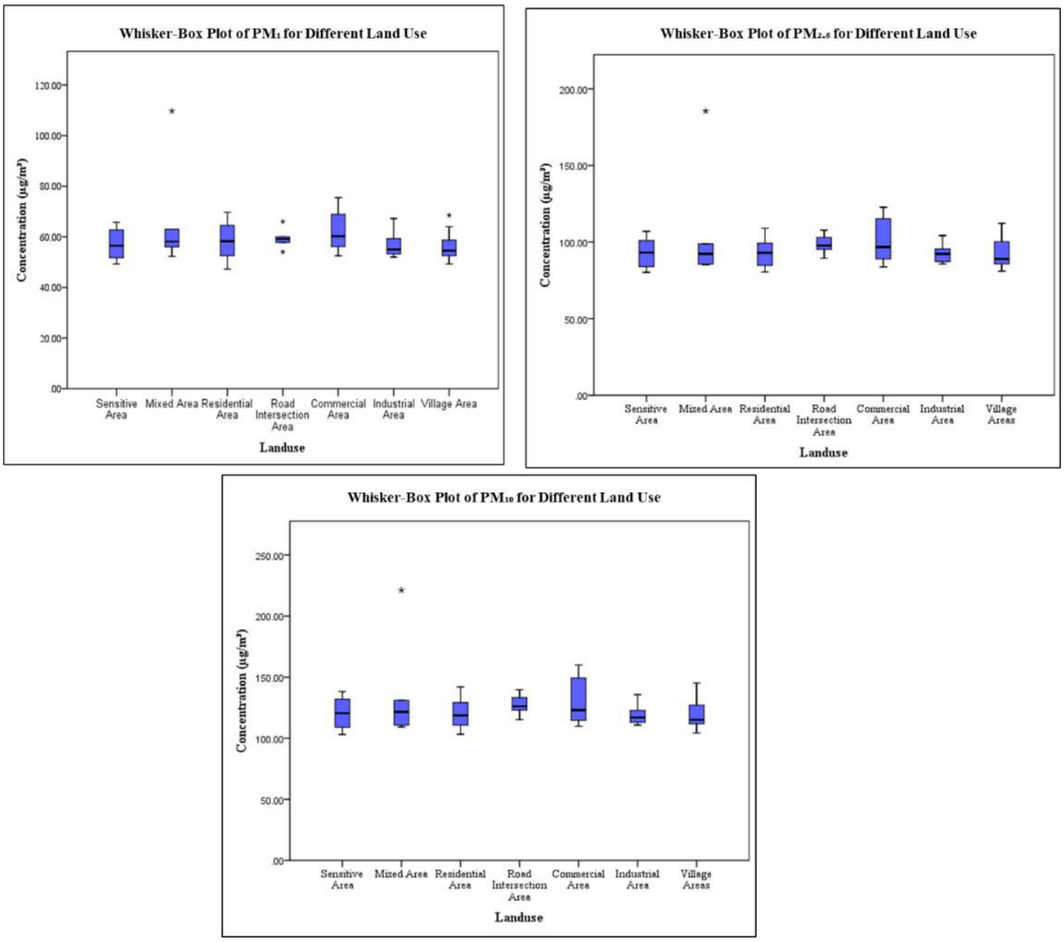

Fig 3: Whisker-Box Plot of PM_1, $PM_{2.5}$, and PM_{10} in Different Land Use

3. Significance Test

Table 2 describes Analysis of variance (ANOVA) for the significant test. ANOVA has been performed to find whether the changes in the concentration of all the parameters between and within land uses are significant. Here the F value of found to be 1.240 for PM_1, 0.898 for $PM_{2.5}$, and 0.503 for PM_{10} respectively. P values found for PM_1, $PM_{2.5}$, and PM_{10} are 0.301, 0.678, and 0.437 respectively. The following tables revealed that that the concentrations of none of the parameters change significantly as the p values are greater than 0.05.

Table 2: Significance Test

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
PM_1	Between Groups	598.189	6	99.698	1.240	0.301
	Within Groups	4181.068	52	80.405		
	Total	4779.256	58			
$PM_{2.5}$	Between Groups	1282.517	6	213.753	.898	0.503
	Within Groups	12374.854	52	237.978		
	Total	13657.371	58			
PM_{10}	Between Groups	1982.870	6	330.478	.997	0.437
	Within Groups	17229.935	52	331.345		
	Total	19212.805	58			

