MIJRD Multidisciplinary International Journal of Research and Development

Multidisciplinary International Journal of Research and Development

Volume: 02 / Issue: 06 / 2023 - Open Access - Website: www.mijrd.com - ISSN: 2583-0406

Spatial Distribution of Air Quality in Lakshmipur District Town, Bangladesh: A Winter Time Observation

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Abstract— The district town is experiencing an upward trend in the amount of air pollution. The focus of this research is to monitor the concentration of particulate matter (PM_1, $PM_{2.5}$ and PM_{10}) in Lakshmipur district town based on its different land uses. This research has been carried out with the assistance of portable Air Quality Monitors in sixty distinct locations throughout the Lakshmipur district town. It was observed that, on average, sixty different places in the town of Lakshmipur district had concentrations of PM_1, $PM_{2.5}$ and PM_{10} that were 91, 149, and 193 μg/m3 respectively. The level of Bangladesh's National Ambient Air Quality Standards (BNAAQS) level has been determined to be exceeded by an average concentration of $PM_{2.5}$ and PM_{10} that was 2.29 and 1.29 times higher, respectively. The three most polluted places were Temuhoni CNG station (mixed area), Mia Bari Abasik (road intersection area), and Temuhoni mor (road intersection area), while the three least polluted were Khoya Sagar Degirpar, Banchanagar Beribad, and Eidgah Dalal Bazar three least-contaminated sites are villages. Also estimates, the ratio of $PM_{2.5}/PM_{10}$ was 77.11%, while the ratio of $PM_{2.5}/PM_{10}$ was 60.84%. Based on the findings of this study, the different types of land uses that were investigated have been ranked in descending order according to the average concentration of Particulate Matter (PM). The order is as follows: commercial area > residential area > road intersection area > industrial area > mixed area > sensitive area > village area.

Keywords— Air Pollution, Particulate Matters, Lakshmipur District, Spatial Distribution, Winter Observation.

I. INTRODUCTION

Around the world, air pollution is a severe health hazard [1]. A large portion of the world's population is exposed to increasing levels of air pollution that their risk of developing diseases like pneumonia, cancer, chronic obstructive pulmonary disease, heart disease, and stroke raises. World Health Organization (WHO) monitors air pollution exposure levels and negative health impacts on a national, regional, and international stage [2]. Air pollution can occur by the natural or anthropogenic removal of harmful substances into the atmosphere [3]. Both natural and anthropogenic activities cause particulate air pollution. The sources of anthropogenic activities can be both stationary and mobile [4]. Huge population expansion especially in the urban areas and rapid industrialization have led to dust deposition, biomass, and fossil fuel burning. This in turn has degraded the quality of air in developing countries such as Bangladesh. However, this issue is not only limited to urban regions but has also reached rural areas too [5]. The degradation of air quality occurs because of various human actions like the combustion of fossil fuel (i.e. coal, oil, natural gas, etc.) to power motor-engine vehicles, industrial machinery, brick kilns, industrial activities, etc. which generates many key pollutants in the atmosphere [6].

Along with widespread urbanization, and industrial emissions, high traffic congestion, and construction and demolition activities are the main generators of the various pollutants e.g. $PM_{2.5}$, PM_{10}, COx, NOx, SOx, dust, etc. which are found in most urban areas in Bangladesh, especially Dhaka [7].

A quick increase in urban population demands changes in land use patterns due to urban expansion. This has become one of the chief reasons behind the degradation of urban air quality in developing countries, where both indoor and outdoor air quality is worsening from the given standard [6].

Expansion in the level of emission and in the lower-mixing layer height including thermal inversions in brick kilns during the winter, are responsible for the rise in PM level [8]. Particulate matters are very tiny materials of solid or liquid matter and maybe of organic or inorganic nature. Industrial processes, burning of fossil fuel, farming, the dust raised by road building, large construction projects, industrial processes, and jet plane exhaust- all are responsible for the production of particulate matter [9].

Fine particulates can penetrate through the nose and throat, reach the lungs and cause breathing problems and irritation of the lung capillaries. Particulate pollution causes pulmonary fibrosis in asbestos mine workers, black-lung disease in coal miners, and emphysema in the urban population. Airborne particulates such as dust, mist, fumes, and soot can cause harm to various other substances, including damage to sculptures and paints, and accelerate corrosion of metals. The physical and chemical properties of the particulate matter determine the extent of damage it could cause. Particulates in the air could help in the formation of clouds and snow and may influence the climate. They also reduce visibility by absorbing solar radiation [10]. Women and children are at higher risk since they remain indoors more than others [11].

Indoor air pollution takes the lives of 1.5 to 2 million people worldwide annually, out of which 1 million are children up to the age of 5 years who die due to acute respiratory tract infection (ARTI) and women due to COPD and lung cancer [12]. Particulate matter can cause respiratory and cardiovascular diseases by penetrating the lungs [3]. There is a strong association between exposure to fine particles and premature death from heart and lung illnesses. Fine particles also cause chronic diseases such as cardiac arrest, bronchitis, asthma, and various other respiratory illnesses.

There is an epidemiological relationship between the concentration of fine particulate matter in the range of 10 to 30 $\mu g/m^3$ and morbidness and mortality rates in large populations. Particles that are finer have the ability to stay in the air for longer than heavier particles.

