International Journal of Research in Environmental Science (IJRES)
Volume 10, Issue 1, 2024, PP 1-13
ISSN No. (Online) 2454-9444
DOI: http://dx.doi.org/10.20431/2454-9444.1001001
www.arcjournals.org

Status of Ambient Air Quality in Chattogram Metropolitan, Bangladesh

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Abstract:*In the last few decades, Chattogram, which is the port city and the financial center of southern Bangladesh, has been battling significant levels of air pollution. The purpose of this research is to determine the levels of Particulate Matter (PM_1, $PM_{2.5}$, and PM_{10}) and Carbon Monoxide (CO) in the Chattogram metropolitan depending on the various land uses. For this study, 64 sites in the Chattogram metropolitan were assessed using a portable Air Quality Monitor and a portable CO Meter. Therefore, the metropolitan area of Chattogram had average concentrations of 100.23, 165.28, and 213.46 µg/m^3 for (PM_1, $PM_{2.5}$ and PM_{10}), respectively. It is estimated that the average $PM_{2.5}/PM_{10}$ ratio was 77.99%, while the $PM_1/PM_{2.5}$ ratio was 60.74%. Moreover, The three most polluted locations in terms of $PM_{2.5}$ were Halishohor (250 µg/m^3), Technical mor (244 µg/m^3), and Notun para (232.25 µg/m^3), where $PM_{2.5}$ concentrations were 3.85 times higher than Bangladesh National Ambient Air Quality Standards (BNAAQS) level in most polluted locations. Furthermore, CO concentration was also found to be 1.65 times higher than the national standard in the most polluted area while the average concentration of CO is determined to be 25.10 ppm in the mixed zone. The following is a hierarchy of areas based on the average concentration of $PM_{2.5}$: industrial area > mixed area > road intersection area > village area > residential area > commercial area > sensitive area. It can be concluded that the air pollution in Chattogram city is rapidly getting into worst condition and it is high time to reduce such devastation.*

Keywords:*Air Pollution, Particulate Matter, Gaseous Pollutants, Chattagram Metropolitan, Bangladesh.*

1. INTRODUCTION

Air pollution is a growing environmental concern in every modern civilization (Hossen et al., 2018). Its effect on the surrounding has become the prime concern and the most exigent issue to deal with (Kumar and Dash, 2018).It can be defined as the release into the atmosphere of various gases, finely divided solids, or finely dispersed liquid aerosols at rates that exceed the natural capacity of the environment to dissipate and dilute or absorb them and these substances may reach concentrations in the air that cause undesirable health, economic or aesthetic effects (Nathanson et al., 2020). Poor air quality is the fourth leading cause of early death, which covers about five million deaths every year (Islam et al., 2020). Due to the severe impacts on humans as well as the whole ecosystem, air pollution is considered a global threat, which itself is increasing due the enhanced anthropogenic activities. Bangladesh suffers from terrible air quality and the adverse health impacts that result from it. Urban areas including major cities are in grave danger because of the air pollution surrounding them which is damaging to the community's health. The rising level of air pollution in the country leads to an increase in health effects like asthma, bronchial and pulmonary disease, and lung cancer (Hoque et al., 2020). It has severe consequences on global public health such as causing diseases like respiratory and cardiovascular disease (Kayes et al., 2019). Women and children are at higher risk since they remain indoors more than others (Hasan et al., 2019). 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 (Khalequzzaman et al., 2020).Particulate matter, often known as particle pollution, is a phrase used to describe a mixture of solid particles and liquid droplets that can be found in the air. Some particles, such as dust, dirt, soot, or smoke, are sufficiently large or dark to be visible to the naked eye(US Environmental Protection Agency, 1996; Ciencewicki and Jaspers, 2007).Particles are clarified by their diameter for air quality regulatory purposes. PM with a diameter of 10 micrometers (PM_{10}) is considered to be a coarseparticle. However, particles that are 2.5 microns or less in diameter ($PM_{2.5}$) is defined as fine particulate matter (Nayeem et al., 2020). Particle pollution was exacerbated by brick kilns, growing traffic and construction, rapid economic growth, industrial changes and increased energy use (Hossen et al., 2018). $PM_{2.5}$are able to travel deeply into the respiratory tract and can reach the lungs. There is a strong relationship between PM concentration and health impacts due to the size and composition of the particle (Du et al., 2016).Suspended particles, in the air, could cause severe damage to human health since aerosol particulate matter is linked to toxic trace metals (Hasan et al., 2020).Around 1200 to 3500 people's lives could be saved each year, if the exposure to air pollution in urban areas could be reduced to 20-80%, and to add to that it creates negative economic externalities for investment in the country (Hoque et al., 2020b). In 2018, air pollution caused by fossil fuels alone cost US $2.9 trillion which was more than 3% of the world's GDP. In addition to that it caused around 4 million children to suffer from asthma, 2 million preterm births, and 4.5 million deaths, which led to 1.8 days of absence in working days. Country Environmental Analysis (CEA), an analytic tool of the World Bank, revealed that 1% is being reduced from Bangladesh's annual GDP, due to growth in air pollution levels (Islam et al., 2020).It is estimated that the economic cost of illness, and death from air pollution is $132 to $583 million per year for Dhaka (Rouf et al., 2012). Natural sources of carbon monoxide are volcanic activity, natural gas, and marsh gas emissions, electrical discharge in the atmosphere during storms, seed germination, etc. However, the majority of the amount of carbon monoxide found in the air is due to anthropogenic activities like fossil fuel combustion in cars, buses, trucks, and other vehicles (Rahman et al., 2020), agricultural burning and forest fire (i.e. burning of forest debris, crop residue, bushes, weed, and vegetation), industrial operations such as electric and blast furnaces in iron and steel industry, paper industry, petroleum refining, gas manufacture and coal mining (Dara, 2004 and Botkin & Keller 2011). The major source of CO emission is mobile sources, which are responsible for 40.5% of the total annual CO emission; followed by fossil fuel, 27.1%; and industrial emission (including brick kilns) 16.4%, in the Greater Dhaka (Rahman et al., 2020).In developing countries, air pollution in urban areas is a major issue to deal with (Kayes et al., 2019). Urban air pollution, although current is a well-known issue and has become a matter of grave concern for society. This is due to the fact that it has severe consequences for health since air pollution consists of fine air particles. In May 2016, in more than 80% of the urban areas, the air pollution was higher than the air quality standard guideline set by WHO, (Rahman et al., 2019) whereas in low to middle-income countries it increased by 98% of the cities, and in high-income countries 56% of cities.Pollution caused by particles is one of the most serious issues that has plagued the Chattogram metropolitan area in the recent past. In different parts of Chittagong City, the amount of $PM_{2.5}$ is higher than the DOE standard value (Jubaer et al., 2022).The city of Chittagong has several different causes of Particulates Matters pollution, the most significant of which is the city's unsuitable automobiles and its industries. Every year sees an increase in the proportion of automobiles that have been extensively restored. One-third of these vehicles lack any sort of valid certification for their safety (Hossen and Hoque et al., 2018). Because of the availability of port facilities, this city is appealing to investors who wish to establish new industries there. Some steel mills and cement factories are located in business and residential areas, which means that the people who live there are exposed to a lot of PM_1, $PM_{2.5}$& PM_{10} (Majumder et al., 2020). Chattogram's daily average concentrations of total Suspended Particulate Matter in the city's ambient air were 671.65 µg/m³, which is significantly higher than the daily average set by the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA) (Mondol et al., 2014). The concentration of Suspended Particulate Matter (SPM) in Agrabad, New Market and A.K. Khan Gate, Pahartali, Chittagong are 510,420 and 250µg/m³, respectively, which was significantly higher than the standard value.Again, the average concentrations of SPM were found significantly higher than Environmental Conservation Rules (2005) in the markets of Agrabad, New Market and A.K. Khan Gate, Pahartali, Chittagong (Hossen et al., 2016).Although the government has introduced policies like- the use of lead-free fuel in the vehicle sector, and an increase in industrial chimney height (for brick kilns, steel mills, and cement industries in Chattogram); not much implementation is seen (Masum and Paul et al., 2020). 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 (Hasan et al., 2020).

