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Research Article

Monsoon Season Spatial Distribution of Particulates Concentration in the Road Intersection Area of Different Land Use in Major City in South Asian Countries

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Abstract

Air pollution has become one of the most significant issues in the metropolitan area of Dhaka in recent years. There are various sources of air pollution in Dhaka city, among them, unfit vehicles and industries are notable with under construction work done by Dhaka city Corporation. With regard to various land uses in the Dhaka metropolitan region, this study intends for monitoring the Particulate Matters ($PM_{2.5}$ and PM_{10}) concentrations and its relationship to the various types of land use in the region. This investigation was carried out in 82 different places throughout the Dhaka metropolitan area by using instrument named Aeroqual S-500. Study found that the average concentrations of $PM_{2.5}$ and PM_{10} in these locations were 31.10 and 72.03 g/m^3, respectively. The average concentration of $PM_{2.5}$ and PM_{10} across all land uses was found to be 1.4148 and 1.7082 times higher than the WHO standard threshold, respectively. It is estimated that the average $PM_{2.5}/PM_{10}$ was 46.32%. It also revealed that the concentrations of the parameters do not change significantly with land use as the p values are greater than 0.05. Average concentration of $PM_{2.5}$ & PM_{10} follows as mixed area > residential area > commercial area > silent area > industrial area.

Keywords

Air Pollution, Particulate Matter, Road Intersection Area, Dhaka Metropolitan

1. Introduction

Air pollution is one of the environmental catastrophes that are currently occurring all over the globe as a direct result of human activity [1]. Air pollution is a situation in which substances are in the air in amounts that are high enough above their normal ambient levels to have a noticeable effect on people, animals, plants, or things. "Substances" are any natural or man-made chemical elements or molecules that can be carried through the air [2]. These can be found in the air as gases, liquid drops, or solid particles and can be either harmful or harmless. However, the term 'measurable effect' often confines attention to compounds that have negative consequences. Air quality has deteriorated mainly due to human activities with some extent of natural phenomena such as sea salt, dust (like airborne dirt), and Volcanic eruptions and

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particles made from natural gaseous precursors are also natural sources of PM [3, 4]. Coarse particle emissions are majorly influenced by local sources for instance fine particles are released from chemical process [5]. Fine Particles ($PM_{2.5}$) denotes the particles with an aerodynamic diameter of ≤2.5 µm and Coarse particles (PM_{10}) denotes ≤10 µm [6]. They come from many different places, like power plants, factories, transportation, brick kilns, burning biomass, wind-blown dust, and sea spray. They can also be made in the atmosphere by changing the way air emissions behave. heir chemical and physical compositions depend on the characteristics of the emission sources, location, time of year, and prevailing weather conditions [5, 7]. Particle conversions through chemical processes in the atmosphere by burning of biomass, gas, and fossil fuel is the main source of the $PM_{2.5}$ while coarse particles ($PM_{2.5\text{-}10}$) are the result of mechanical activities such as wind-blown dust, grindings, re-suspended road dust, etc. [8].

Therefore, 50% of $PM_{2.5}$ is generated from motorized vehicles, while 15% is generated from brick kilns according to receptor modeling studies, another study found that In Dhaka, an average of 22% and 36% of fine particulates originate from brick kilns and automobiles, [9, 10]. Moreover, $PM_{2.5}$ in Mirpur 10, a heavily motorized area in Dhaka city was found to be as high as 172.2 µg/m^3 [10, 11]. The mean PM_{10} and $PM_{2.5}$ values are noticeably higher in Dhaka in comparison with the Air Quality Standard of WHO and the pollution level of PM_{10} and $PM_{2.5}$ is highly significant, and points out an elevated level of pollution in Dhaka. From 2002 to 2010, the average $PM_{2.5}$ in the Dhaka urban area was between 62.75 and 89.5 g/m^3, and the average PM_{10} was between 110.66 and 147.34 g/m^3 [12]. Apart from this, according to IQAir 2020 the average of $PM_{2.5}$ in the air of Bangladesh was found 77.1 µg/m^3 which is 5.5 folds higher than the standard level of this country [13]. Moreover, Dhaka also ranked as most polluted country in terms of Particulates Matters pollution. Dhaka has become one of the fastest growing megacities in the world, with a population of 18.94 million people, due to the migration of people from rural areas in search of better opportunities [11]. In the past ten years, the population of Dhaka experienced substantial growth, resulting in an increase in the number of automobiles. Consequently, this has led to a rise in levels of pollution in the air due to the increased emission of pollutants [11]. Fossil fuel and biomass combustion also produce fine particles identified as $PM_{2.5}$ [6]. The emission of particulate matter is contingent upon the engine's design, namely whether the engine is underpowered and inadequately maintained, as well as the presence of fuel loss due to excessive fueling. [1]. Besides, in comparison to vehicle-free and non-motorized areas, more fine particles were found in main motorized areas of Dhaka [9] The brick production sectors have contributed significantly to air pollutant and destruction of the environment due to the use of dated traditional kilns and poor-quality fuels [6]. According to a study strong linkage has been found between $PM_{2.5}$ and the number of brick kilns in Dhaka city and their proximity. In addition to all these emissions, the brick kiln is also one of the main factors contributing to the air pollution in Dhaka, particularly during the dry seasons. Salam et al. 2008 [14] found that average $PM_{2.5}$ mass was 136.1 µg/m^3 during day time and 246.8 µg/m^3 during night time in Dhaka. He revealed weekends had lower concentrations than weekdays due to less vehicular traffic in the streets and aerosol were about 15.0% (ranging from 9.4% to 17.3%) higher during traffic peak hours (6:00am-8:00pm) than off hours (8.00pm-6.00am). Razib et al. 2020 [3] identified that the winter season in Dhaka had the highest amount of $PM_{2.5}$ of any season. In addition, the study revealed that the yearly concentration in Dhaka in 2017 was 79.94±75.55 µg/m^3, above both the Bangladesh National Ambient Air Quality Standards (NAAQS) threshold and the World Health Organization (WHO) guidelines. Brick kilns combust coal, resulting in the release of Particulate particles and the incomplete combustion of coal have detrimental effects on human health and contribute to climate change [15]. In addition, shortness of breath (dyspnea), chest pain, coughing, and wheezing are some of the minor symptoms linked to $PM_{2.5}$ inhalation [16]. This study conduct to determine the level of air pollution in the Dhaka Metropolitan area, In order to evaluate the association between land use and measure each locations particulate matters, prepare a map on spatial distribution of PM concentrations and illustrate the Dhaka Metropolitan AQI map based on $PM_{2.5}$ concentrations.

