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

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Abstract- Air pollution is the biggest threat to human survival, particularly in emerging nations. The objective of this study is to estimate the Particulate Matter (PM_1, $PM_{2.5}$ and PM_{10}) and Carbon Monoxide (CO) concentration in Manikgonj district town. This study was conducted on 60 locations based on seven land use in Manikgonj district town, by using a portable Air Quality Monitor and portable CO meter. It is found that average concentrations of PM in 60 places in Manikgonj district town were 61.96, 101.95 and 132.19 µg/m3 respectively which were 4 and 2.5 times higher than World Health Organization (WHO) standard levels. It is estimated that the average $PM_{2.5}/PM_{10}$ was 77.25% and $PM_1/PM_{2.5}$ was 60.80%. The average concentration of $PM_{2.5}$ in different land-use was found higher which is 1.57 folds than the daily Bangladesh National Ambient Air Quality Standard (NAAQS) level. The average concentration of CO was found 1.1 to 2.15 times higher than standard level. Further found that the changes in the concentration of all the selected parameters within land uses were significant. The average concentration of $PM_{2.5}$ follows as commercial area > road intersection area > village area > sensitive area >mixed area > industrial area > residential area. Air pollution can reduce by making people aware of it as well as implementing the law.

Index Terms- Particulate Matter, Concentration, Manikgonj District town, Distribution, ANOVA, Cluster.

I. INTRODUCTION

Air pollution may be defined as an atmospheric condition in which various substances are present at concentrations high enough above their normal ambient levels to produce a measurable effect on people, animals, vegetation, or materials. The word 'substances' refers to any natural or manufactured chemical elements or compounds capable of being airborne, which can be in all or either of the gaseous, liquid and solid form [1]. It consists of any substance whether they are environmentally threatening or benign. However, the term 'measurable effect' generally restricts attention to those substances that are the roots of undesirable effects. Air Quality has deteriorated both due to human activities and natural phenomena such as windblown dust particles. Recently, air pollution has received priority among environmental issues in Asia as well as in other parts of the world [2]. Exposure to contaminated air is the most severe environmental threat to human health in different towns and cities. Bangladesh is at the highest position in the Air Quality Report for the years 2019 and 2020 in terms of air pollution [3, 4]. As is evident in the report, about 7 million people expire per year in the world due to air pollution. An approximate population of 1 lakh 58 thousand Bangladeshi people died of air pollution in 2018 [2]. Pollutants are taking a rising percentage in suburban areas with urban areas, especially surrounding the realm of Dhaka city. With reference to the study area in question, particulate matter pollution has arisen in Manikganj district town [5]. Fossil fuel burning and biomass also happen to generate fine particles that we know as $PM_{2.5}$ [6]. The emission of particulate matter is dependent on the design of the vehicle engines when the engine is underpowered and poorly maintained and if there is fuel loss from overfueling [7]. PM originates from a variety of sources; such as power plants, industrial processes, transports, brick kilns, biomass burning, wind-blown dust, and sea spray, and also, they are formed in the atmosphere by the transformation of gaseous emissions [8-10]. Gazipur,

Manikganj, Barisal, Noakhali, Chittagong, Faridpur and Kustia and Pabna are being polluted where PM concentration is 3-6 times higher than standard level [11]. Rana et al., 2015 found that during colder months, the PM10 levels in Dhaka, Gazipur, and Narayanganj were, respectively 257.1, 240.3, and 327.4 g/m3. Another study found that Joydebpur (Gazipur) has higher $PM_{2.5}$ and PM_{10} levels than Farmgate (Dhaka) because to longdistance transportation and brick kilns. A different study discovered that other locations have different types of PM ranges from 0.3µm to 5 µm [12]. Air pollution seriously affects the respiratory tract and causes high respiratory disease, headache, asthma, high blood pressure, and even cancer. One of the most stubborn problems is irritation of the eyes or throat, coughing, sneezing, high fever, etc. [13-16]. The mental capability of children will be adversely affected by PM pollution, which can also affect the central nervous system and can be the breeding ground for renal damage and hypertension [1.18]. Pollutants, especially $PM_{2.5}$ considered to be more harmful due to their

characteristics; it is capable of traveling deeper, into internal parts of the respiratory system and can also pass through the alveoli into the bloodstream that causes premature mortality, and lung cancer and increasing the risk of respiratory and heart disease. Developing countries like Bangladesh suffer $PM_{2.5}$ exposures that are four to five times more than developed countries and worldwide, air pollution is the fifth risk factor for mortality [17-19]. Majumder et al., 2020 [7] found that PM levels changed periodically, accelerating during the winter and going down during the wet seasons. It has also been mentioned that annual $PM_{2.5}$ concentration was 5-6 folds and PM_{10} concentration was 3 folds higher than the BNAAQS level. The effects of long-term exposure to elevated ambient concentrations of CO are often associated with cardiovascular problems among exposed individuals. Acute exposure to high concentrations of CO