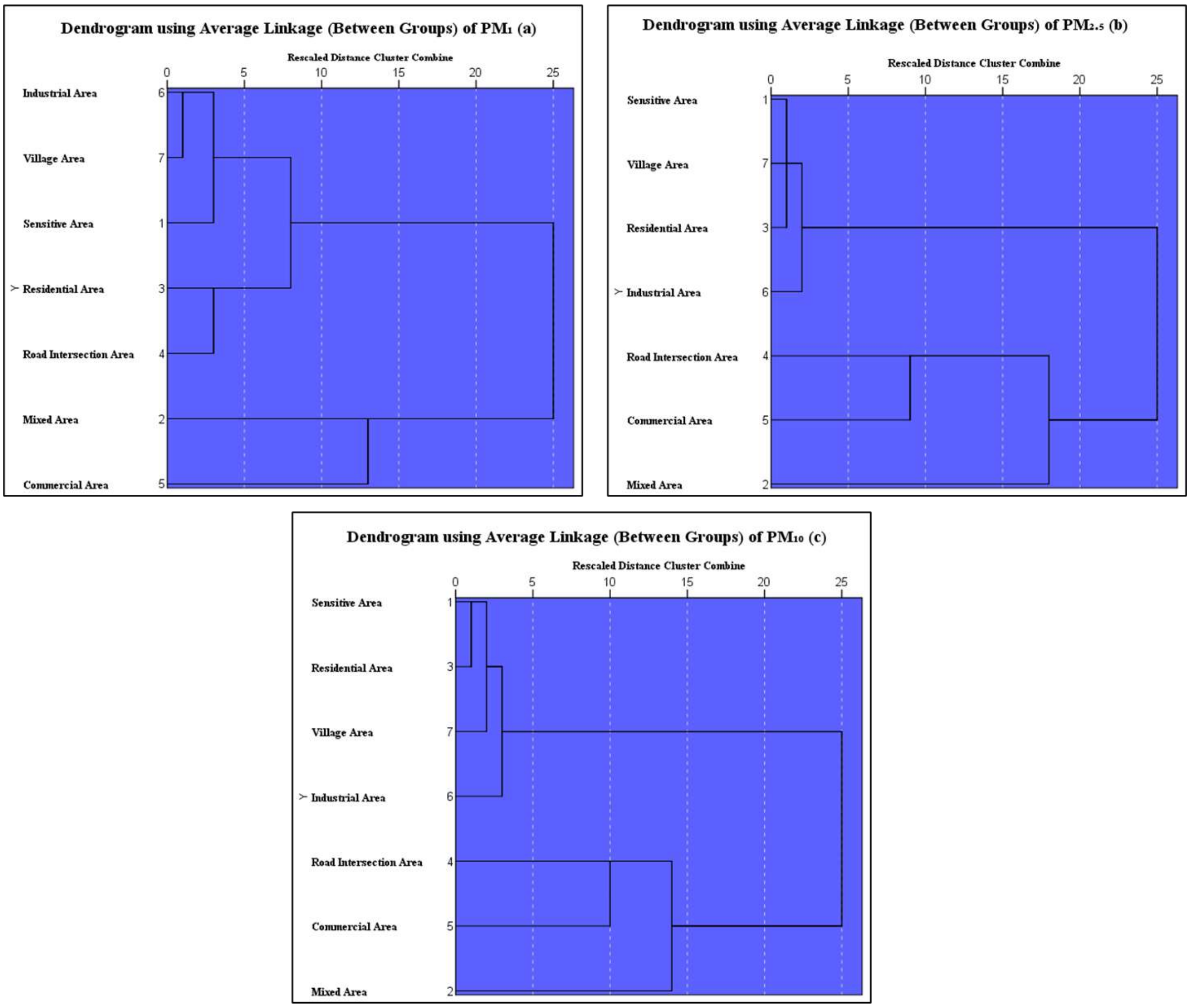

Fig 4: Rescaled Distance Cluster Combine for PM_1, $PM_{2.5}$, and PM_{10}

4. Land Use Based Cluster Analysis

Fig 4 clarify the dendrogram plot obtained from cluster analysis in terms of PM_1, $PM_{2.5}$, and PM_{10} with Z-score normalization. For this analysis, group linkage and Euclidean distance have been considered. Four clusters have been found for PM_1, $PM_{2.5}$, and PM_{10}. For PM_1 first cluster is consisted of industrial area, village area and sensitive area; second cluster includes residential area and road intersection area; third and fourth clusters include mixed area and commercial area respectively. First and second clusters join at the approximate distance of 8; again, third and fourth clusters join at the approximate distance of 13. These two broad clusters join at the approximate of 25. First cluster is consisted of sensitive area, village area, residential area and industrial area; Second, third and fourth cluster includes road intersection area, commercial area and mixed area respectively. Second and third cluster join at the approximate distance of 9 which join with fourth cluster at the approximate distance of 18. This broad cluster joins with first cluster at the approximate distance of 25. First cluster is consisted of sensitive area, residential area, village area and industrial area; Second, third and fourth cluster includes road intersection area, commercial area and mixed area respectively. Second and third cluster join at the approximate distance of 10 which join with fourth cluster at the approximate distance of 14. This broad cluster joins with first cluster at the approximate distance of 25.