2. Methodology

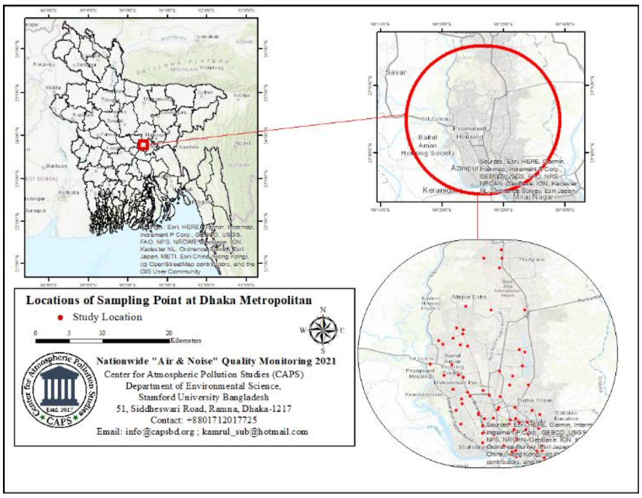

Figure 1. *Study area (Dhaka metropolitan area and data collection locations point).*

This study was carried out in the metropolitan area of Dhaka, which is situated at a coordinate of 23.8103 degrees North and 90.4125 degrees East. Figure 1 illustrates the 82 places that have been chosen for this investigation (table 1), which were classified according to five distinct kinds of land use: sensitive, residential, mixed, commercial, and industrial. There are a total of thirteen silent areas that have been chosen, and these consist of administrative Bhaban, hospitals and clinics, schools, colleges, mosques, madrasas, temples, and churches. Bazaars, buildings, main roadways, and many different kinds of establishments can be found in mixed areas. The remaining five locations were classified as residential areas, nineteen locations were classified as mixed areas, forty-one sites were classified as commercial areas, and four of these locations were classified as industrial. The collected data was analyzed using IBM SPSS V20 and Microsoft Excel 2020, and maps were generated using ArcGIS version 10.8. Different colors indicated particles pollution concentrations. A formula was applied for converting $PM_{2.5}$ concentration to AQI in the study. This equation was used to convert concentration to If multiple pollutants are measured, the AQI is calculated from the equation above and applied to each pollutant.

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

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 [17].

3. Results

3.1. Status of Air Pollution Studies in Road Intersection Area in Dhaka Metropolitan

3.1.1. Comparison Among Concentration of $PM_{2.5}$ and PM_{10} in Silent Area

Figure 2 illustrates the concentration (μg/m^3) of $PM_{2.5}$ and PM_{10} of some locations in silent areas in Dhaka metropolitan. The specific areas comprised administrative offices, educational institutions, and religious establishments. Among these 13 silent areas, Jagannath University had the greatest levels of pollution in terms of $PM_{2.5}$ and PM_{10}, with values of 75.36 and 182.73 μg/m^3 respectively. On the other side, comparatively less contaminated places were Bangladesh Hospital Dhanmondi-2, Mintu Road mor and Radio mor with the $PM_{2.5}$ & PM_{10} concentration of 15.50 and 33.80 μg/m^3, 20.60 and 53.80 μg/m^3 and 21.70 and 36.20 μg/m^3 respectively. Nevertheless, the levels of $PM_{2.5}$ and PM_{10} detected in the most heavily polluted area were 1.16 and 1.21 times more than the National Ambient Air Quality Standards (NAAQS) established by the Department of Environment (DoE), which are 65 and 150 μg/m3 respectively [18]. The study estimated that in all silent areas, 53.59% of $PM_{2.5}$ was present in PM_{10}.

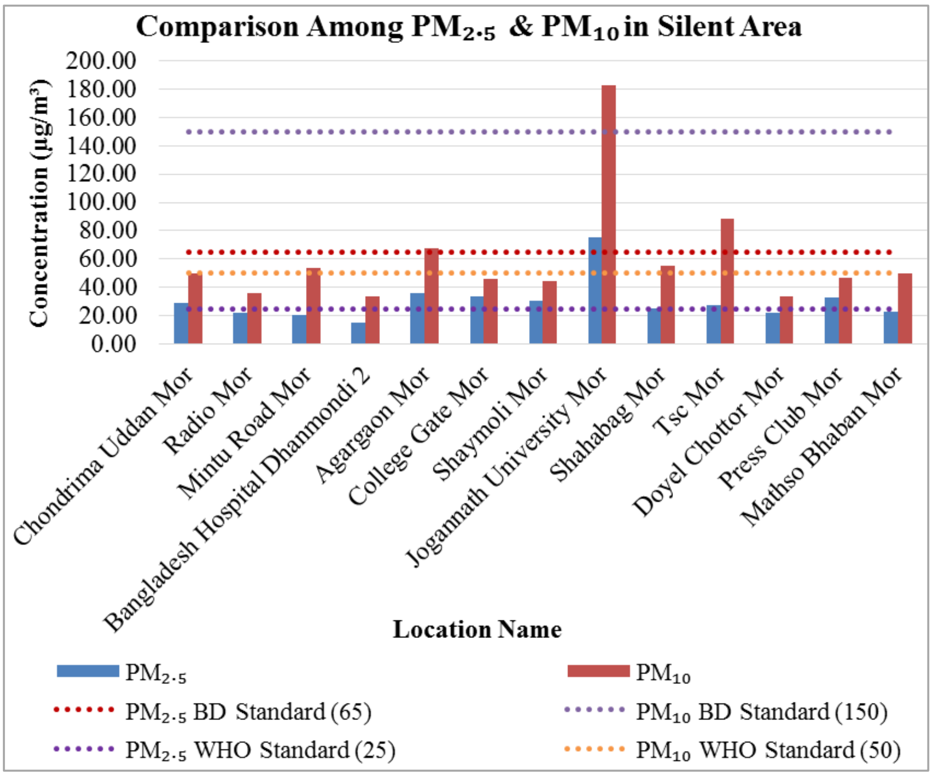

Figure 2. Comparison among concentration of $PM_{2.5}$ & PM_{10} in Silent area.

3.1.2. Comparison Among Concentration of $PM_{2.5}$ and PM_{10} in Mixed Area

Figure 3 shows the concentration (μg/m^3) of $PM_{2.5}$ and PM_{10} of some locations in mixed areas in Dhaka metropolitan. It has been found that out of 19 mixed areas, three most polluted places according to $PM_{2.5}$ Bonani Mor (101.46 μg/m^3), Dhanmondi 27 mor (88.78 μg/m^3) and Vasanktek mor (63.11 μg/m^3) and Comparatively less contaminated places were Rampura Bridge mor (3.94 μg/m^3), City College mor (15.78 μg/m^3) and Khamar Bari mor (16.40 μg/m^3). Furthermore, three most polluted places according to PM_{10} concentration were Dhanmondi 27 mor (328.11 μg/m^3), Bonani or (190.92 μg/m^3) and Vasanktek mor (153.78 μg/m^3). Comparatively less polluted places were City College mor (26.78 μg/m^3), Khilkhet mor (30.11 μg/m^3) and Dhanmondi-15 mor (32.55 μg/m^3) respectively. However, the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted location were 1.56 and 2.19 times higher than the NAAQS. The study estimated that the ratio of $PM_{2.5}/PM_{10}$ was 49.72%.