2. METHODOLOGY

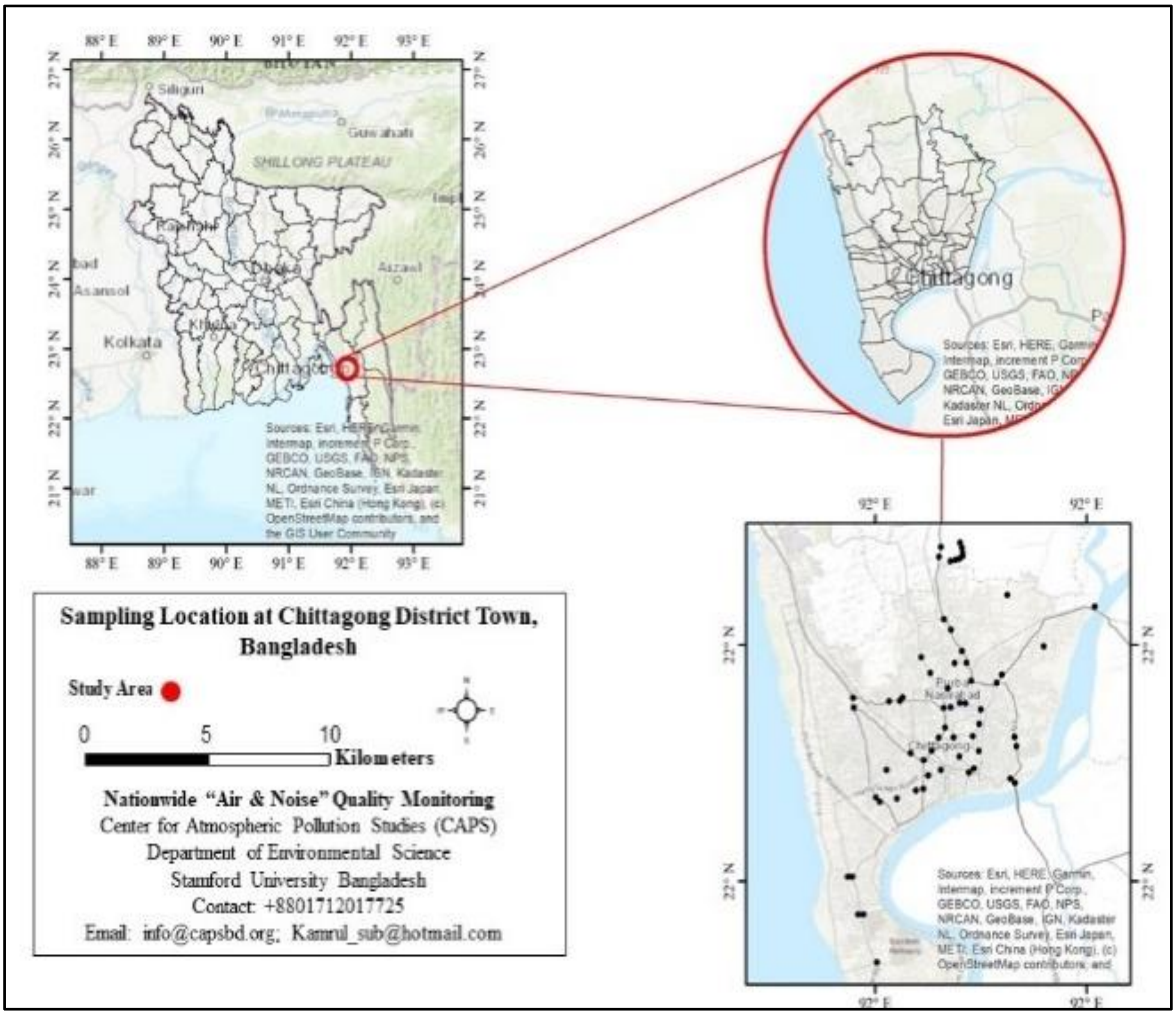


Figure1.*Study Area (Chattagram Metropolitan area and Data Collection Locations Point)*

Sixty-four locations have been selected for this study based on their land use. here The coordinates for the greater Chattagram Metropolitan are 22°14′–22°24′ N and 91°46′–91°53′ E. The places were then divided into seven groups based on their intended use: sensitive (9 spots), residential (10 spots), mixed (10 spots), road intersection (10 spots), commercial (9 spots), industrial (9 spots), and village area (7 spots). On the map, the locations of all of the samples have been shown. Using an Air Quality Monitor, we gathered data for seven days from each place within the study region to determine the levels of particulate matter (PM_1, $PM_{2.5}$& PM_{10}) there. Following that, the gathered information was evaluated using IBM SPSS V20 and Microsoft Excel 2020. Multiple graphs, a table that demonstrates a comparison of parameters, and a whisker box were developed so that the nature of the data could be better understood. In addition to that, descriptive statistics were analyzed to better understand the nature of the data, and an Analysis of Variance (ANOVA) was employed to determine whether or not the results were significant. For the preparation of the Air Quality Index (AQI) map for the Chattagram Metropolitan region, the study made use of the ArcGIS 10.4.1 edition. Different projection locations were used for making concentration and AQI maps in the GIS. To convert from concentration to AQI this equation was used:

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

If multiple pollutants are measured, the calculated AQI is the highest value calculated from the above equation applied for each pollutant.(Majumder et al., 2023)

Where:

I = the (Air Quality) index

C = the pollutant concentration

C_{low} = the concentration breakpoint that is ≤ C

C_{high} = the concentration breakpoint that is ≥ C

I_{low} = the index breakpoint corresponding to C_{low}

I_{high} = the index breakpoint corresponding to C_{high}

3. RESULT & DISCUSSION

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

Figure 2 (a), (b), (c), (d), (e), (f)(g) demonstrate the concentration (µg/m^3) of PM_1, $PM_{2.5}$& PM_{10} of locations in sensitive, residential, mixed, commercial, industrial, road intersection, and village areas, in the ChattagramMetropolitan area. Sensitive areas include administrative offices, schools, colleges, mosques and universities. It can be seen that out of nine sensitive locations, on the basis of concentration of PM_1, $PM_{2.5}$& PM_{10}; two highly polluted places were Pahertali(112.50, 184.25 and 238.75 µg/m^3) and in front of Chattogram Medical College Hospital(107, 181.50 and 231µg/m^3). However,most contaminated place was Chattogram Diabetic Hospital area(28.25, 49.25 and 62.25 µg/m^3). However, comparatively two less polluted places among sensitive areas are CSCR & Metropolitan area and B. Memorial Hospital with $PM_{2.5}$ concentration of 93.75 and 121.50 µg/m^3 respectively.The concentration of $PM_{2.5}$andPM_{10}foundin the most polluted areawere 2.83 and 1.59 times higher than the Daily NAAQS acceptable limit (65 and 150 µg/m^3) in all study locations. The study found that in all sensitive areas, 77.71% of $PM_{2.5}$was present in $PM_{10}$and about 60.02% of PM_1 was present in $PM_{2.5}$.The amount of $PM_{2.5}$released into the air by urban building sites accounts for roughly 54 percent of the city of Chittagong's total $PM_{2.5}$ emissions(BAPS, 2015).

The study also found that among ten residential locations, three extremelypolluted places were Halishohorresidential area with PM_1, $PM_{2.5}$ & PM_{10} concentrations of Halishohor residential area (157.50, 250and 328.75 µg/m^3),Badamtoli area (118.25, 192.50 and 249.75 µg/m^3) and Anonna area (98.75, 165.25 and 212 µg/m^3) and the three least polluted places were Khulshiresidential area (69.75, 117.50 and 150.50µg/m^3) and Chandgoan residential area (71.75, 118.50 and 153 µg/m^3) and Port Colony (74.25, 127.50 and 161.50 µg/m^3) respectively. Noted that in the residential areas, the concentrations of $PM_{2.5}$& PM_{10} werefound to be 3.84 and 2.19 times higher than NAAQS level in the most polluted location.A high concentration of $PM_{2.5}$was observed in Chattagram, which is mostly caused by the burning of biomass, the burning of waste in open areas, and activities involving vehicles (Majumder et al., 2020).Due to the fact that a large number of roads in Chittagong city are being repaired for a number of development projects, the citizens of Chittagong city were forced to contend with a severe dust problem during the dry season. The construction of residential buildings, an elevated expressway, and roads that are being dug for the maintenance of utility services have caused the air to grow overwhelmingly with dust (Dhaka Tribune, 2020).

Figureillustrate that among ten mixed locations, according to PM_1, $PM_{2.5}$& PM_{10} concentration; three highly polluted areas were Notun Para Bangladesh Road Transport Corporation Depo(142, 230.75 and 300µg/m^3) and Chattogram, Kodomtoliarea (114, 194. 25 and 249.25 µg/m^3) and Laldighie area(109.50, 180 and 232.75 µg/m^3) and comparatively less polluted places among mixed areas were and Chawk Bazar area, Kalamiar bazar area and Bahaddarhat area with the $PM_{2.5}$concentrations of136.25, 137 and 137 µg/m^3 respectively. Moreover, the concentrations of $PM_{2.5}$was3.55 timesand $PM_{10}$was 2timeshigher than the national standardlevel; found in the most polluted location.The mixed area includesseveral housings, offices, retail, entertainment, institutions, services, restaurants etc.so air pollution was also higher due to increased congestion, increase pollutant exposure and social gathering. Chittagong Metropolitan area has the largest port in Bangladesh and has to bear heavy traffic especially the central area of the city that is covering about 10 km^{2}mostly responsible for increasing air pollution (Begum et al., 2014).

It has been found that out of ten road intersection locations, three highly polluted areas were KathghorMorarea(134.25, 213.75 and 280.25 µg/m^3) followed by AK Khan mor area (111, 186and

238.50 µg/m^3) and Amna Bazar area(108, 182.50 and 233.50µg/m^3) respectively. Nevertheless, less polluted places were Tiger Pass area, KazirDewriMor and WASA Mor, Chattogram with$PM_{2.5}$concentration of104.25, 132.50 and 134.75 µg/m^3 respectively. The concentration of$PM_{2.5}$& PM_{10} in the most polluted location werefound3.27 and 1.87 times higher thannational standard levels. Again study estimated a $PM_{2.5}/PM_{10}$ ratio of 77.53% and $PM_{2.5}$ made up 60.63% of the total PM_1 mass.To cover the necessity of the increased population, public transport, as well as private transport, has increased further in recent years (Yeasin., 2021). The emission of black smoke from unfit vehicles and dust from open spaces is one of the biggest contributors to severe air pollution, which has contributed to an increase in cases of bronchitis, asthma, and other respiratory-related diseases among city dwellers over the past few decades. One-third of these vehicles, or more than 32,000, do not have a specific kind of fitness certificate (The Daily Star, 2015).