This increases their chances of getting inhaled by a living being. And due to their sheer size, they can infiltrate deep into the lungs where some may even reach the circulatory system, by passing through the nose and throat [13]. Around 1200 to 3500 people's lives could be saved each year, if the exposure to air pollution in urban areas could

MIJRD Multidisciplinary International Journal of Research and Development
Multidisciplinary International Journal of Research and Development
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be reduced to 20-80%, and to add to that it creates negative economic externalities for investment in the country [14]. Many researches have revealed that particles in the air, can influence climate change and have dreadful health effects. Atmospheric PM has a severe influence on agriculture and atmospheric chemistry due to its adverse effects on human health and reduction of visibility [5]. Last few years this particulate matter pollution is increasing at the district level. The objectives of the study:

- To identify the status of air pollution in Lakshmipur District Town.
- To assess the relationship between land use and all parameters (PM_1, $PM_{2.5}$ and PM_{10}).
- Geospatial mapping on the concentration of PM_1, $PM_{2.5}$ and PM_{10}.
- To identify the AQI of Lakshmipur based on PM2.5 and do the spatial map.

II. RESEARCH METHODOLOGY

This study was conducted in Lakshmipur District (Chattogram division) area of 1367.59 sq km, located between 22°30' and 23°10' north latitudes and in between 90°38' and 90°01' east longitudes [15]. Based on different land use, 60 locations were selected.

All locations were divided into seven types according to the use of land, which were 9 locations in sensitive area (hospitals and clinics, schools, colleges, mosques, madrasas, temples, churches, and administrative bhaban), 8 locations in residential areas, 4 locations in mixed areas (bazars, buildings, main roads), 13 locations in commercial areas, 6 locations in road intersection or busiest road junctions and bends, 10 locations in industrial area and 10 locations in village area.

The primary data of this study was gathered on a field survey from selected locations. As per the study three individual air pollutants: PM_1, $PM_{2.5}$ and PM_{10} were collected from those selected locations using Air Quality Monitor, model no. B07SCM4YN3. Moreover, IBM SPSS V22 and MS Excel 2020 were used for data analysis. ArcGIS 10.4.1. Version for preparing the concentration map of Lakshmipur district town area.

Collected data was input in an IBM SPSS V20 and MS Excel 2020, analysed it where descriptive statistics were done to know the dispersion of every parameter of land use and do an Analysis of Variance (ANOVA) for the significance test between land use and parameters. A formula was used for the conversion of the concentration of $PM_{2.5}$ to AQI in the study. To understand the concentration of particulate matter and gaseous pollutants different colour codes were used; along with that below equation has been applied to convert from concentration 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 equation above and applied to each pollutant. Here, 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 Clow, I_{high} = the index breakpoint corresponding to C_{high}.

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Table 1: Showing the list of the number of locations in each land use type

S. N.	Land Use Type	Number of Locations
1	Sensitive area	9
2	Residential area	8
3	Mixed area	4
4	Commercial area	13
5	Road Intersection area	6
6	Industrial area	10
7	Village area	10
	Total	**60**

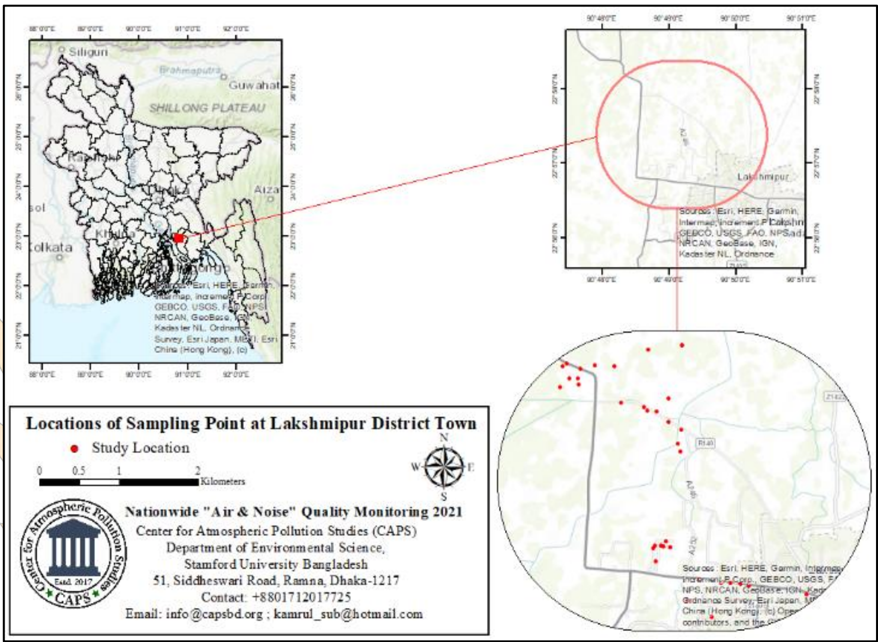

Figure 1: Study Area (Lakshmipur District Town Area and Data Collection Locations Point)

III. RESULT

Analysis of PM_1, $PM_{2.5}$ and PM_{10} on Different areas in Lakshmipur District

The status of air pollution in Lakshmipur District was investigated by comparing PM data from 7 areas (sensitive, residential, mixed, commercial, road intersection, industrial and village area) shown in figure 02 (a), (b), (c), (d), (e), (f) & (g).