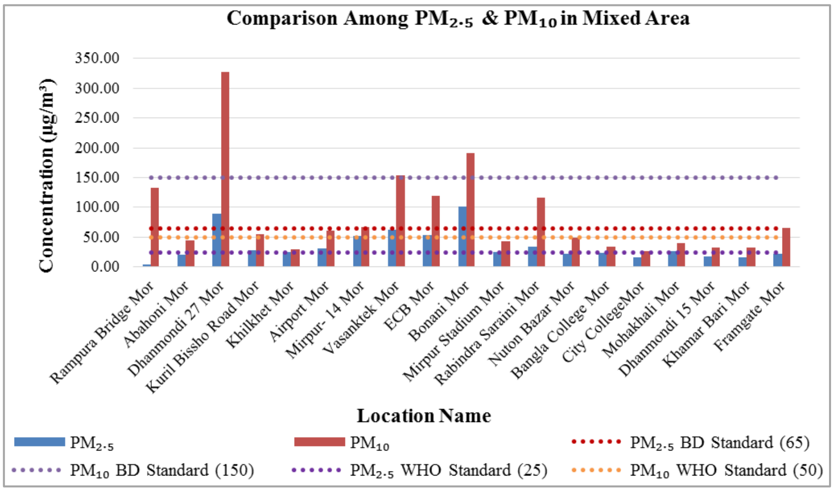

***Figure 3**. Comparison among concentration of $PM_{2.5}$ & PM_{10} in Mixed area.*

3.1.3. Comparison Among Concentration of $PM_{2.5}$ and PM_{10} in Residential Area

Figure 4 demonstrates the concentration (μg/m^3) of $PM_{2.5}$ and PM_{10} of some locations in residential areas in Dhaka metropolitan. It has been found that out of 5 residential places, three most contaminated places according to $PM_{2.5}$ & PM_{10} concentration were Beribadh Chowrasta Mohammadpur (48.82 and 130.27 μg/m^3), AGB Colony Mor (30.90 and 76.60 μg/m^3) and Azimpur Mor (25.50 and 69.92 μg/m^3) and comparatively less contaminated places were Nakhal Para Mor (23.33 and 41.00 μg/m^3) and Town Hall Mor (23.67 and 39.17 μg/m^3) respectively. However, the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted location were 1.95 and 2.60 times higher than the World Health Organization (WHO) which are 25 and 50 μg/m^3 respectively. The study estimated that in all residential areas, 46.32% of $PM_{2.5}$ was present in PM_{10}.

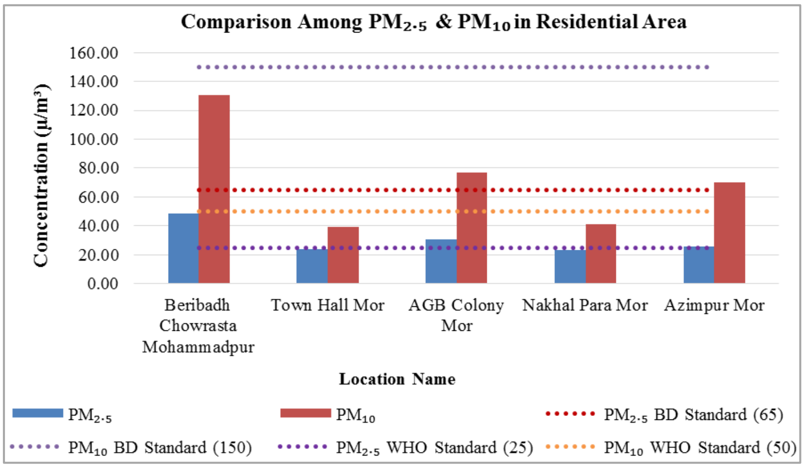

***Figure 4**. Comparison among concentration of $PM_{2.5}$ & PM_{10} in Residential area.*

3.1.4. Comparison Among Concentration of $PM_{2.5}$ and PM_{10} in Commercial Area

Figure 5 exhibits the concentration (μg/m^3) of $PM_{2.5}$ and PM_{10} of some locations in commercial areas in Dhaka metropolitan. It has been found that out of 41 commercial places, three most polluted places according to $PM_{2.5}$ English Road Mor (73.82 μg/m^3), Malibagh Rail Gate (55.00 μg/m^3) and Mohammadpur Bus Stand Mor (54.22 μg/m^3) and Comparatively less contaminated places were Bata Signal Mor (15.00 μg/m^3), Puran Polton Mor (16.17 μg/m^3) and Gulistan Mor (18.36 μg/m^3). Besides, three most polluted places according to PM_{10} concentration were Malibagh Rail Gate (211.30 μg/m^3), Gulshan-2 Mor (204.40 μg/m^3) and Mohammadpur Bus Stand Mor (184.89 μg/m^3). Comparatively less contaminated places were Bata Signal Mor (25.80 μg/m^3), Malibagh Mor (27.11 μg/m^3) and Sony Cinema Hall Mor (29.27 μg/m^3) respectively. However, the concentrations of $PM_{2.5}$ and PM_{10} found in the most polluted location were 1.14 and 1.40 times higher than the NAAQS. The study estimated that in all commercial areas, 49.26% of $PM_{2.5}$ was present in PM_{10}.

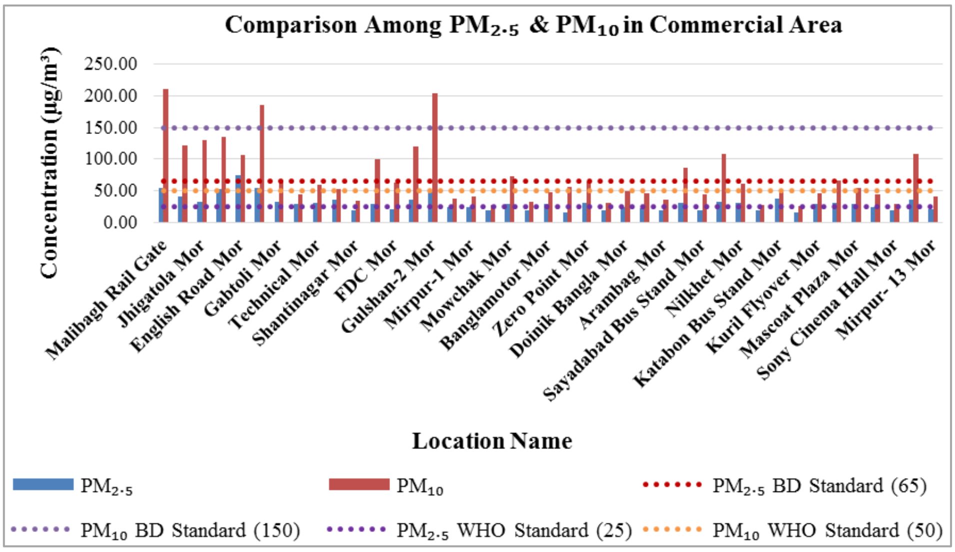

Figure 5. *Comparison among concentration of $PM_{2.5}$ & PM_{10} in Commercial area.*