II. METHODOLOGY: SITE SELECTION AND DATA COLLECTION AND PROCESSING

Manikgonj Sadar is an upazila of Manikgonj district in the division of Dhaka, Bangladesh. Manikganj district town is located at 23.8644° N, 90.0047° E. [21]. In the study of concern, we considered 4 important parameters. These 4 parameters are Particulate Matter (PM_1, $PM_{2.5}$ and PM_{10}) and Carbon monoxide (CO) along with the 60 locations that were selected on the basis of land use. 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. There is a total of 10 sensitive areas selected, which include hospitals and clinics, schools, colleges, mosques, madrasas, temples, churches, and administrative bhaban. On the other side, mixed areas contain bazars, buildings, main roads, etc. The rest of the 50 locations were categorized into residential areas with 10 locations, mixed areas having 4 locations, commercial areas including 8 locations, road intersection or busiest road junctions and bends in 8 locations, industrial areas of 10 locations and village area consisting of 10 which can also affect the central nervous system and can be the breeding ground for renal damage and hypertension [1.18]. Pollutants, especially $PM_{2.5}$ considered to be more harmful due to their may result in CO poisoning with an onset of symptoms including nausea, vomiting, headaches, shortness of breath, and confusion, and can quickly lead to death [17, 20].

The objectives of the Study:

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

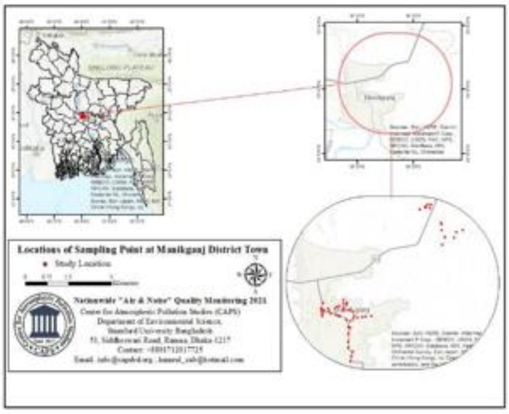

Fig 1: Study Area (Manikganj District Town Area and Data Collection Locations Point)

1. Data Collection

As part of the survey, Air Quality was measured in different locations of Manikganj district town area with the help of various automated portable instruments named Air Quality Monitor and Handheld Carbon Monoxide Meter and GPS data was also collected by an android software name "GPS Location Camera". Four individual data of PM_1, $PM_{2.5}$, PM_{10} and CO were collected from each location. Data were collected from 60 different locations by the CAPS team. Data were collected at different times in a seven-day time frame from morning to late evening.

2. Data Processing

Collected data was input in an IBM SPSS V20 and MS Excel 2020, and analyzed where descriptive statistics were done to know the dispersion of every parameter of land use and an ANOVA for significance test between land use and parameters. A formula was used for the conversion of the concentration of $PM_{2.5}$ and PM_{10} to AQI in the study. Different colors were used to understand the concentration of particulates matters and gaseous pollutants. This equation was used for the formula for conversion- to convert from concentration to AQI:

$$I_P = \frac{(I_{HI} - I_{LO})}{BP_{HI} - BP_{LO}}(C_P - BP_{LO}) + I_{LO}$$

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 C low, I high = the index breakpoint corresponding to C high.

III. RESULT AND DISCUSSIONS

1. Analysis of PM_1, $PM_{2.5}$, PM_{10} and CO on Different Areas in Manikganj District

Figure 2 (a, b, c, d and e) displays the PM concentration (µg/m3) of some locations in sensitive, mixed, residential, road intersection and commercial areas in Manikgonj district town. Among these 10 sensitive places, in front of Government Debendronath College and outside of Aftabia Jame Masjid with the concentration of PM 82.25, 141.50 and 179.00 µg/m3 and75.50, 122.75 and 159.75 µg/m3 two were highly polluted followed by Manikganj Govt. High School with $PM_{2.5}$ concentration of 105 µg/m3 where comparatively less contaminated places were outside of Govt. Debendro Collage, outside of Manikganj Sorkari Mohila Collage and near Sadar Thana Manikganj with $PM_{2.5}$ concentrations of 67.25, 80.75 and 85.75 µg/m3 respectively. However, it has also been noted that the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted places were 2.18 and 1.19 times higher than Bangladesh National Ambient Air Quality Standards (NAAQS) levels which are 65 and 150 µg/m3 set by the Department of Environment (DoE).