5. Concentration Map on PM_1, $PM_{2.5}$, and PM_{10}

Fig 5 illustrates the concentrations of particulate matter (PM_1, $PM_{2.5}$, and PM_{10}) across various locations in the Sylhet Metropolitan area during 2021, expressed in µg/m³. Higher concentrations are depicted in red and orange, while lower concentrations are shown in yellow. In Fig 5 (a), PM_1 concentrations ranged from 78 to 107 µg/m³ in the Sadipur area, central Ward No. 1, and Ward No. 14, while moderate levels (58-77 µg/m³) were observed in Darga Gate (Ward No. 1) and large portions of Wards 3, 4, 5, 11, 12, and Kastoghar Road, extending through Wards 13, 15-22, and parts of Sylhet City Corporation. Lower PM_1 levels (below 57 µg/m³) were found in areas such as Government Agragami Girl's High School & College, Digonto, Kollo-gram, Rustampur, and eastern Kadimpara. Fig 5 (b) shows that $PM_{2.5}$ concentrations were highest (126-185 µg/m³) in Sadipur, central Ward No. 1, and Ward No. 14, with moderate levels (96-125 µg/m³) in Darga Gate and several wards across the city, while lower concentrations (below 95 µg/m³) were detected in similar areas as those noted for PM_1.

In Fig 5(c), PM_{10} concentrations peaked (164-223 µg/m³) in Sadipur, with moderate levels (124-183 µg/m³) across much of the same areas as those for PM_1 and $PM_{2.5}$, and lower concentrations (below 95 µg/m³) in Government Agragami Girl's High School & College, Digonto, Kollo-gram, Rustampur, and eastern Kadimpara.

Fig 5 (d) illustrates the AQI map for the Sylhet Metropolitan area based on $PM_{2.5}$ concentrations. The map employs a color-coded system to represent different AQI categories according to the Bangladesh National Ambient Air Quality Standards. In this system, AQI values are classified as follows: 0-50 indicates "Good," 51-100 is "Moderate," 101-200 denotes "Unhealthy for Sensitive Groups," 201-300 is "Unhealthy," and 301-500 represents "Very Unhealthy." The map reveals that all locations fall into the "Very Unhealthy" category, indicated by the orange color, with AQI values ranging from 301 to 500. These widespread color-coding highlights severe air quality conditions across the entire area.

Conclusion and Recommendations

Multiple sources, including increased urbanization, industrial emissions, vehicle pollution, and the uncontrolled burning of rubbish, contribute significantly to the increasing air pollution in Sylhet City Corporation. Recent assessments of particulate matter concentrations suggest that the air quality in the city is worsening. The Department of Environment recorded levels of PM_1, $PM_{2.5}$, and PM_{10} at 59.44 µg/m³, 97 µg/m³, and 124.91 µg/m³, respectively, which above the recommended safety guidelines. Upon analyzing the data related to various land uses, notable disparities in $PM_{2.5}$ concentrations were observed. The following list presents land uses in descending order based on their average $PM_{2.5}$ concentration: The air pollution levels in different regions are as follows: mixed-use area (106.54 µg/m³), commercial area (101.68 µg/m³), road crossings (98.50 µg/m³), residential area (93.58 µg/m³), sensitive areas (93.25 µg/m³), village areas (93.03 µg/m³), and industrial area (92.40 µg/m³). Significantly, the mixed-use area displayed a $PM_{2.5}$ concentration that was 1.63 times greater than the established acceptable threshold. Additional examination showed that $PM_{2.5}$ accounted for 77.55% of the total PM_{10} mass, whereas PM_1 comprised 63.36% of the $PM_{2.5}$ mass. The dispersion of PM_1, $PM_{2.5}$, and PM_{10} was most widespread in mixed and commercial neighbourhoods, whereas the range was tightest around road intersections and industrial regions. In mixed-use and commercial sectors, the standard deviation and coefficient of variation were higher, suggesting that there were larger variations in particulate matter concentrations in these zones. Box plot analysis revealed that the dispersion of PM_1, $PM_{2.5}$, and PM_{10} values was greater in commercial, mixed-use, residential, and sensitive areas, whereas concentrations were more tightly grouped at road crossings. The statistical tests indicated that there were no significant differences in the amounts of particulate matter (p-values > 0.05). This indicates a consistent pattern of high pollution across all examined locations, despite fluctuations. The results suggest that the air quality in Sylhet City Corporation, especially in the winter months, is consistently low, with levels of particle matter surpassing the prescribed requirements in most regions. Urgent action is required to prevent further deterioration of air quality. To improve the quality of the air in Sylhet City Corporation, it is imperative to implement more stringent rules, particularly in regions with high levels of pollution, such as mixed-use and commercial zones. It is critical to reduce automotive emissions by implementing better traffic management, improving public transportation, and promoting the use of electric vehicles. Increasing the size of urban green areas would aid in pollutant absorption, while improving waste management practices would effectively mitigate open burning, which is a significant contributor to pollution. Improving air quality monitoring guarantees prompt reactions to sudden increases in pollutant levels. Ultimately, it is crucial for public awareness campaigns to provide citizens with information about the detrimental health effects of air pollution and to promote actions such as minimising household emissions and refraining from using polluting fuels.