3.1.5. Comparison Among Concentration of $PM_{2.5}$ and PM_{10} in Industrial Area

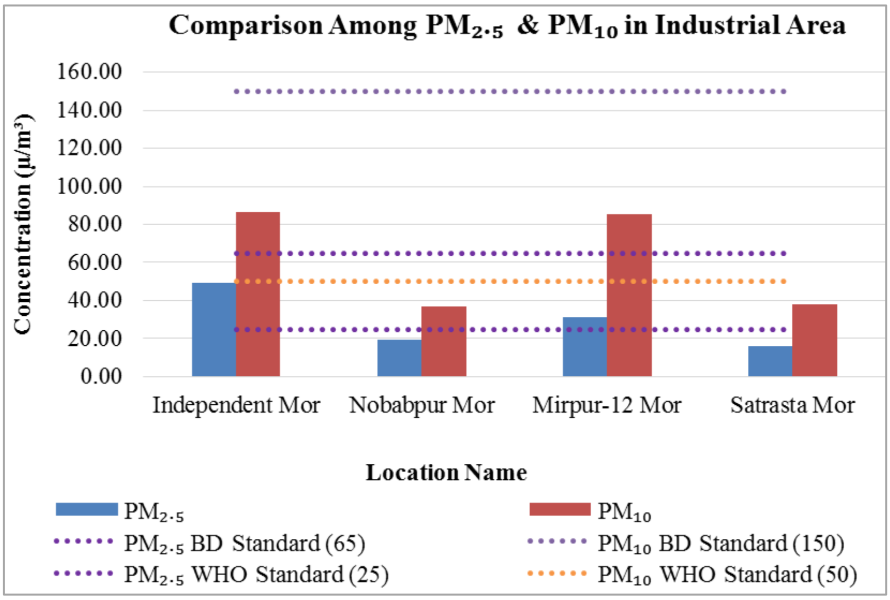

Figure 6. *Comparison among concentration of $PM_{2.5}$ & PM_{10} in Industrial area.*

Figure 6 explains the concentration (μg/m^3) of $PM_{2.5}$ and PM_{10} of some locations in industrial locations in Dhaka metropolitan. It has been found that out of 4 industrial places, the highest contaminated place with the $PM_{2.5}$ & PM_{10} was Independent Mor with concentration of 49.40 and 86.30 μg/m^3 and relatively less contaminated places were Satrasta Mor, Nobabpur Mor, Mirpur-12 Mor with $PM_{2.5}$ and PM_{10} concentration of 16.18, 19.30 and 31.33 μg/m^3 respectively. However, the concentrations of $PM_{2.5}$ and PM_{10} found in the most contaminated location were 1.98 and 1.73 times higher than WHO standard which are 25 and 50 μg/m^3. The study estimated that in Industrial areas, 47.31% of $PM_{2.5}$ was present in PM_{10}.

3.1.6. Comparison Among Average Concentration of $PM_{2.5}$ and PM_{10} of Different Land Use

The Figure 7 shows the comparison of the average concentration of $PM_{2.5}$ and PM_{10} of five lands uses in road intersection in Dhaka metropolitan. Study found that the average concentration of $PM_{2.5}$ and PM_{10} were higher in mixed area with the concentration with 35.37 μg/m^3 and 85.41 μg/m^3 respectively. The average concentration of $PM_{2.5}$ and PM_{10} found in the least contaminated area was in industrial area 29.05 μg/m^3 and 61.59 μg/m^3 respectively. Moreover, the most contaminated concentration were 1.41 and 1.70 times higher than WHO standard level which are 25 μg/m^3 and 50 μg/m^3 respectively.

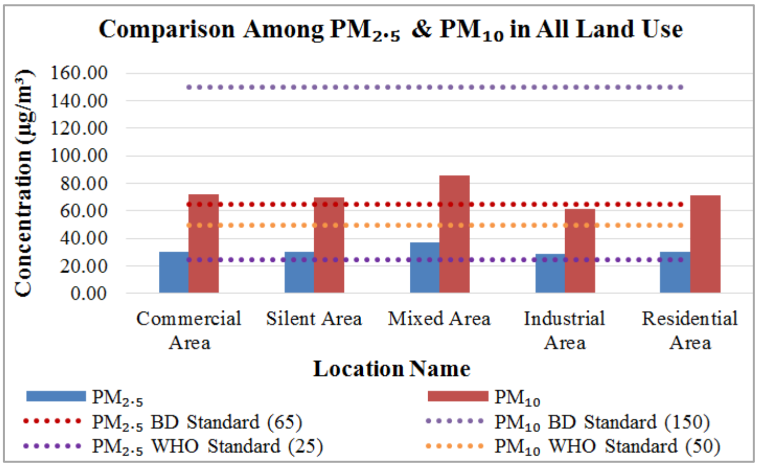

Figure 7. Comparison among average concentration of $PM_{2.5}$ & PM_{10} in all Land use.

3.2. Descriptive Statistics of $PM_{2.5}$ and PM_{10}

3.2.1. Descriptive Statistics of $PM_{2.5}$

The following table 1 shows the descriptive statistics for $PM_{2.5}$ of the studied five land uses. The mixed area revealed the highest concentration, measuring 97.52 μg/m^3, while the silent area had a slightly lower concentration of 59.86 μg/m^3. The residential area had the lowest concentration, measuring at 25.49 μg/m^3. The mean value of $PM_{2.5}$ was found to be at its highest in the mixed area, which measured 35.37 μg/m^3, while the mean value was found to be at its lowest in the industrial region, measuring 29.05 μg/m^3. A mixed region had the highest standard deviation, which was measured at 25.46 μg/m^3, while a residential area had the lowest standard deviation, which was measured at 10.71 μg/m^3. With a coefficient of variation of 35.18%, the residential area had the lowest coefficient of variation, while the mixed area had the highest coefficient of variance, which was 71.99%. This information is presented in the table.

Table 1. Descriptive Statistics for $PM_{2.5}$

$PM_{2.5}$						
S. N.	Land Use	Number of locations	Range (μg/m^3)	Mean (μg/m^3)	Std. Deviation (μg/m^3)	Coefficient of Variation (%)
1.	Silent Area	13	59.86	30.24	14.77	48.83
2.	Mixed Area	19	97.52	35.37	25.46	71.99

PM2.5						
S. N.	Land Use	Number of locations	Range (μg/m^3)	Mean (μg/m^3)	Std. Deviation (μg/m^3)	Coefficient of Variation (%)
3.	Residential Area	5	25.49	30.44	10.71	35.18
4.	Commercial Area	41	58.82	30.40	12.20	40.12
5.	Industrial Area	4	33.22	29.05	15.06	51.82