As it is visible, 4 mixed places and 2 polluted places were found in Belayet Hossen road with $PM_{2.5}$ concentration of 97.75 µg/m3 and near Bitul Mamur Jame Mosque with $PM_{2.5}$ concentration of 96.00 µg/m3; and the comparatively less polluted places were near Government women Organization and outside of Dutch Bangla Manikganj with the $PM_{2.5}$ concentration of 89.50 and 90.50 µg/m3 respectively. Observation also shows that concentration PM concentrations of Belayet Hossen road were 60.50, 97.75 and 127.50 µg/m3; and near Government Women Organization were 53.00, 89.50 and 114.00 µg/m3. In the year 2016, the highest $PM_{2.5}$ concentration was found at 152.0, 181.0, and 178.7 µg/m³ at Nawabganj, Manikganj, and Dhaka city respectively [11]. Power plants present in different areas may be the cause of expanding pollution. The collected information also indicates that the $PM_{2.5}$ concentration recorded from the highest contaminated location was 1.50 times higher than the NAAQS limit. Also, in the most polluted location, the concentration of $PM_{2.5}$ was 3.91 times and PM_{10} was 2.55 times higher than WHO standard level. The Air Quality Standards (24-hour) set by the WHO for $PM_{2.5}$ and PM_{10} are 25 and 50 µg/m3 respectively.

It has been found that out of 10 residential places, three polluted places were Nimtoli, Bonogram residential area and Durgamondir road with $PM_{2.5}$ concentrations of 109.25, 100.00 and 98.25µg/m3 respectively and comparatively less polluted places were Professor Housing Society, North Bonogram and West Bonogram with $PM_{2.5}$ concentration of 79.50, 82.50 and 82.50 µg/m3. It has been observed that concentrations of PM_1, $PM_{2.5}$ and PM_{10} of Nimtoli and Professor Housing Society were 69.25, 109.25 and 140.50µg/m3 and 49.50, 79.50 and 104.00µg/m3 respectively. It was also noted that the concentrations of $PM_{2.5}$ found in the most polluted place was 1.68 times higher than the NAAQS level. Also, the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted location were 4.37 and 2.81 times higher than WHO standard level respectively.

Again it has been found that out of 8 road intersection places, one highly polluted place was Chouraster mor with PM concentration of 75.75, 127.00 and 162.75 µg/m3and two polluted places were Singgail road, Chowrasta and Begam Jarina Collage mor with the $PM_{2.5}$ concentration of 110.25 and 109.00 µg/m3 respectively and comparatively less polluted places Khilpar, Manikganj Bus Stand and Department of Agricultural Extension, Bazar Bridge mor with the $PM_{2.5}$ concentration of 96.25, 100.00 and 102.25 µg/m3 respectively. The concentrations of $PM_{2.5}$ and PM_{10} discovered in the most polluted place were 1.95 and 1.085 times higher than the NAAQS level in the road intersection area.

In this study among 8 Commercial places, three highly polluted places were Shahid Rofiq Road, Manikgonj Bazar and Dudh Bazar with the PM concentration of 123.50, 216.00 and 271.25 µg/m3, 110.75, 180.50 and 234.25 µg/m3 and 67.75, 114.75 and 162.67 µg/m3 respectively and comparatively less polluted places were Customs, near Shonali Bank Manikgonj and Pubali Bank Manikganj with the $PM_{2.5}$ concentration of 86.75, 97.00 and 97.50 µg/m3 respectively. For commercial areas, $PM_{2.5}$ and PM_{10} concentrations found in the most polluted place were 3.32 and 1.81 times higher than NAAQS levels.

Figure 2 (f and g) displays the concentration (µg/m3) of PM of some locations in industrial and village areas in Manikgonj district town. Selected 10 industrial places, Corbel International with PM concentration of 113.50161.75 and 241.50 µg/m3 was the highly polluted place and Iron & Arsenic removal water treatment plant and Eraton with PM2.5 concentration of 111.00 and 95.25 µg/m3 were in 2nd and 3rd position and comparatively less polluted places were Kalam cotton enterprise, Family Products and Nayeem Enterprise with the $PM_{2.5}$ concentration of 68.75, 69.00 and 69.50 µg/m3. The concentrations of PM2.5 and PM10 found in the most polluted place were 2.49 and 1.61 times higher than the NAAQS level. Tasnuva et al., (2014) investigate the concentration of air pollutants at Kushtia sugar mills, it is found maximum concentration of PM10 was 380.339 µg/m3.