Figure (a) indicates the concentration (μg/m³) of PM_1, $PM_{2.5}$ and PM_{10} in some locations in sensitive areas in Lakshmipur district town including administrative offices, educational institutes and mosques. It could be seen that among 9 sensitive places, the most polluted places were Forest office (120.5, 195.5 and 254.25 μg/m³), Moddho Banchnagar Primary Girls School (113.5, 191.5 and 244.75 μg/m³) and besides Titakha Mosjid (111.5, 184.5 and 237.75 μg/m³) respectively and comparatively less polluted place was Ansar camp with $PM_{2.5}$ concentration of 86.75, 96.25 and 110 μg/m³ respectively. It was also found that the levels of $PM_{2.5}$ and PM_{10} that

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had been found in the most polluted location were three and two times higher than the BNAAQS limit, which was set by the Department of Environment (DoE) to be 65 and 150 micrograms per cubic meter respectively.

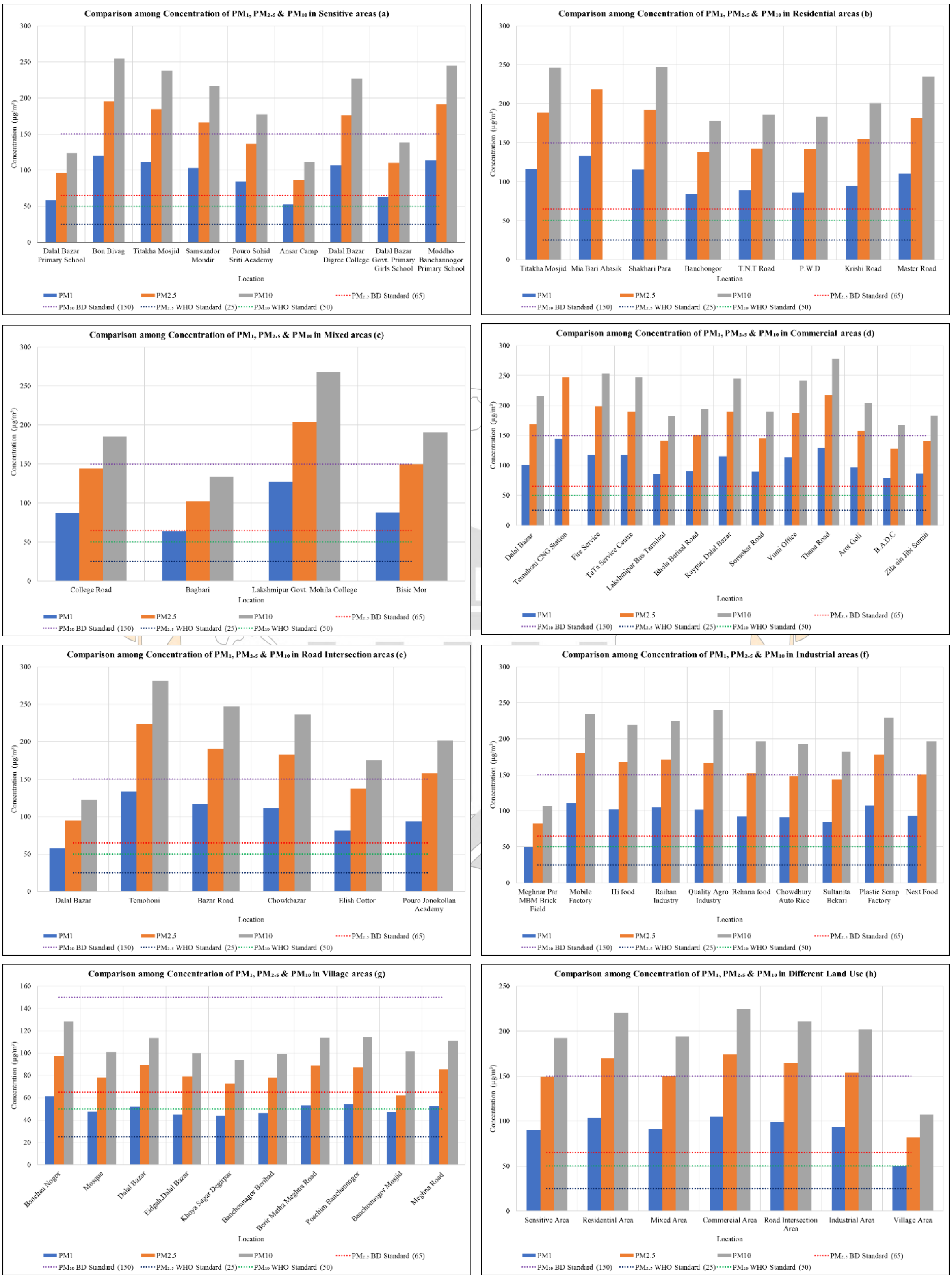

Figure 2: Comparison among Concentration of PM_1, $PM_{2.5}$ and PM_{10} in Sensitive Area, Residential Area, Mixed Area, Commercial Area, Road Intersection Area, Industrial Area, Village area & different Land Use.