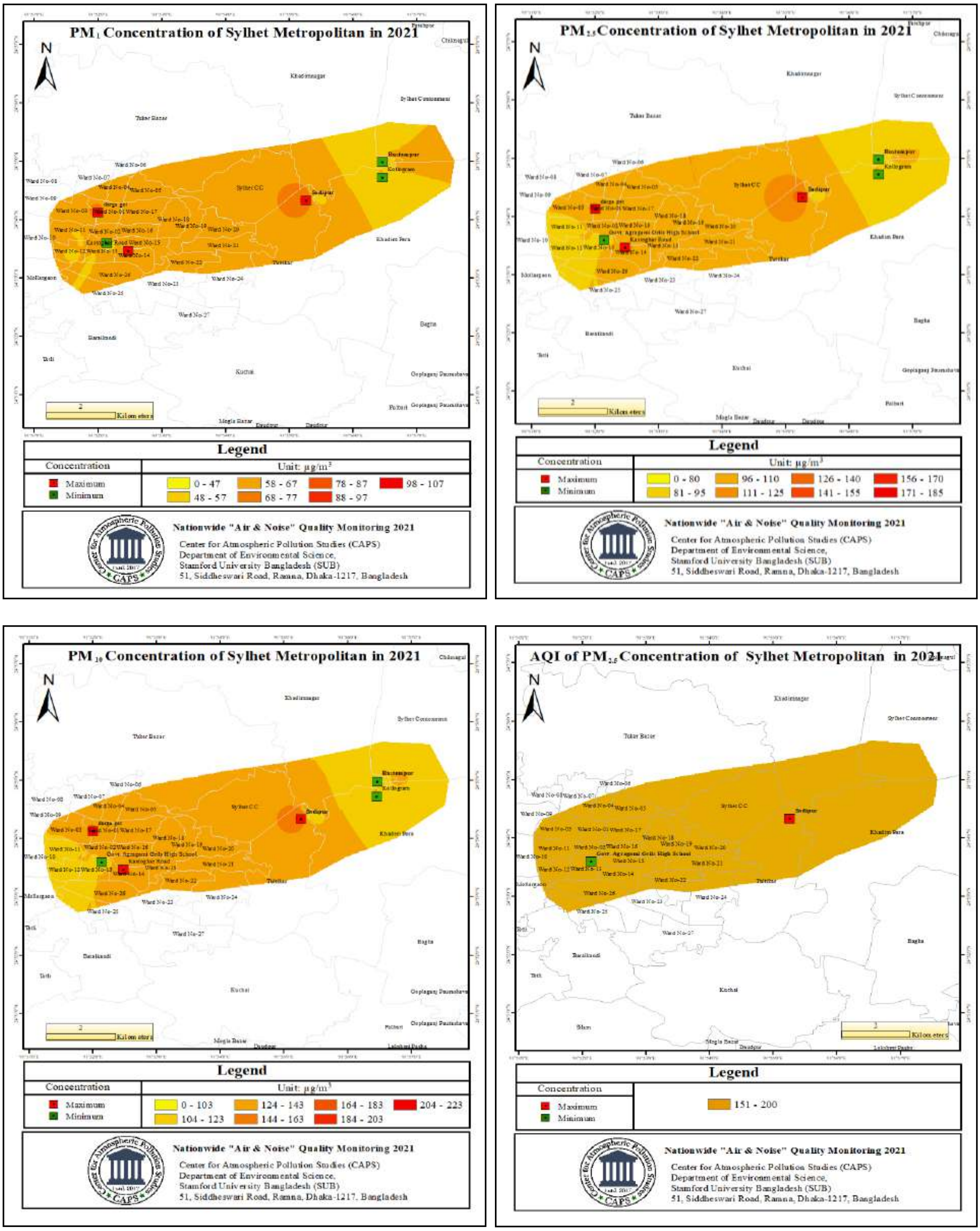

Fig 5: Concentration Maps of PM_1, $PM_{2.5}$, and PM_{10}, and AQI Map Based on $PM_{2.5}$ for Sylhet City Corporation Area in 2021

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