Among 10 selected village places, one highly polluted place was Golora Jame Mosque with PM concentration of 129.00, 212.75 and 274.50 µg/m3 and two polluted places were Daira, Vhobanipur and Khanbari mor, Chandipara with the $PM_{2.5}$ concentration of 129.75 and 116.75 µg/m3 respectively and comparatively less polluted places were Middle Golora, Golora and Chandi guora with the $PM_{2.5}$ concentration of 70.25, 74.25 and 76.75µg/m3 respectively. It was also established that the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted place were 3.27 and 1.83 times higher than the NAAQS level. Among the average concentration of PM of seven land uses in Manikgonj district town the highest was found in the commercial area (76.16, 125.91 and 164.52 µg/m3) followed by road intersection area (63.97, 106.81 and 137.19 µg/m3) and village area (63.95, 105.43 and136.08 µg/m3) respectively. Mondol et al., 2014 estimated that in Dhaka, Noakhali, Chittagong, Faridpur and Kustia the average values of total suspended particulate matter were 413.02,671.65, 292.63, 301.13 and 184.09 g/m3 respectively. It was also noted that the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted area were 1.94 and 1.0968 times higher than the NAAQS level. Here, concentrations of PM were found relatively lower in residential areas, industrial areas and mixed area. Moreover, the average concentrations of PM_1 (54.80 µg/m3), $PM_{2.5}$ (90.85 µg/m3) and PM_{10} (116.78 µg/m3) were found to be the least in residential areas.

In figure 2(h) illustrate the comparison of average CO concentration among seven land use in Manikgonj district town. In this study, the graph shows that the average CO was found to be higher in the commercial area, sensitive area, road intersection area and mixed area which are also higher than the standard level.

The average concentration of CO in commercial area, sensitive area, road intersection area and mixed area were found 19.38, 15.80, 10.75 and 10.00 ppm respectively. The CO concentration was 1.1 to 2.15 times higher than the NAAQS level, being 9 ppm (8-hour) set by the Department of Environment (DoE). Whereas, the average concentration of CO of residential area, village area and industrial area where the concentration did not exceed the standard level. The average concentrations of CO were found least in industrial area.

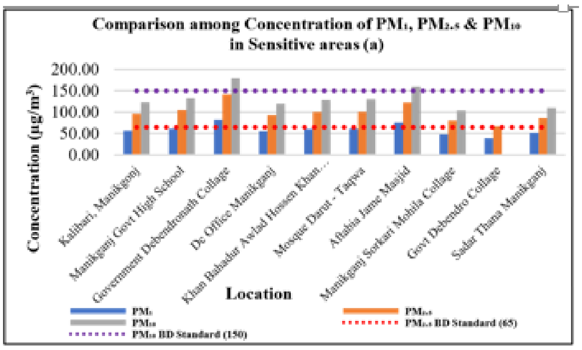

Fig 2 (a): Comparison among concentration of PM_1 $PM_{2.5}$ and PM_{10} in sensitive area

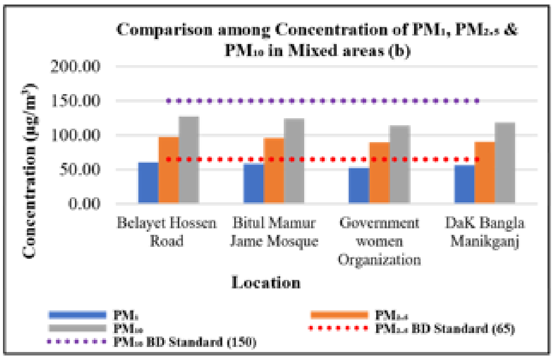

Fig 2 (b): Comparison among concentration of PM_1 $PM_{2.5}$ and PM_{10} in mixed area

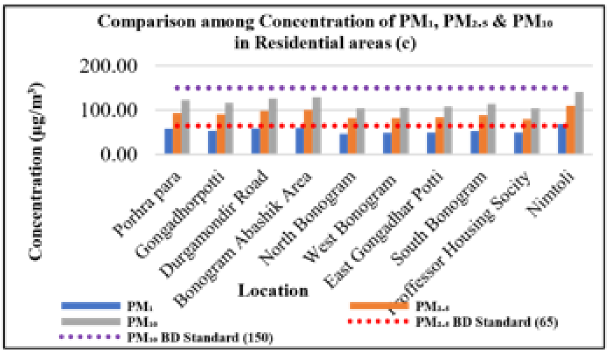

Fig 2 (c): Comparison among concentration of PM_1 $PM_{2.5}$ and PM_{10} in Residential area

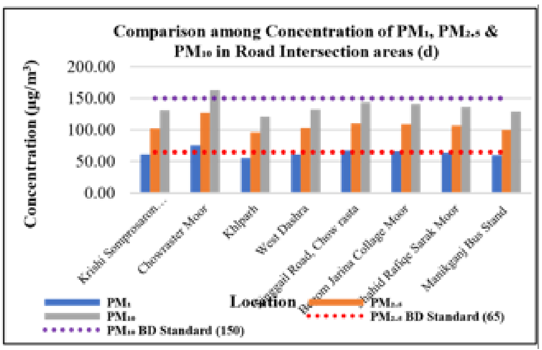

Fig 2 (d): Comparison among concentration of PM_1 $PM_{2.5}$ and PM_{10} in Road Intersection area