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Besides, among 8 residential places, three highly polluted places were Mia Barie Abashik, Shakhari Para mor and Titakha Mosjid with PM concentration of 133.25, 218.75 and 283.25 μg/m^3, 115.5, 192.25 and 247.25 μg/m^3 and 116.75, 189 and 246.5 respectively. Comparatively less polluted places were Banchongor, P.W.D and T.N.T road with $PM_{2.5}$ concentrations of 138, 142.5 and 141.5 μg/m^3 respectively. It was also noted that the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted places were 3.16 and 1.89 times higher than the national level. In addition to using solid cooking fuels, there are more than 60 other risk factors linked to the burden of residential air pollution increasing which contributes to outdoor air pollution also [16]. The motor vehicle including two strokes contributes about 48% of the $PM_{2.5}$ mass in the case of semi-residential area Dhaka [17]. The outside of Lakshmipur Govt. Mohila College was the most polluted site among the four mixed places. It had PM concentrations of 127, 204.25, and 267.75 μg/m^3, while Bag Bari had PM concentrations of 64, 102, and 133.75 μg/m^3 respectively. The least polluted place was Bag Bari. On the other hand, the levels of $PM_{2.5}$ and PM_{10} that researchers observed in the polluted were respectively 3.14 and 1.79 times higher than the standard level. According to the findings of the study, in all mixed regions, 77.11% of the $PM_{2.5}$ that was present in PM_{10} was also present in $PM_{2.5}$, and 61.09% of the PM_1 that was present in $PM_{2.5}$ was also present. The outside of Lakshmipur Govt. Mohila College was the most polluted place of the four mixed places with PM concentration of 127, 204.25 and 267.75 μg/m^3 while the comparatively least polluted place was Bag bari with PM concentration of 64, 102 and 133.75 μg/m^3 respectively. However, the concentrations of $PM_{2.5}$ and PM_{10} found in the polluted location were 3.14 and 1.79 times higher than the national standard level. The study estimated that in all mixed areas, 77.11% of $PM_{2.5}$ was present in PM_{10} and 61.09% of PM_1 was present in $PM_{2.5}$. The study identified that out of 6 road intersection places, three highly polluted places were Temohonie (133.75, 224 and 281.75 μg/m^3), Bazar Road (116.5, 190.75 and 247.5 μg/m^3) and Chowbazar (111, 183.25 and 236.5 μg/m^3) respectively and relatively less polluted places were Dalal Bazar Elish chatter and Pouro Jonokollan Academy with $PM_{2.5}$ concentration of 94.5 μg/m^3, 137.5 μg/m^3 and 157.75 μg/m^3 respectively. It was also observed that the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted places were 3.44 and 1.87 times higher than the national level. The study estimated that the ratio of $PM_{2.5}$ /PM_{10} was 78%. It was also found that 60.24% of PM_1 mass was present in $PM_{2.5}$. along with that from 13 commercial places, Thana Road, Fire service office and Tata Service center were highly polluted places with PM concentration of 129.25, 217.25 and 278.25 μg/m^3, 117, 199 and 253.25 μg/m^3 and 117.75, 189 and 247.25 μg/m^3 respectively and comparatively less polluted places were Bangladesh Agriculture and Development Commission, Lakshmipur bus terminal and Bar Council office respectively. The study also observed that the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted places were 3.34 and 1.85 times higher than the national standard level. More than 50% of the total particulate air pollutants are emitted from the traffic sector, in many countries. Black diesel smoke is emitted from the old and heavily loaded trucks in the industrial areas due to the combination of hill areas and congested traffic [4]. Among 10 industrial places, Agricultural Industry, Mobile Factory and Plastic Scrap Industry with PM concentrations of 101.25, 166.5 and 239.75 μg/m^3, 110.5, 180.25 and 234 μg/m^3 and 107.25, 178.25 and 229.25 μg/m^3 respectively were highly polluted and comparatively less polluted places were Meghnar Par MBM Brick Field, Sultanita Bekari and Chowdhury Auto Rice with $PM_{2.5}$ concentration of 82.75, 143 and 148.50 μg/m^3 respectively. The study also observed that the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted places were 2.56 and 1.56 times higher than the Standards level. The study estimated that the ratio of $PM_{2.5}$ /PM_{10}

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was 76.40% and PM_1/ $PM_{2.5}$ was 60.73%. In the study, out of 10 village areas, the most polluted place was Banchanagar with PM concentration of 61.25, 97.75, and 128.25 μg/m^3 respectively and the least contaminated place was Banchanagar mosque with PM concentration of 47, 62.25 and 101.75 μg/m^3 respectively.

The study observed that the concentrations of $PM_{2.5}$ found in the most polluted place were 1.50 times higher than the national standards level. It was also noted that the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted place were 3.91 and 2.57 times higher than the WHO standard. It was reflected in a study that rural areas experience air pollution as a result of both natural and human-caused activity. The quality of the air in rural areas is significantly influenced by meteorological variables. Agricultural activity is the most significant human contributor to the current issue of air pollution in rural areas.