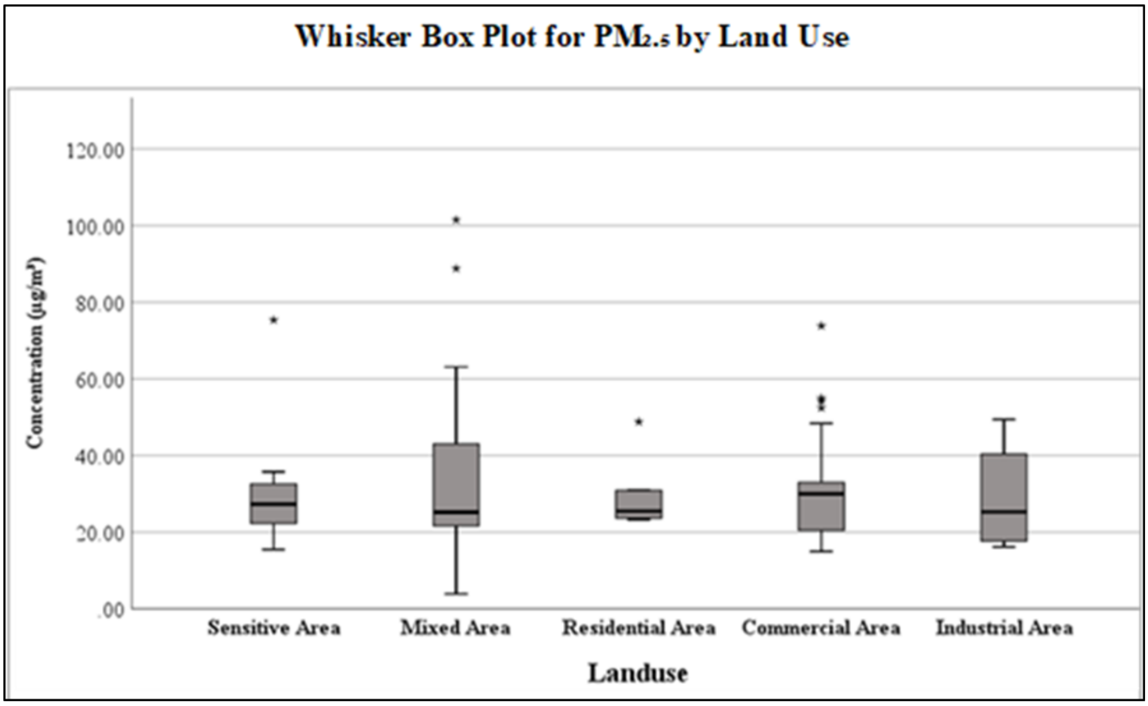

Figure 8. *Whisker box plot for the concentration of $PM_{2.5}$ in different land use.*

Following whisker box plot (Figure 8) of $PM_{2.5}$ revealed that mixed area and industrial area had the higher dispersion with positively skewed distributed values along with two outliers in mixed area. These situations were observed in Bonani mor due to road dust and on-going elevated highway construction work and in Dhanmondi-27 Mor due to enormous transportation movements. Moderate distribution was found in commercial area and sensitive area with normal to negative distributed values along with four outliers in commercial area and one outlier in sensitive area. These episodes were found in English Road Mor, Mohammadpur Bus Stand Mor, Malibagh Rail Gate and Kakrail Mor in commercial area due to these road intersections are includes busy roads, enormous vehicular movement and road dust and in Jagannath University Mor in sensitive area due to huge vehicular movements. The residential area had less moderate dispersion with extremely positive skewed values along with one outlier which was found in Beribadh Chowrasta Mohammadpur due to road dust and heavy transportation and huge vehicular movements.

3.2.2. Descriptive Statistics of PM_{10}

The following table 2 displays the descriptive statistics for PM_{10} of the studied five land uses. The industrial area had the lowest range of concentrations at 49.60 μg/m^3, while the mixed area had the biggest range at 351.00 μg/m^3. The commercial area followed with 185.50 μg/m^3. The highest mean value of PM_{10} was found in mixed area (85.41 μg/m^3) and the lowest mean value was found in silent area (60.70 μg/m^3). The highest standard deviation was seen in mixed area (75.64 μg/m^3) and the lowest was seen in industrial area (28.10 μg/m^3). Mixed area showed the largest coefficient of variance, measuring 88.56%, while the industrial area displayed the lowest coefficient of variation at 45.63%.

Table 2. *Descriptive Statistics for PM_{10}.*

PM_{10}						
S.N.	**Land Use**	**Number of locations**	**Range (µg/m³)**	**Mean (µg/m³)**	**Std. Deviation (µg/m³)**	**C. of Variation (%)**
1.	Silent Area	13	148.93	60.70	39.51	65.09
2.	Mixed Area	19	301.33	85.41	75.64	88.56
3.	Residential Area	5	91.10	71.39	36.94	51.74
4.	Commercial Area	41	185.50	72.24	47.53	65.79
5.	Industrial Area	4	49.60	61.60	28.10	45.63

Following whisker box plot (figure 9) of PM_{10} revealed that mixed area had the highest dispersion with positively skewed distributed values along with one outlier which was found in Bonani Mor due to road dust and on-going elevated highway construction work. Moderate distribution was found in commercial area, industrial area and residential area with positive to negative distributed values along with two outliers in commercial area and one outlier in residential area. These episodes were found in Malibagh Rail Gate and Gulshan-2 Mor in commercial area due to these road intersections have a lot of traffic and road dust and Beribadh Chowrasta Mohammadpur in residential area due to road dust and massive vehicles movement. The sensitive area contained concentrated concentrations with typically skewed values, as well as two outliers caused by busy highways and anthropogenic activities in Jagannath Mor and TSC mor.

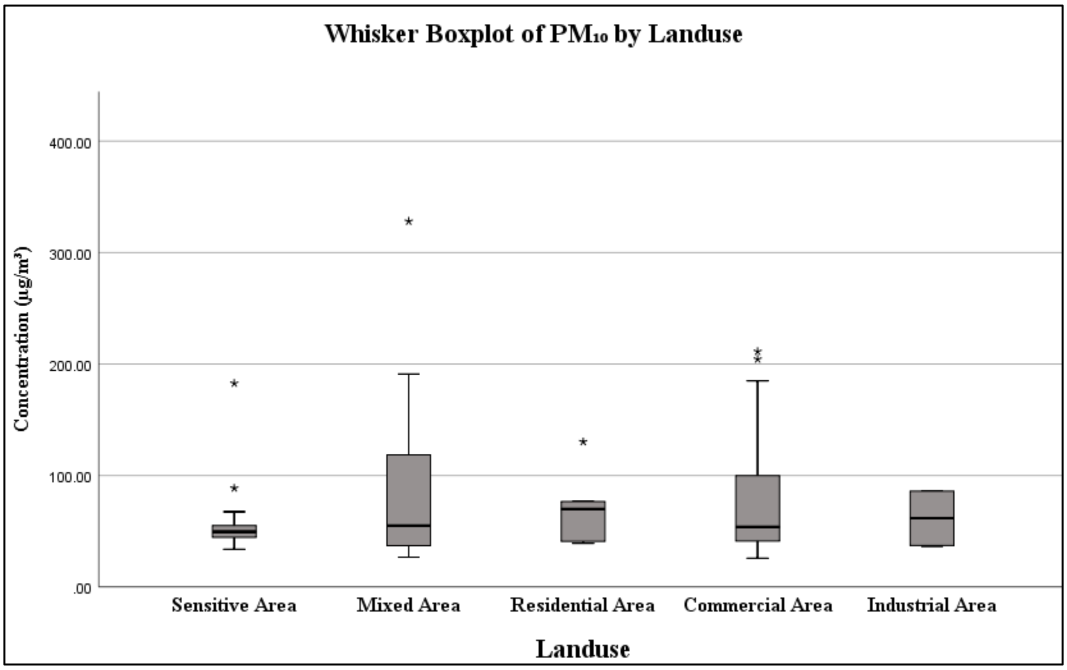

Figure 9. *Whisker box plot for the concentration of PM_{10} in different land use.*

3.3. Significance Test

Table 3 shows ANOVA for 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 determined for $PM_{2.5}$ and PM_{10} were 0.346 and 0.477, respectively. The p-values for $PM_{2.5}$ and PM_{10} were 0.846 and 0.752, respectively. The table demonstrates that the concentrations of $PM_{2.5}$ and PM_{10} remain rather stable both between and within different land uses, as indicated by the P values exceeding 0.05.