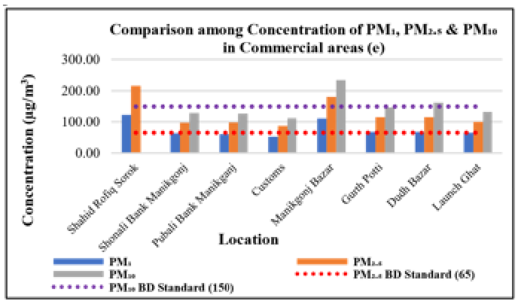

Fig 2 (e): Comparison among concentration of PM_1 $PM_{2.5}$ and PM_{10} in Commercial area

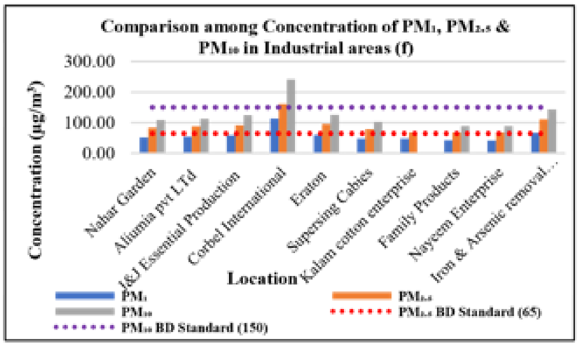

Fig 2 (f): Comparison among concentration of PM_1 $PM_{2.5}$ and PM_{10} in Commercial area

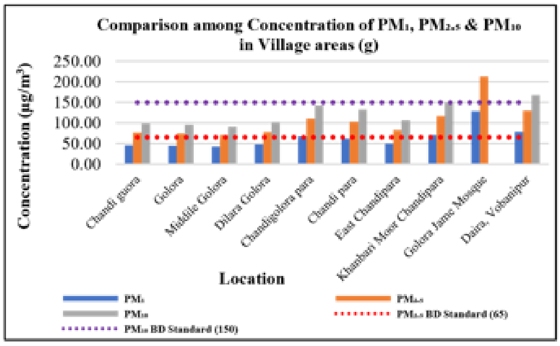

Fig 2 (g): Comparison among concentration of PM_1 $PM_{2.5}$ and PM_{10} in Industrial area

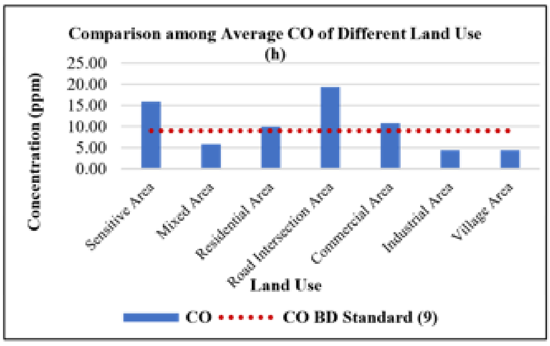

Fig 2 (h): Comparison among concentration of PM_1 $PM_{2.5}$ and PM_{10} in Different Land area

2. Dispersion of PM1, $PM_{2.5}$, PM_{10} and CO

The following table-1 shows the descriptive statistics for PM_1, $PM_{2.5}$, PM_{10} and CO of the studied seven land uses. The highest range was found in the village area (86.25, 142.50 and 183.25 µg/m3) for the PM, and sensitive area (48 ppm) for CO and the lowest range was found in mixed area for all the parameters. Among all those land uses, the highest mean value of PM and CO were found in commercial area (167.16 µg/m3, 125.91 µg/m3, 164.52 µg/m3 and 19.38 ppm) and the lowest mean was found in residential area (54.80, 90.85, 116.78 µg/m3) for PM. Study found average mean values for PM