It has beenfound that out of nine commercial locations, all of their$PM_{2.5}$concentrationwas above the daily national standard level; three excessively polluted areas were Pahartalibazar area, Agrabad area and New Market area with $PM_{2.5}$ concentration of 211.75, 198.25 and 190.75 µg/m^{3}and comparatively less polluted places among commercial areas were GEC mor area, Dewanhat area and Patenga area with $PM_{2.5}$ concentration of112.50, 114.75 and 135 µg/m^3 respectively.This study also estimated the ratio of $PM_{2.5}/PM_{10}$ was 77.27%and 60.89% ofPM_1mass was present in $PM_{2.5}$. In addition, the primary sources of fine PM include brick kilns, outdated automobiles, and the burning of biomass (Majumder et al., 2020). In the studied areas, selected nine industrial locations shown that Technical Mor area, Sha Amanat Bridge area and Oxygen Mor area with $PM_{2.5}$concentrations of 244, 216.75 and 215.50 µg/m^{3}were three highly polluted areas; relatively less polluted places were and KaptayRastarMatha, Sar TranzitKalurghat area and Chittagong Export Processing Zone (CEPZ) area with the concentration of 105.50, 142.25 and 148 µg/m^3 as well. It has been observed that concentrations of PM_1, $PM_{2.5}$& $PM_{10}$of were Technical Mor area and KaptayRastarMatha were found at 151.75, 244 and 317.75 µg/m^3 and 63, 105.50 and 135.25 µg/m^3 respectively.Because of the port facility, the Chattagram Metropolitan area is an investment hotspot for a growing number of industries. Local and international investors have established a number of "Export Processing Zones" (EPZ) (BBS, 2010). The majority of industries aren't paying attention to environmental regulations, and city air pollution continues to rise (Hossen et al., 2016).

Among seven locations in village areas in the Chattagram Metropolitan area. Here three most polluted locations were Notun Para area with PM_1, $PM_{2.5}$ & PM_{10} of 140.50, 232.25 and 299.50 µg/m^3 and the other polluted places werePurboNotun para area and Zogir Hat arearespectively and comparatively less polluted places among village areas wereCikondondi area, South Zugir Hat area and Jamtola area with $PM_{2.5}$of 133.50, 143.50 and 144.50µg/m^3. It was also noted that the concentration of $PM_{2.5}$was 2.05to 3.57 times and $PM_{10}$was 1.23 to 2.00 higher than the NAAQS limit.By emitting unburned gasoline, out-of-date, unfit vehicles have significantly degraded the air quality in the village. Sources of the decrease in village area air pollution may include the clearing effect of the local vegetation, the proximity of the HaldaRiver, and the absence of polluting sources such as industry and heavy traffic (Ahmed. et. al., 2006). The study furthermore found that the average concentration of PM_1, $PM_{2.5}$& $PM_{10}$was higher in a sensitive area, industrial area and mixed area with values of 114.08, 188.10 and 243.03 µg/m^3,102.15, 168.40 and 217.55 µg/m^{3}and 99.98, 165.55 and 213.38 µg/m^3 where highest in the sensitive area. Nevertheless, the concentration was found comparatively less high in position in sensitive, commercial and residential areas. Moreover, the average concentration of PM_1 (94.75 µg/m^3), $PM_{2.5}$ (156.05 µg/m^3) and PM_{10} (201.45 µg/m^3) were found to be least in road intersection area.

Figure 2(h) shows a comparison of the average concentration of CO among seven land use in Chattogrammetropolitan area. The average concentration of CO was found higher than the standard,in mixed areas (25.10 ppm), industrial areas (21.20 ppm) and commercial areas (15.63 ppm) respectively. Moreover, it was seen that in the mixed area, CO was almost 2.79 times higher than the standard level where only the residential area didn’t cross that level. The quantities of carbon monoxide (CO) and hydrocarbons (HC) in the emissions from CNG/gasoline cars, as well as the opacity of the emissions from diesel vehicles, were measured by Rana et al., (2016). Emissions from about 75% of diesel vehicles had an opacity that was greater than 65 HSU, which is the national limit value for emissions from diesel vehicles. Diesel vehicles have been identified to be the most polluting vehicles in the vehicle sector.

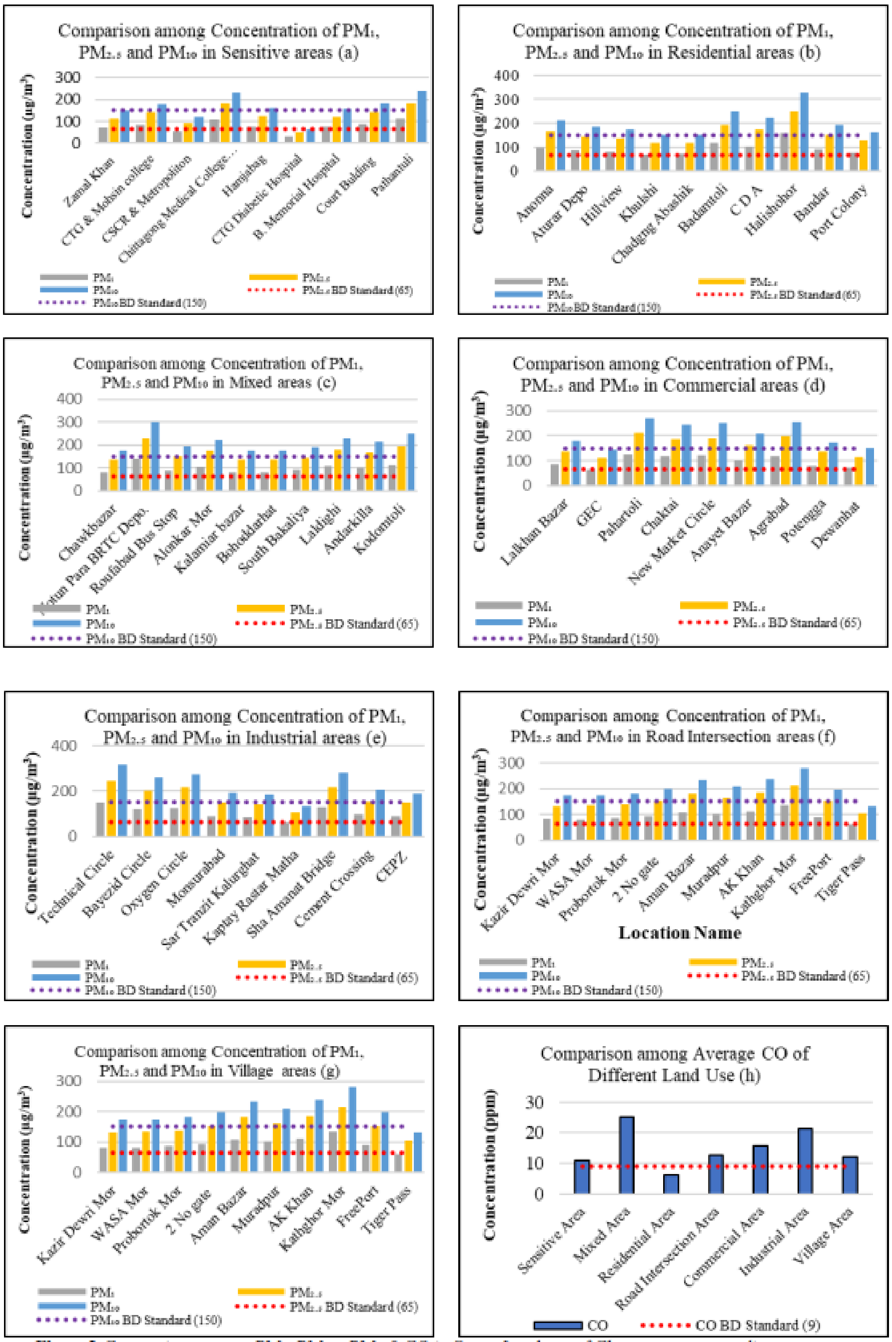


Figure2. *Comparison among* PM_1, $PM_{2.5}$, PM_{10}*&CO in Seven Land use of Chattagrammetropolitan area*