Threshing operations, grain dust, and the widespread use of tractors, combines, and diesel-powered tube wells are significant contributors to air pollution. Additional major contributions include burning crop residue in the field after harvesting has been completed. [18]. In Bangladesh, unplanned urbanization, industrial development, and excessive resource consumption are the main contributors to air pollution. The elemental composition of the atmosphere has significantly changed as a result of increased fossil fuel use.

The atmosphere contains significant amounts of air pollutants such as ozone (O_3), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NOx), particulate matter ($PM_{2.5}$ and PM_{10}), volatile organic compounds (VOCs), and heavy metals [19]. In the figure 9 shows the comparison of the average concentration of PM_1, $PM_{2.5}$ and PM_{10} of seven land uses in Lakshmipur district town.

The average concentration of PM_1, $PM_{2.5}$ and PM_{10} was higher in the commercial area and residential area and road intersection area with values of 105, 174 and 224 μg/m^3; 104, 170 and 220μg/m^3 and 99, 165 and 211 μg/m^3 respectively with highest in the road intersection area. The concentration of PM was found relatively lower in industrial areas, village areas, and residential areas. Moreover, the average concentration of PM_1 (93.38 μg/m^3), $PM_{2.5}$ (154.18 μg/m^3) and PM_{10} (199.50 μg/m^3) were found to be the least in industrial area.

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

The following table 02 shows the descriptive statistics analysis for PM_1, $PM_{2.5}$ & PM_{10} of the studied seven land uses. The highest range was found in the road intersection area (76, 130 and 160 μg/m^3) for three of the concentrations and lower ranges were found in the village area (18, 36 and 35 μg/m^3) for particulate matters.

Among all those land uses the highest mean value of PM_1, $PM_{2.5}$ & PM_{10} were found in commercial area (105, 174 and 224 μg/m^3) and the lowest mean was found in village area which were 50, 82 and 108 μg/m^3 respectively. As before the findings for three different particulate matters the highest standard deviation was seen in the road intersection area (27, 45 and 57 μg/m^3).

Therefore, the lowest standard deviation and coefficient of variation were seen in the same area (village). Though the highest coefficient of variation was seen in sensitive areas with a value of 29% and the lowest variation seen in village area (10%).

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Table 2: Descriptive Statistics for PM_1, $PM_{2.5}$ & PM_{10}

Serial Number	Land Use	No. of Locations	PM_1				$PM_{2.5}$				PM_{10}			
			Range (µg/m³) (Min-max)	Mean (µg/m³)	Std. Deviation (µg/m³)	Coefficient of Variation (%)	Range (µg/m³) (Min-max)	Mean (µg/m³)	Std. Deviation (µg/m³)	Coefficient of Variation (%)	Range (µg/m³) (Min-max)	Mean (µg/m³)	Std. Deviation (µg/m³)	Coefficient of Variation (%)
1.	SA	9	68	90	26	29	109	149	43	29	143	192	56	29
2.	MA	4	63	92	26	29	102	150	42	28	134	195	55	28
3.	RA	8	49	104	18	17	81	170	30	18	105	220	38	17
4.	RIA	6	76	99	27	27	130	165	45	28	160	211	57	27
5.	CA	13	65	105	19	19	119	174	35	20	147	224	43	19
6.	IA	10	61	94	18	19	98	154	28	18	134	202	39	19
7.	VA	10	18	50	5	11	36	82	10	12	35	108	10	10
SA-Sensitive area, MA-Mixed area, RA-Residential area, RIA- Road Intersection Area, CA-Commercial area, IA-Industrial area, and VA- Village area														