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

	Land Use	NoL	PM1 Range (ug/m3)(Min-max)	PM1 Mean (ug/m3)	PM1 Std. Deviation (ug/m3)	PM1 Coefficient of Variation (%)	PM2.5 Range (ug/m3) (Min-max)	PM2.5 Mean (ug/m3)	PM2.5 Std. Deviation (ug/m3)	PM2.5 Coefficient of Variation (%)	PM10 Range (ug/m3)(Min-max)	PM10 Mean (ug/m3)	PM10 Std. Deviation (ug/m3)	PM10 Coefficient of Variation (%)	CP Range (ppm) (Min-max)	CP Mean (ppm)	CP Std. Deviation (ppm)	CP Coefficient of Variation (%)
1	SA	9	43.00	59.25	12.50	21.11	74.25	99.45	20.97	21.09	94.00	127.3	26.79	21.0	48	15.80	14.47	91.61
2	MA	9	7.50	57.06	3.16	5.55	8.25	93.44	4.05	4.34	13.50	120.94	5.99	4.96	4	10.00	2.00	20.00
3	RA	6	22.25	54.80	6.90	12.60	29.75	90.85	9.42	10.37	37.00	116.7	12.49	10.6 9	23	5.80	8.51	146.7
4	RIA	5	20.50	63.97	6.13	9.58	30.75	106.8	9.39	8.79	41.50	137.1	12.49	9.10	13	10.75	4.65	43.28
5	CA	12	71.50	76.16	26.00	34.14	129.25	125.91	46.59	37.0	159.75	164.52	57.33	34.8 5	55	19.38	18.51	95.53
6	IA	9	72.25	58.55	20.93	35.75	93.00	91.75	28.02	30.54	153.50	122.48	45.63	37.2 5	11	4.30	4.62	107.44
7	VA	10	86.25	63.95	26.03	40.70	142.5	105.4	42.93	40.72	183.7	136.0	55.39	40.7 1	18	4.40	6.67	151.5
Total				61.96	14.52	Total		101.95	23.05	Total		132.20	30.87	Total		10.06	8.49	

SA- Sensitive area, MA- Mixed area, RA- Residential area, RIA- Road Intersection Area, CA- Commercial area, IA- Industrial area, VA- Village area and NoL- Number of Locations.

The whisker box plot displays in figure 3 (a), (b), (c) and (d) that the average of PM and CO concentrations in seven land uses. A horizontal black line within the box marks the median; the lower boundary of the box indicates the 25th percentile, the upper boundary of the box indicates the 75th percentile. The whisker represents the maximum (upper whisker) and minimum value found the highest standard deviation was in village area for PM_1 and commercial area for $PM_{2.5}$, PM_{10} and CO and the lowest was seen in mixed area for all the parameters. Average stand. Deviation was found (14.52, 23.05 and 10.06 µg/m3), average stand. Deviation value was found ± 42.41 and ±58.91 for $PM_{2.5}$ and PM_{10} at Manikganj in 2016 [11]. The table also shows that; the highest coefficient of variation was seen in village area and the lowest was seen in mixed area for all the parameters. (Lower whisker) for each land use. The following whisker box plot of PM revealed that commercial area had the highest dispersion with an extremely positively skewed distribution which is contradicted to descriptive statistics where village area had shown the highest variation. The higher values observed in Shahid Rofiq Road due to economic activities was the reason behind the higher dispersion in commercial area. The village area, industrial area and sensitive area had moderate distribution with normally skewed values along with one distant outlier in each; these episodes were found in Golora Jame Mosque in village area due to burning of dry leaves and biomass, Corbel International in industrial area due to industrial activities and in Government Debendronath Collage in sensitive area due to sudden vehicular movements. The residential and road intersection areas had less dispersed concentration with negative to maximal negative skewness with one outlier in road intersection area in $PM_{2.5}$ and PM_{10} whisker box due to heavy traffic. The mixed area had the least dispersed concentration with normal distribution. Commercial area and residential area had higher dispersion with positive to utmost positively skewed distribution. That is contradicting descriptive statistics where village area had shown the highest variation. The sensitive area and commercial area had one distant outlier in each; these episodes were found in Manikganj Sorkari Mohila College in sensitive area due to sudden vehicular movements and Launch Ghat in commercial area due to sudden vehicular movements and economic activities.

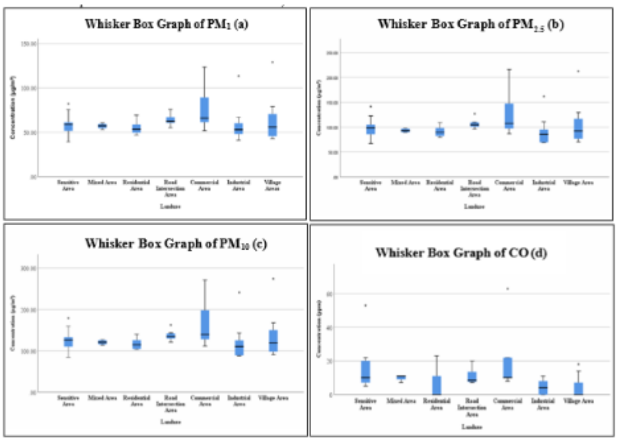

Fig. 3 Whisker Box Plot of the Concentration of PM_1 $PM_{2.5}$, PM_{10} and CO in Different Land use

3. Significance Test

Table 2 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 1.297 for PM_1, 1.502 for $PM_{2.5}$, 1.438 for PM_{10} and 2.879 for CO respectively. P values found for significantly except of CO as the p values are greater than 0.05. For CO it is less than 0.05. Therefore, the concentration of CO might change significantly between and within the land uses.