Additionally, motorcycles were among the biggest contributors to air pollutants; sixty percent of the motorcycles investigated had CO and HC concentrations that were higher than the permitted emission limit levels for the nation. Tanzim et al., found the concentrations of carbon monoxide were 210 µg/m³, 200 µg/m³, and 310 µg/m³ correspondingly, in January, March, and July of 2015. In mixed areas, different economic activities are taking place and also old vehicles are suddenly crossing the area which might be another becauseof it. Acute exposure to high concentrations of CO can result in CO poisoning with the onset of nausea, vomiting, headaches, shortness of breath, and confusion, and can speedily lead to mortality (Tusher et al., 2018).

3.2. Descriptive Statistics of PM_1, $PM_{2.5}$, PM_{10}& CO

The following table 1 demonstrates the descriptive statistics for PM_1, $PM_{2.5}$& $PM_{10}$of the studied seven land uses, here measured the pollution level in µg/m³. The highest ranges were found for PM_1, $PM_{2.5}$ & PM_{10} in industrialarea (89, 139 and 183 µg/m³) and lower ranges were found in village areas (58.25 µg/m³) for PM_1but for $PM_{10}$and $PM_{2.5}$lower range found in the mixed area (94.50 and 125.50µg/m³).For PM_1, $PM_{2.5}$& PM_{10}concentration the higher mean values were calculated (106.72, 176.36 and 226.89 µg/m³) in the industrial area followed by (99.98, 165.55 and 213.38 µg/m³) in mixed areas where the study found fewer mean values in sensitive and road intersection areas.The monthly mean concentrations of $PM_{2.5}$& PM_{10}exceeded the NAAQSfor 24 hours (January-February-December-November) (Majumder et al., 2020). Again, the highest coefficient of variation was seen in sensitive area which were 33.22%, 32.75% and 32.82% for PM_1, $PM_{2.5}$& PM_{10}respectivelyand the lowest was seen in mixed areas which were 18.98%, 18.49% and 18.80%.

Table1. Descriptive Statistics for PM_1, $PM_{2.5}$, PM_{10} and CO

Serial No.	Land Use	Number of Location	PM_1				$PM_{2.5}$				PM_{10}				CO			
			Range ($\mu g/m^3$)(Min-max)	Mean ($\mu g/m^3$)	Std. Deviation ($\mu g/m^3$)	Coefficient of Variation(%)	Range ($\mu g/m^3$)(Min-max)	Mean ($\mu g/m^3$)	Std. Deviation ($\mu g/m^3$)	Coefficient of Variation (%)	Range ($\mu g/m^3$)(Min-max)	Mean ($\mu g/m^3$)	Std. Deviation ($\mu g/m^3$)	Coefficient of Variation (%)	Range ($\mu g/m^3$)(Min-max)	Mean ($\mu g/m^3$)	Std. Deviation ($\mu g/m^3$)	Coefficient of Variation (%)
1	SA	9	84	77	26	33%	135	128	42	33%	177	164	54	33%	14	11	4	40%
2	MA	10	61	100	19	19%	95	166	31	18%	126	213	40	19%	62	25	20	78%
3	RA	10	88	95	27	28%	133	158	41	26%	178	203	55	27%	3	6	1	15%
4	RIA	10	73	95	20	21%	110	156	32	20%	148	201	42	21%	17	13	5	41%
5	CA	9	61	98	23	24%	99	161	38	23%	129	209	49	23%	28	16	13	80%
6	IA	9	89	107	27	26%	139	175	45	26%	183	227	59	26%	67	22	22	101 %
7	VA	7	58	97	20	21%	99	160	33	21%	126	207	43	21%	31	12	11	94%
	Total	64	73	96	23	24%	115	158	37	24%	152	204	49	24%	32	15	11	64%

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

However, the variation was found more in the sensitive area but was less in the in the mixed area. On the other hand, table 1again illustrates the descriptive statistics for CO of the studied seven land uses. The higher ranges are found in industrial area (67 ppm), mixed area (62 ppm) and village area (31.50 ppm) and lower ranges are found in residential area (3 ppm) and sensitive area (14 ppm). Among all those land uses the minimum concentration is seen in the industrial area (0 ppm) and the maximum concentration is in the mixed area (67 ppm) and industrial area (67 ppm); the highest mean value of COis also found in the industrial area (22.11 ppm) and lowest mean found in the residential area (6.20 ppm).

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

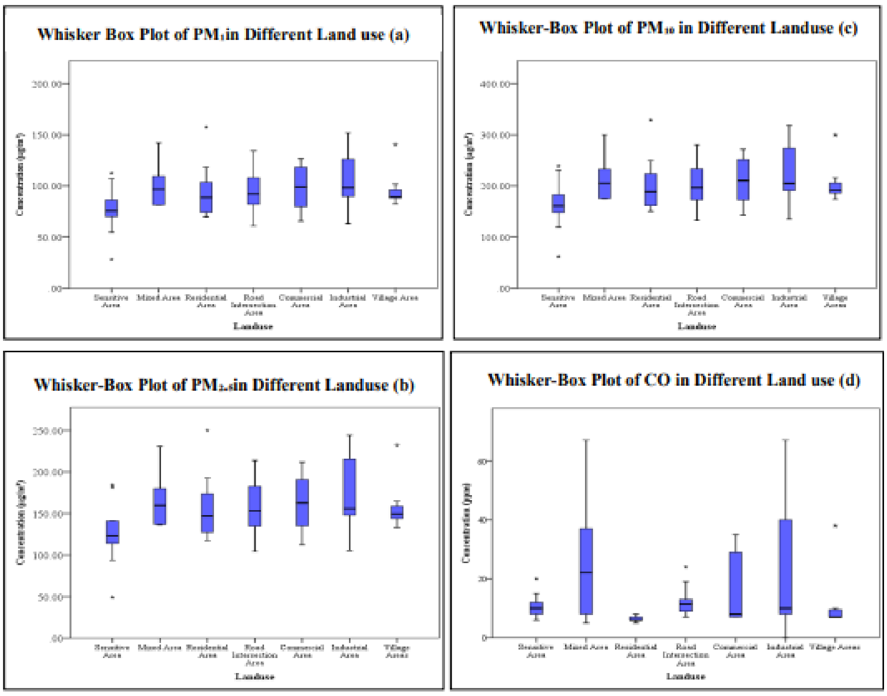


Figure3. *Whisker box plot of the concentration of PM_1, $PM_{2.5}$, PM_{10}& COin Different Land use*