Table 3. Significance Test.

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
$PM_{2.5}$	Between Groups	384.312	4	96.078	0.346	0.846
	Within Groups	21373.845	77	277.58		
	Total	21758.157	81			
PM_{10}	Between Groups	5449.485	4	1362.371	0.477	0.752
	Within Groups	219902.021	77	2855.870		
	Total	225351.506	81			

3.4. Land Use Based Cluster Analysis

The dendrogram plot produced by cluster analysis in terms of $PM_{2.5}$ and PM_{10} with Z-score normalization is depicted in figures 10 and 11. For this analysis, the average connectivity between groups has been taken into account. Two clusters have been identified on the $PM_{2.5}$ graph. The first cluster comprises a sensitive area, an industrial sector, a residential area, and a commercial area. It is connected to the second cluster, which consists of a mixed area, at a distance of around 25 units. Again. the PM_{10} cluster analysis used average connectivity between groups. Three clusters have been identified in the graph below. The first cluster comprises a sensitive area an industrial sector, and a residential area, which are connected to the second cluster consisting of a commercial area at a distance of around 8 units. The broad cluster merges with the third cluster, encompassing a diverse region located approximately 25 units away.

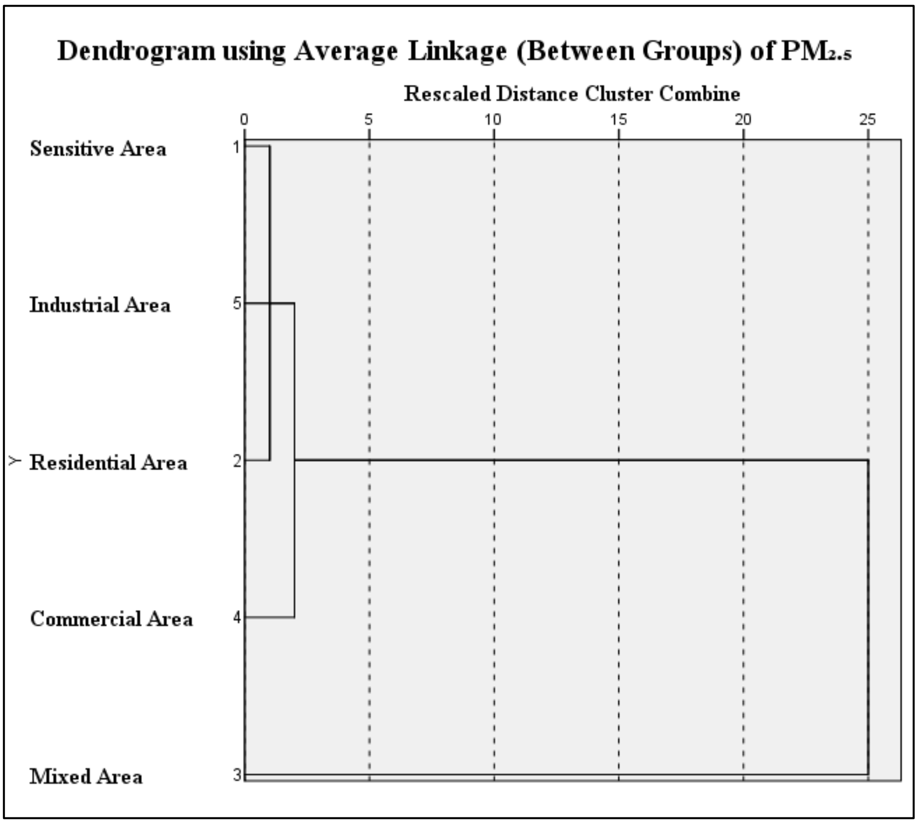

Figure 10. Rescaled distance cluster combine for $PM_{2.5}$.

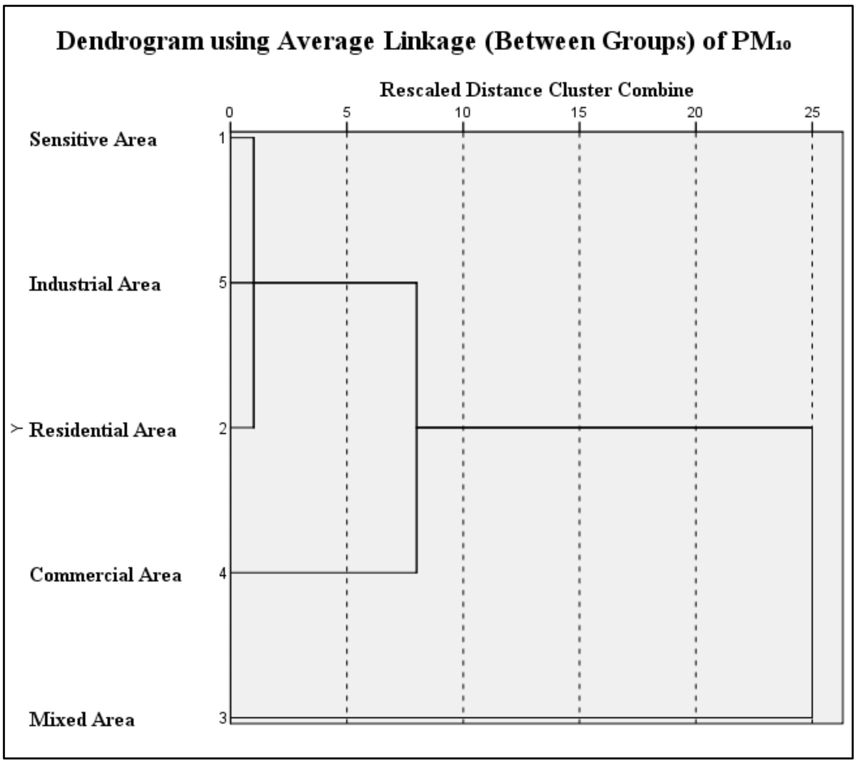

Figure 11. *Rescaled distance cluster combine for PM_{10}.*

3.5. Concentration Map on $PM_{2.5}$ and PM_{10} in Dhaka Metropolitan Area in 2022

3.5.1. $PM_{2.5}$ Concentration Map of Road Intersection in Dhaka Metropolitan Area in 2022