Table 2: Significance Test PM_1, $PM_{2.5}$, PM_{10} and CO are 0.275, 0.196, 0.218 and 0.017 respectively. The following tables revealed that the concentrations of none of the parameters change

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
PM_1	Between Groups	2482.334	6	413.722	1.297	.275
	Within Groups	16900.769	53	318.882		
	Total	19383.103	59			
$PM_{2.5}$	Between Groups	7525.214	6	1254.202	1.502	.196
	Within Groups	44269.764	53	835.279		
	Total	51794.978	59			
PM_{10}	Between Groups	12770.534	6	2128.422	1.438	.218
	Within Groups	78422.023	53	1479.661		
	Total	91192.557	59			
CO	Between Groups	1854.658	6	309.110	2.879	.017
	Within Groups	5691.075	53	107.379		
	Total	7545.733	59			

4. Land Use Based Cluster Analysis

Figure 4 (a, b, c and d) shows 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 average linkage between groups has been considered. At very primary level two clusters have been found from below PM graph. In PM_1 graph, first cluster is consisting of road intersection area and village area; second cluster consist of sensitive area, industrial area and mixed area. The residential area individually joined with the second cluster at the approximate distance of 3. This grouping joined with first cluster at the approximate distance of 5. These large grouping joined with the commercial area at the approximate distance of 25. In addition, residential area, industrial area and mixed area were incorporated in the first cluster; second cluster includes road intersection area, village area, and sensitive area; and only commercial area is included in third cluster. So, it is apparent that first and second cluster joins at the approximate distance of 5, which then joins with third cluster at the approximate distance of 25. Consequently, first cluster is consisted of road intersection area and village area, mixed area, industrial area, residential area and sensitive area; and second cluster includes commercial area only. Two clusters join at the approximate distance of 25. However, three clusters have been found from the dendrogram for CO. Where first cluster is consisted of industrial area, village area and residential area; second cluster includes mixed area and road intersection area. Third cluster consisted of sensitive area and commercial area. First cluster and second cluster joined at the approximate distance of 7 and these two large grouping joined with third cluster at the approximate distance of 25.

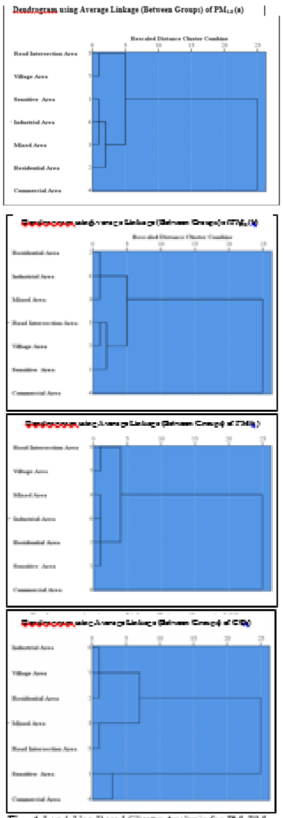

Fig. 4: Land Use Based Cluster Analysis for PM_1, $PM_{2.5}$, PM_9 and CO

5. Concentration Map on PM_1, $PM_{2.5}$, PM_{10} and CO of Manikganj District Town in 2021

Figure 5 (a), (b), (c) & (d) show the concentration of Particulate Matter (PM) and CO at various location of Manikjong district town in the year of 2021.

Concentrations of Particulate Matter (PM1) are expressed in µg/m3. The concentration of µg/m3 means one millionth of a gram of PM_1, $PM_{2.5}$ and PM_{10} per cubic meter of air. The maximum concentration of PM_1, PM_{10} and CO was found in outside of Golora Jame Mosque and $PM_{2.5}$ concentration map showed maximum concentration was found in Shahid Rofiq Road and the least concentration of PM_1 was found in Middle Golora area and $PM_{2.5}$ and PM_{10} was found in font of Govt. Debendronath Collage and minimum concentration of CO was found in near to Launch Ghat.