The whisker box plot shows in figure 3 (a), (b), (c) and (d) the average of PM_1, $PM_{2.5}$& PM_{10}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 and the upper boundary of the box indicates the 75th percentile. The whisker represents the maximum (upper whisker) and minimum value (lower whisker) for each land use. Whisker box plot revealed that in PM_1commercial and industrial area and $PM_{2.5}$andPM_{10}industrial and commercial had the most dispersed concentration and the values are normally distributed in commercial area but positively skewed in industrial area.The later dispersed concentration of PM_1, $PM_{2.5}$&$PM_{10}$was found in residential and road intersection area in contrast to the descriptive analysis findings. The coefficient of variation was found high due to the presence of distant outliers. However, sensitive e and residential area have very distant outliers,possibly due to the sudden movement of vehicles or waste burning.Beyond that,a great dispersion also can be seen in mixed area. Though,the values of the village area are tightly clustered andthe values are positively skewedwith one outlier. The reasons behind the higher dispersion in concentration in industrial and commercial area are various industrial and economic activities. This may have further been affected by the increased vehicular traffic in these two zones. However, the whisker box plot for CO demonstrate that the values are highly dispersed and distributed in industrial and mixed area due to industrial activities and economic activities.Again,the least variation is found in residential area and the values are also closer to the mean. The movement of the different sorts of vehicles and the burning of fossil fuel in the industries might be the cause of it.

3.4. Significance Test

Table 2 illustrates ANOVA for the significance test. ANOVA is performed to find whether the changes in the concentration of all the parameters between and within land uses are significant. The F values were calculated to be 1.387 for PM_1, 1.388 for $PM_{2.5}$, 1.384 for PM_{10}, and 2.419 for CO. P values of the PM_1, $PM_{2.5}$, PM_{10} and CO were 0.040, 0.064, 0.053 and 0.038. The following table shows that the concentration of PM_1, $PM_{2.5}$&PM_{10} does not change significantly as the p-value is greater than 0.05. The changes in the concentration of CO are significant within land uses as the p-value is less than 0.05.

Table2.*Significance Test by ANOVA*

ANOVA of PM_1					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	4566.347	6	761.058	1.387	0.235
Within Groups	31265.746	57	548.522		
Total	35832.093	63			
ANOVA of $PM_{2.5}$					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	11785.467	6	1964.245	1.388	0.235
Within Groups	80649.873	57	1414.910		
Total	92435.340	63			
ANOVA of PM_{10}					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	20067.277	6	3344.546	1.384	0.237
Within Groups	137745.723	57	2416.592		
Total	157813	63			

ANOVA of CO					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2515.261	6	419.210	2.419	0.038
Within Groups	9876.915	57	173.279		
Total	12392.176	63			

3.5. 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,the average linkage between groups has been considered. Two clusters have been found for PM_1, $PM_{2.5}$& PM_{10}graph. Here, PM_1 &

PM_{10} clusters consisted same land use, the first clusterconsisted of the residential area, road intersection, commercial area, village area, mixed area and industrial area and the sensitive area is alone in the second cluster. However, for $PM_{2.5}$ the first one has consisted of the commercial area, village area, residential area, road intersection area, mixed area and industrial area and the sensitive area is alone in the second cluster. For all PM_1, $PM_{2.5}$& PM_{10}two broad clusters join with each other at an approximate distance of 25. On the other hand, three clusters have been found for CO graph. Where, the first cluster consists of road intersection area, village area, sensitive area and commercial area;thesecond cluster includes residential area alone and the third cluster consisted of mixed area and industrial area respectively. The first and second cluster joins at the approximate distance of 8 which joins with the third cluster at the approximate distance of 25.

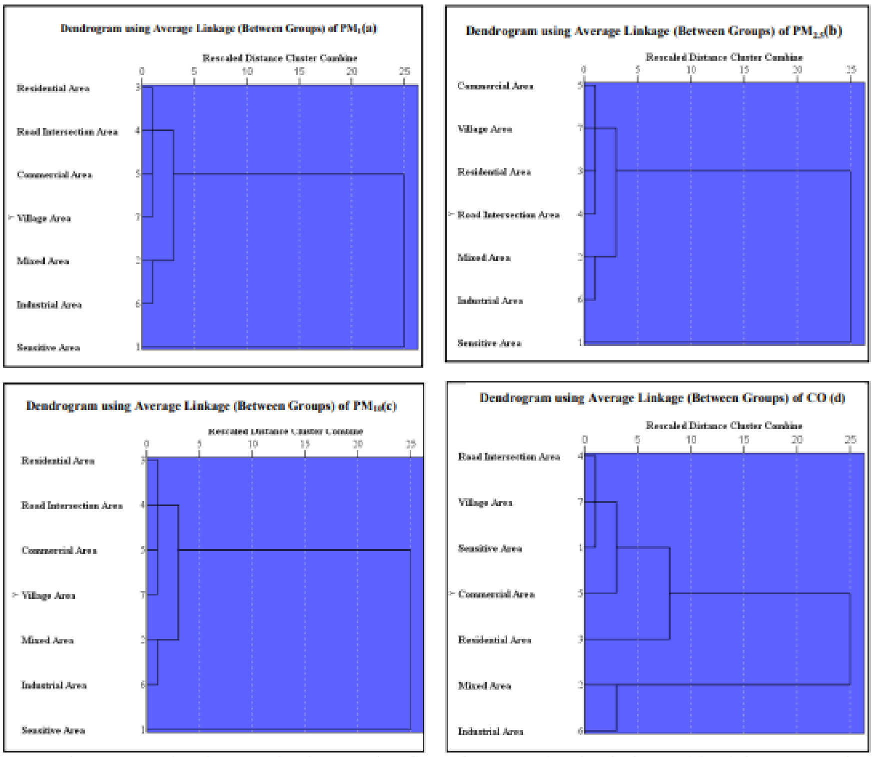
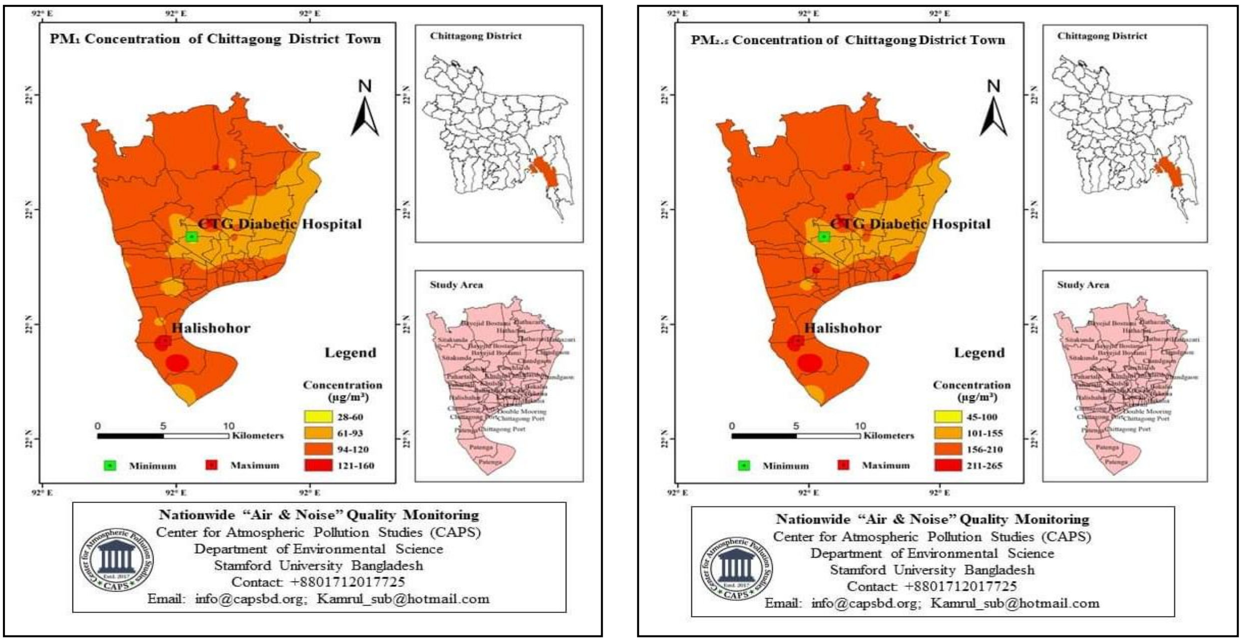