Figure 12 illustrates the concentration of Particulate Matter ($PM_{2.5}$) at various road intersection location of Dhaka metropolitan area in the year of 2022. Concentrations of Particulate Matter ($PM_{2.5}$) are expressed in $\mu g/m^3$. The concentration of $\mu g/m^3$ means one-millionth of a gram of PM per cubic meter of air. Yellow areas have less, while progressively higher concentrations are shown in orange and red. The concentration of $PM_{2.5}$ was found to higher (81-101 $\mu g/m^3$) in Dhanmondi 27 Mor and Bonani Mor area. Also shows that $PM_{2.5}$ concentrations were found lower (59-80) $\mu g/m^3$ in English Road Mor, Jagannath University Mor and Vasanktek Mor area. Also shows that $PM_{2.5}$ concentrations were found lower than 58 $\mu g/m^3$ in the most of the sampling area including Motijheel Mor, TSC Mor, Doyel Chottor Mor, Sayadabad Bus Stand Mor, Airport Mor, Zero Point Mor area. The highest concentration of $PM_{2.5}$ was found in Bonani Mor area showing in the map with red point and the lowest concentration was in Bata Signal Mor area showing in the map with green point.

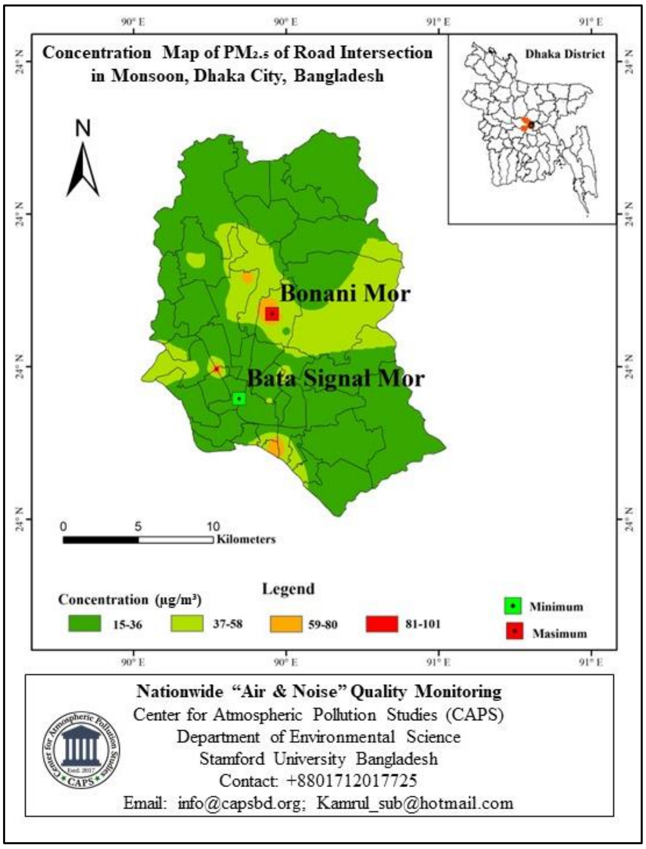

Figure 12. *$PM_{2.5}$ concentration of Dhaka metropolitan in 2022.*

3.5.2. PM_{10} Concentration Map of Road Intersection in Dhaka Metropolitan Area in 2022

Figure 13 demonstrates the concentration of Particulate Matter (PM_{10}) at various road intersection location of Dhaka metropolitan area in the year of 2022. Concentrations of Particulate Matter (PM_{10}) are expressed in $\mu g/m^3$. The concentration of $\mu g/m^3$ means one-millionth of a gram of PM per cubic meter of air. Yellow areas have little, while progressively higher concentrations are shown in orange and red. The concentration of PM_{10} was found to higher (181-330 $\mu g/m^3$) in Malibagh Rail Gate, Mohammadpur Bus Stand Mor, Gulshan-2 Mor, Jagannath University Mor, Dhanmondi 27 Mor and Bonani Mor area. Also shows that PM_{10} concentrations were found lower (101-180) $\mu g/m^3$ in Abul Hotel Mor, Jhigatola Mor, Kakrail Mor, English Road Mor, Gulshan-1 Mor, Bongobazar Mor, Mirpur-10 Mor, Rampura Bridge Mor, Vasanktek Mor, ECB Mor, Rabindra Saraini Mor and Beribadh Chowrasta Mohammadpur area. Also shows that PM_{10} concentrations were found lower than 100 $\mu g/m^3$ in most of the sampling area including Motijheel Mor, TSC Mor, Doyel Chottor Mor, Sayadabad Bus Stand Mor, Airport Mor, Zero Point Mor area. The highest concentration of $PM_{2.5}$ was found in Dhanmondi 27 Mor area showing in the map with red point and the lowest concentration was in Bata Signal Mor area showing in the map with green point.