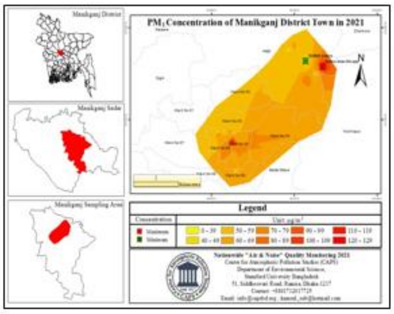

Fig. 5 (a): PM_1 Concentration Map of Manikganj District Town

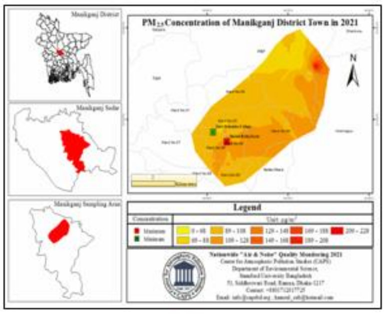

Fig. 5 (b): $PM_{2.5}$ Concentration Map of Manikganj District Town

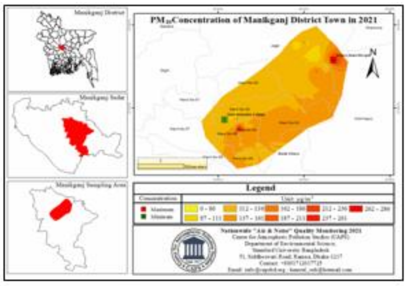

Fig. 5 (c): PM_{10} Concentration Map of Manikganj District Town

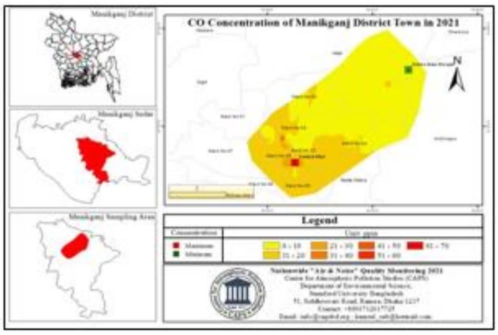

Fig. 5 (d): CO Concentration Map of Manikganj District Town

6. AQI on $PM_{2.5}$ Concentration of Manikgonj District Town in 2021

Figure 6 shows the Manikgonj district town based on $PM_{2.5}$. In the map above, the categories of AQI are represented by different colors according to Bangladesh National Ambient Air Pollution Standard. It is visible that AQI (201-300) was recorded to be in vastly unhealthy conditions; it also displays that the whole sample area was around the AQI (151-200). The maximal concentration is marked by red flag, and the minimum concentration with green flag. Shahid Rofiq Road evidently had the maximum concentration, and the least concentration was found outside of Government Debendronath Collage.

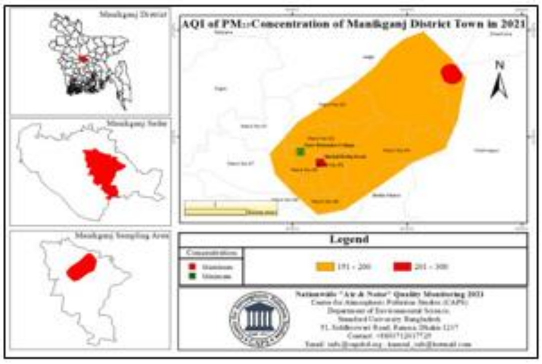

Fig. 6: AQI on $PM_{2.5}$ Concentration Map of Manikganj District Town

IV. CONCLUSION

Study found that the average concentration of PM_1, $PM_{2.5}$ and PM_{10} of 60 places in Manikgonj district town were 61.96, 101.95 and 132.19µg/m3 respectively. From the outcome of this research the studied land uses are arranged in descending order based on average concentration $PM_{2.5}$ which follows as commercial area (125.91µg/m3)> road intersection area (106.81 µg/m3)> village area (105.43 µg/m3)> sensitive area (99.45µg/m3)>mixed area (93.44 µg/m3)> industrial area (91.75µg/m3)> residential area (90.85 µg/m3). The Concentration of $PM_{2.5}$ (212.75µg/m3) of different land use was found to be very high which was nearly 3.27 times higher than the standard level. The National Air Quality Standard (Daily) set by (DoE) for PM2.5 is 65 µg/m3. On, the basis of PM_1, $PM_{2.5}$ and PM_{10} dispersion among all those land uses the maximum range was found in village area followed by commercial area while minimum was found in mixed area. Std. deviation and coefficient of variation of PM and CO among all those land uses was found higher in commercial area and village area followed by least in mixed area.

Moreover, whisker box graph of PM_1, $PM_{2.5}$ and PM_{10} revealed that commercial area had the highest dispersion with extreme positively skewed distribution. It is impossible to completely eradicate air pollution. Because it is created naturally and at a time when all types of cars use diesel and gasoline. The continuous development of motor transportation is linked to the need to lessen its negative environmental impact. The authorities should have started cleaning up the city sooner. People should also be concerned about air pollution, which can help to limit the number of pollutants in our daily lives.

For personal protection from corrosion using improved quality, masks could be a temporary solution for the individual.

To reduce air pollution, the coordination of governmental bodies is mandatory. Encouraging people to Rooftop Gardening in the area, May, help to improve the air quality. The number of surface water bodies should be increased in the nearness of the area. The Clean Air Act-2019 needs to be implemented as soon as possible. The annual budget allocation of the Ministry of Environment needs to be increased to create environmental protection and awareness.

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