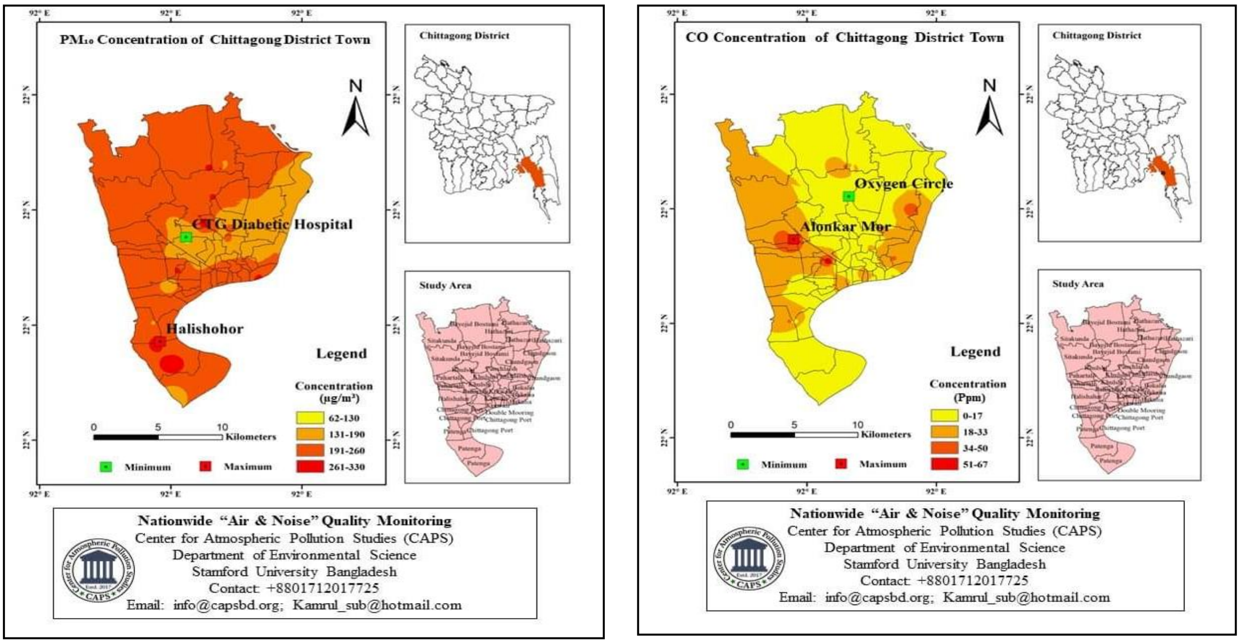
Figure4. *Land Use Based Cluster Analysis for PM_1, $PM_{2.5}$, PM_{10} & CO in Different Land use*

3.5. Concentration Map on PM_1, $PM_{2.5}$, $PM_{10}$and CO of Chattagram Metropolitan area in 2021

Figure 5(a), (b), (c) and (d) illustrate the concentration of Particulate Matters (PM_1, $PM_{2.5}$& PM_{10}) and CO at various locations of Chattogram Metropolitan in the year 2021. Concentrations of Particulate Matters are expressed in $\mu g/m^3$. The concentration of $\mu g/m^3$ means one-millionth of a gram of PM_1, $PM_{2.5}$& PM_{10} per cubic meter of air. Yellow areas have little, while progressively higher concentrations are shown in orange and red. Concentration of Particulate matters found to be higher in 24, 34, 35, 39, 40 no ward, some part of 8 no ward and Chattogram Cantonment area indicating in red color and found lower in 4, 5, 6, 7, 15, 16 and 17 no ward of Chattogram metropolitan. However, concentrations of carbon monoxide are expressed in parts per million by volume (ppm). A concentration of 1 ppm means that for every million molecules of gas in the measured volume, one of them is a carbon monoxide molecule. Heavy pollution observed in ten, eleven and thirteen no ward and comparatively less CO pollution found in most of the area of Chattogram metropolitan area. The maximum concentration of PM_1, $PM_{2.5}$& PM_{10} was found in Halishohor and CO wasfound in AlonkerMor and the leastconcentration of PM_1, $PM_{2.5}$ & PM_{10} was found in CTG Diabetic Hospital and minimum concentration of CO was found in near to Oxygen Circle.