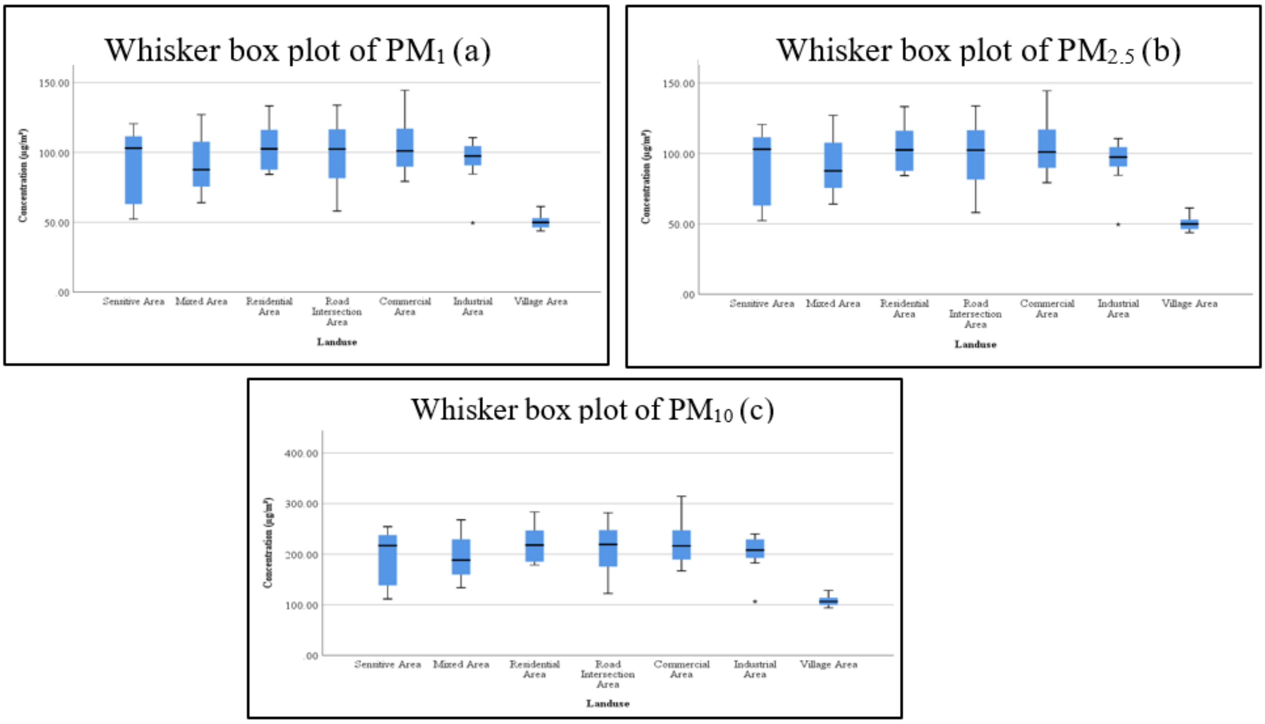

Figure 3: Whisker box plot of PM_1, $PM_{2.5}$, PM_{10} for seven study zone

PM_1, $PM_{2.5}$ and PM_{10} dendrogram plots derived via cluster analysis with Z-score standardization had been shown in figure 4 (a), (b) and (c). As part of this analysis, group linkage and Euclidean distance were considered. There were determined to be third clusters in the graphs. The dendrogram of PM1 showed that the first cluster consisted of the residential area, commercial area, road intersection area; second cluster consisted of mixed area, industrial area and sensitive are respectively; and third cluster included village area alone. Moreover, the dendrogram of

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$PM_{2.5}$ and PM_{10} showed that the cluster consisted of sensitive area, mixed area, and industrial areas; the second cluster was composed of residential areas, commercial areas and road intersection area respectively; and the third cluster included village area only. Figure 4 (a), (b) and (c) shows that the first and second clusters of PM_1, $PM_{2.5}$ and PM_{10} join at an approximate distance of 2. Further, these three figures showed that the first joined with third clusters of PM_1, $PM_{2.5}$ and PM_{10} joined at an approximate distance of 25.

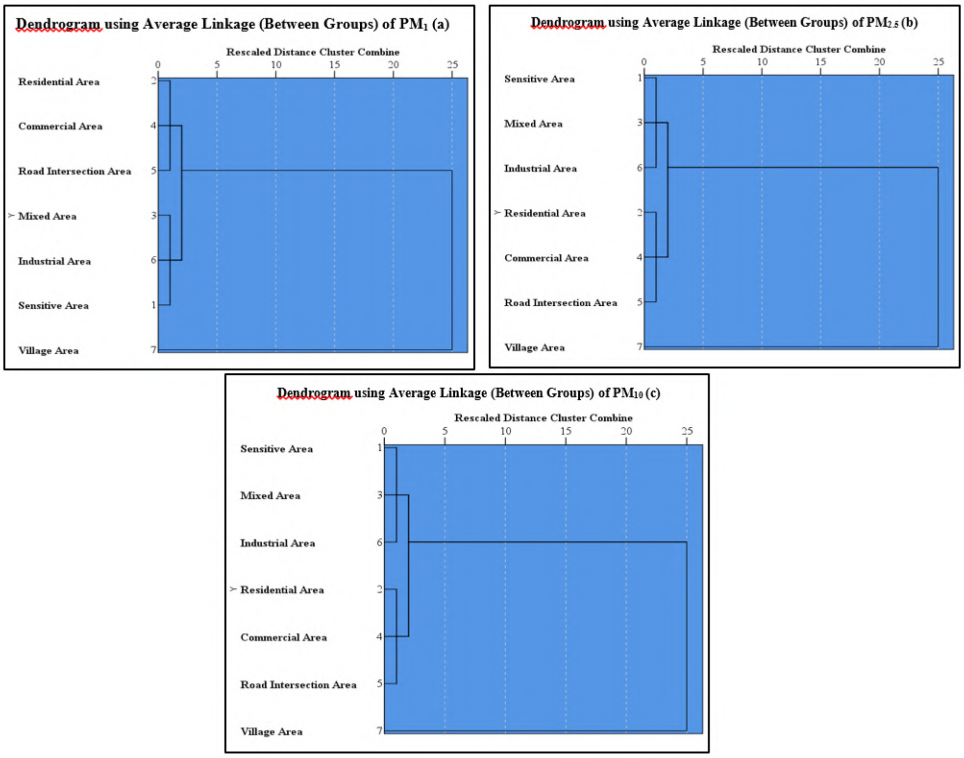

Figure 4: Rescaled Distance Cluster Combine for PM_1, $PM_{2.5}$ and PM_{10}

Significance Test

Table 3 shows 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 8.773 for PM_1, 8.762 for $PM_{2.5}$, and 8.534 for PM_{10} respectively. P values are 0.00 for PM_1, $PM_{2.5}$ and PM_{10}. The following tables revealed that the concentrations of parameters change as the p values less than 0.05. Therefore, the concentration of PM might change significantly between and within the land uses.

Table 3: Significance Test

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
PM1.0	Between Groups	20894.255	6	3482.376	8.773	.000
	Within Groups	21038.829	53	396.959		
	Total	41933.083	59			
PM2.5	Between Groups	58306.578	6	9717.763	8.762	.000
	Within Groups	58777.975	53	1109.018		

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	Total	117084.553	59			
PM10	Between Groups	94213.068	6	15702.178	8.534	.000
	Within Groups	97517.360	53	1839.950		
	Total	191730.428	59			

Interpolation Map of PM_1, $PM_{2.5}$ and PM_{10} in Lakshmipur District Town

Spatial analysis of Particulate Matter (PM) in Lakshmipur District was represented by a Chorochromatic map. The concentration of Particulate Matter (PM) at selected locations of Lakshmipur District town in the year 2021 are shown in fig. 5 (a), (b) & (c). These maps represent the concentration of PM where the Southern part of the city is shown to be significantly more polluted than the Northeast part. The Particulate Matter concentrations here are represented with µg/m3 in the Interpolation maps below. The colors, yellow, orange and red show how concentrated with PM an area is; starting with yellow being the lowest, to increasing to orange and then red, being the highest. PM_1 was found to be highest in the Southern part and some of the Northwestern parts of Lakshmipur, ranging in concentration of 105-144 µg/m3, covering parts of Ward No. 4, 5, 6, 7, 8, 9 and 12. Among these, the most concentrated area is located at Ward No. 5. $PM_{2.5}$ is also the highest in the district town at Ward No. 5 in the South, with a concentration of 243-272 µg/m3. Highest PM_{10} concentration of the area ranges from 275-334 µg/m3, located at parts of Ward No. 1, 4, 5 and 7. All three types of Particulate Matter (PM) are found to be at its peak at Ward No. 5.

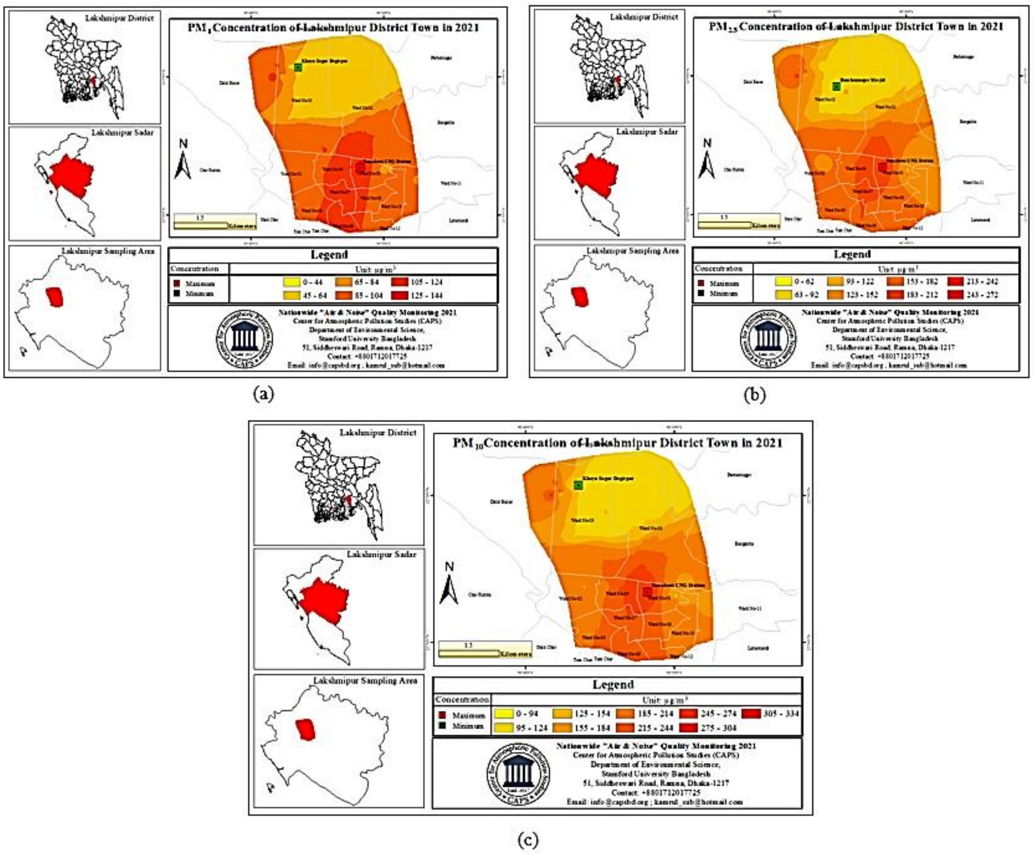

Figure 5: PM_1, $PM_{2.5}$ and PM_{10} Concentration Map of Lakshmipur District Town in 2021

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AQI on $PM_{2.5}$ Concentration in Lakshmipur District Town