3.6. AQI Map (a) (b) **on**



(c) (d)

Figure5.PM_1, $PM_{2.5}$, PM_{10} and CO on Concentration of Chattagram Metropolitan area in 2021

$PM_{2.5}$Concentration of ChattagramMetropolitan area in 2021

Figure 6 illustrates the Chattagram Metropolitan area based on $PM_{2.5}$concentration in this map different colors represent the category of AQI according to Bangladesh National Ambient Air Pollution Standard. The air quality was rated as good (0-50) for green, moderate (51-100) for yellow, unhealthy for sensitive groups (101-150) for yellow, unhealthy (151-200) for orange, very unhealthy (201-300) for red, and hazardous (300+) for purple. The map shows that AQI was very high which is indicated in red color. The map shows that AQI (201-300) was in very unhealthy condition and the whole area was around the AQI (151-200). The graphic indicates that AQI (201-300) was in vary poor air condition, and the majority of the area was deemed to be very unhealthy. The very unhealthycondition was observed in 30 of the 41 wards, moderate concentration in 17 of the 41 wards, and the lowest concentration in 2 of the 41 wards in the Chattagram Metropolitan Area. Ward 13 has qualitysensitive populations., includingsmall area that is harmful for people who are vulnerable.Ward no-2, ward no-3, ward no-10, ward no-11, ward no-12, ward no-15, ward no-18, ward no-19, ward no-22, ward no-25, ward no-26, ward no-27, ward no-28, ward no-29, ward no-30, ward no-31, ward no-32, ward no-33, ward no-34, ward no-35, ward no-36, ward no-38, ward no-39 and ward no-40 area wasobserved very unhealthycondition; again ward no-4, ward no-5, ward no-6, ward no-7, ward no-14, ward no-15, ward no-16, ward no-17, ward no-20 and ward no-23 showed unhealthy conditions.

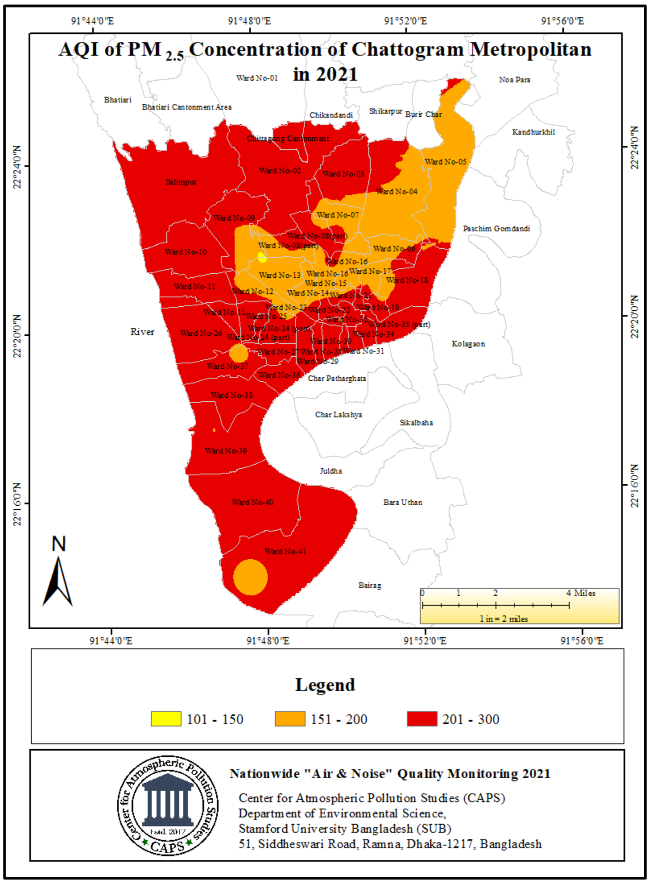


Figure6. *AQI on $PM_{2.5}$ Concentration Map of Chattagram Metropolitan Area in 2021*

4. CONCLUSION

The city of Chattagram has reached an extremely dangerous level of air pollution. The average $PM_{2.5}$& PM_{10}concentrations were found to be 2.54 and 1.42 times higher than the NAAQS threshold, respectively, in this study.Based on the average $PM_{2.5}$ concentrations measured, the studied land uses were ranked as follows: industrial area (175.36 µg/m³) > mixed area (165.55 µg/m³) > road intersection area (161.31 µg/m³) > village area (160.07 µg/m³) > residential area (157.50 µg/m³) > commercial area (156.05 µg/m³) > sensitive area (127.56 µg/m³).The average concentration of CO was calculated to be 14.84 ppm. Moreover, Industrial, residential, and sensitive areas had the most variation in PM, whereas village areas, mixed uses, and commercial areas had the least. The standard deviation and coefficient of variation for PM dispersion were also found to be highest in industrial areas, followed by sensitive areas, and finally residential areas.It has been found that the dendrogram plot for PM_1, $PM_{2.5}$& PM_{10}shows that each plot makes at least 2 clusters and these two clusters join at the approximate distance of 25. Moreover, the whisker box graph ofPM_1, $PM_{2.5}$& $PM_{10}$and CO shows that values are dispersed in the industrial area, sensitive are and residential area and the village area has concentrated value.PM produced naturally and produced in the time when all types vehicles run using diesel and petrol. It is essential to determine the origins of the pollution. More plantations are required to reduce particulate matter pollution, and water sprinklers may be utilized throughout the winter season. In addition, the government ought to exercise authority over the brick kilns that are located in the area surrounding the Chattogram metropolitan. Besides, there should be a rise in the utilization of cement-sand block brick. It is strongly recommended that brick kilns make more use of cutting-edge equipment that is free of harmful emissions. Vehicles that are unfit for use or have expired should be halted. Along with that, be sure to follow all of the relevant rules and regulations while transporting construction supplies. As a result of this, it is necessary to put an end to the practice of burying solid trash everywhere, which requires adequate management. On the other hand, the current legislation needs to be carried out in an appropriate manner. To protect ourselves from PM pollution, we need to first design a plan, then put that plan into action, and lastly monitor it. At both the national and municipal levels, measures should be implemented to combat the issue of air pollution. An educational campaign in both printed and electronic media will help solve these problems.The authority should have taken some earlier steps to make the city clean. Also, people need to concern about air pollution, which can reduce the amount of pollutants in our daily life otherwise the city will have to face worse conditions in the upcoming days.

ACKNOWLEDGEMENTS

The authors are thankful to the Center for Atmospheric Pollution Studies (CAPS).

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Citation:*Ahmad Kamruzzaman Majumder, et.al., "Status of Ambient Air Quality in Chattogram Metropolitan, Bangladesh", International Journal of Research in Environmental Science (IJRES), vol. 10, no. 1, pp. 1-13, 2024. Available: DOI: http://dx.doi.org/ 10.20431/2454-9444.1001001*