The Air Quality Index (AQI) of Lakshmipur district has been represented by different colors in figure 6. The analysis was done according to the Air Quality Index (AQI) set by Department of Environment (DoE) for Bangladesh. The air quality was classified as good (0-50) for green, moderate (51-100) for yellow green, unhealthy for sensitive groups (101-150) for yellow, unhealthy (151-200) for orange, very unhealthy (201-300) for red and hazardous (300+) for purple. Study shows that good, moderate and hazardous AQI levels are absent in the area, only unhealthy and very unhealthy are seen to be present. The map shows that AQI was very unhealthy, mostly in the Southern part of the city and Northeast part of Dalal Bazar, which are indicated with red color. The map also represents that the AQI was found to be the maximum in Temuhoni CNG Station, where it was marked red, and the least AQI was found in Banchonogor Mosjid, which is notified through the green flag.

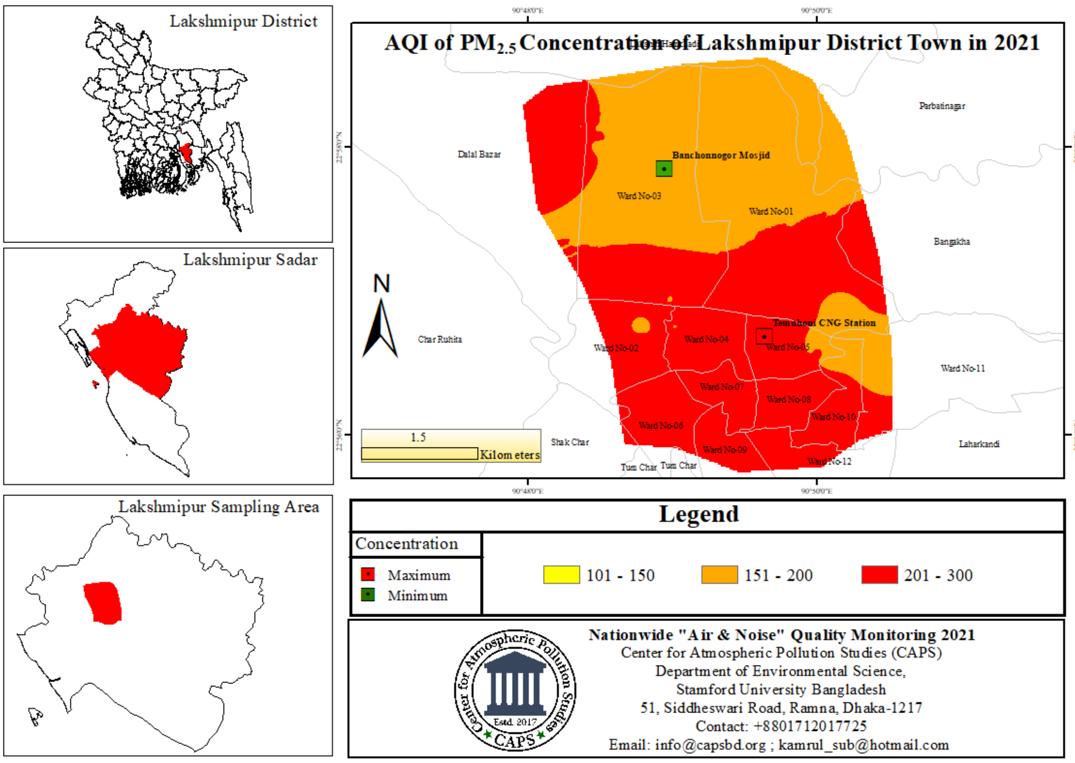

Figure 6: AQI on $PM_{2.5}$ Concentration Map of Lakshmipur District Town in 2021

III. CONCLUSION

According to the above paper's analysis of the atmospheric particulates matter in the Lakshmipur district region, Bangladesh's rural areas are now much more at threat from air pollution. An increase in air pollution in Bangladesh is a reflection of the country's industry and fast unplanned urbanization. As a result, there is pollution of the air, water, and noise.

The Lakshmipur district area is evaluated for air pollution in this study. The leading sources of this pollution are emissions from old motor vehicles, open burning of waste, traditional cooking stoves, construction activities and road dust. The average concentrations of PM in the Lakshmipur district were found to be higher. The average PM concentrations in study areas were assessed to be 105, 174 and 224 µg/m3 respectively. The ANOVA tables revealed that the concentrations of none of the parameters changes significantly. From the AQI map, it was observed that Temuhoni CNG station area in Lakshmipur was found very unhealthy. Air pollution and climate change are strongly connected.

To reduce air pollution in Lakshmipur district, it is recommended that the relevant authority should give special consideration to raising public awareness about the negative effects of air pollution and taking immediate steps to reduce health risks caused by air pollution. Furthermore, upgrading conventional cooking stoves, using stacks to treat industrial emissions, covering construction materials during transportation time, and maintaining old vehicles are all required to improve air quality, the government of Bangladesh should strictly enforce the Air Pollution Control Rules, 2022 as soon as possible to reduce pollution.

IV. CONFLICT OF INTEREST

The author declares that there are no conflicts of interest.

V. ACKNOWLEDGEMENT

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

VI. AUTHORS' BIOGRAPHY

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