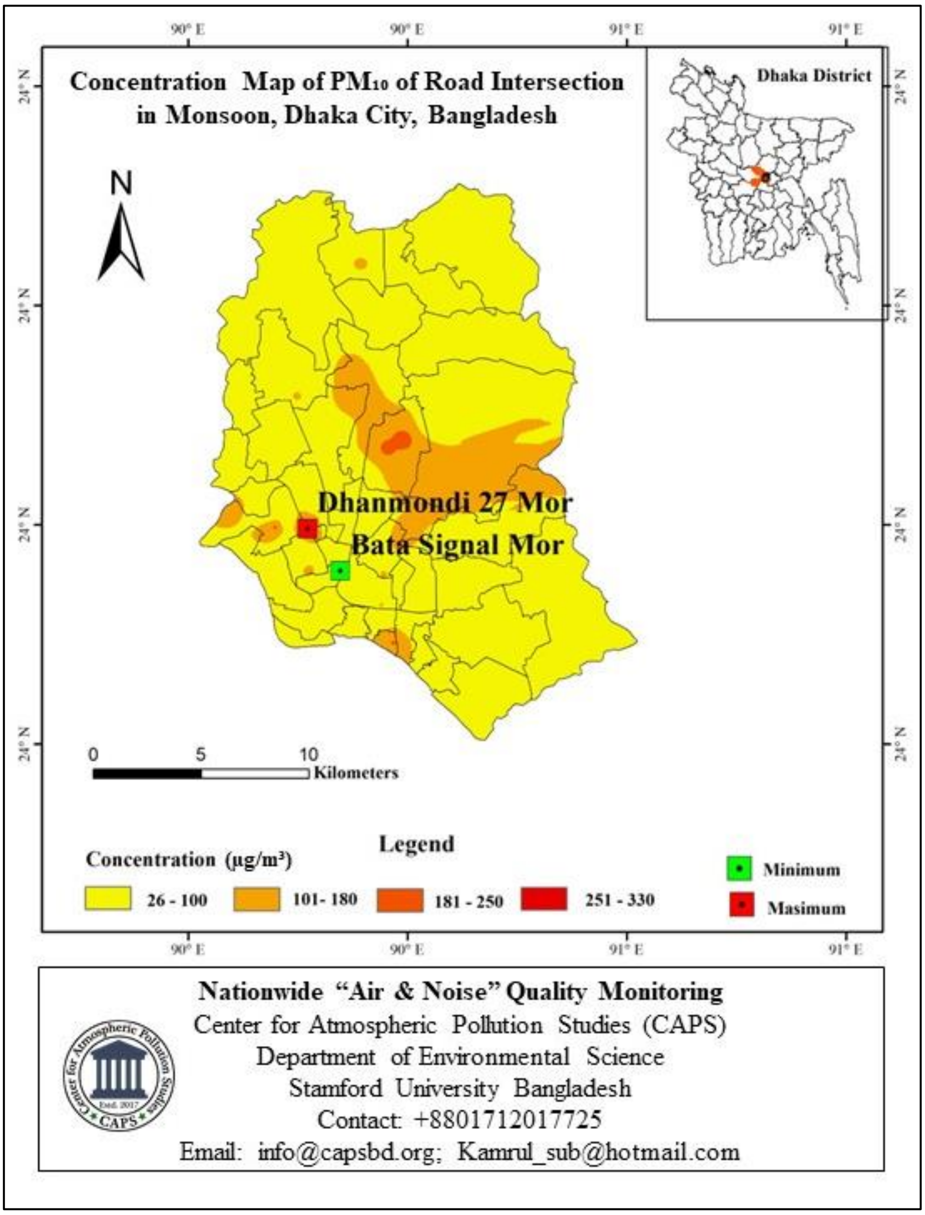

Figure 13. *PM_{10} concentration map of Dhaka metropolitan area in 2022.*

3.6. AQI on $PM_{2.5}$ Concentration of Road Intersection in Dhaka Metropolitan Area in 2022

Figure 14 shows AQI map of the road intersection in Dhaka metropolitan area based on $PM_{2.5}$. In this map, different colors represent the category of AQI according to Bangladesh National Ambient Air Pollution Standard. The map shows that AQI (151-200) was unhealthy in Malibagh Rail Gate, Mohammadpur Bus Stand Mor, Gulshan-2 Mor, Jagannath University Mor, Dhanmondi 27 Mor and Bonani Mor area in orange color. Also shows that, some areas were found in caution condition where the AQI was (101-150) in Abul Hotel Mor, Jhigatola Mor, Kakrail Mor, English Road Mor, Gulshan-1 Mor, Bongobazar Mor, Mirpur-10 Mor, Rampura Bridge Mor, Vasanktek Mor, ECB Mor, Rabindra Saraini Mor and Beribadh Chowrasta Mohammadpur area which indicate by yellow color. Also, AQI (51-100) was moderate condition in most of the sampling area in yellow green color.

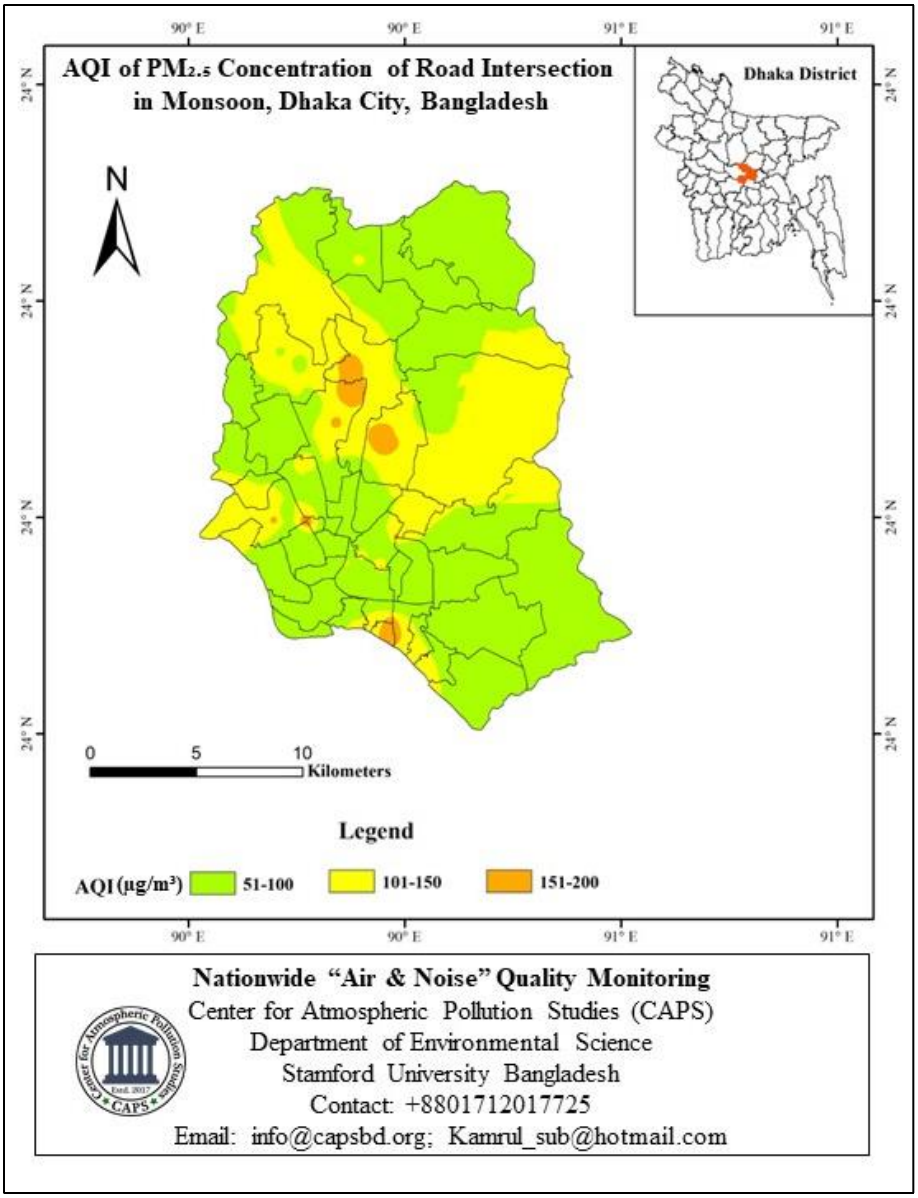

Figure 14. *AQI on $PM_{2.5}$ concentration map of Dhaka metropolitan in 2022.*

4. Conclusion

The study found that the average concentration of $PM_{2.5}$ and PM_{10} of selected places in road intersection in Dhaka metropolitan area found be 31.10 and 72.03 µg/m^3 respectively. From the outcome of this research, the studied land uses are arranged in descending order based on average concentration $PM_{2.5}$ and PM_{10} which follows as mixed area (35.37 and 85.41 $\mu g/m^3$) > residential area (30.44 and 71.39 $\mu g/m^3$) > commercial area (30.40 and 72.24 $\mu g/m^3$) > silent area (30.24 and 69.51 $\mu g/m^3$) > industrial area (29.05 and 61.59 $\mu g/m^3$). Along with that, the average concentration of $PM_{2.5}$ and PM_{10} of different land use found to be very high which 1.4148 and 1.7082 times higher than WHO standard level which are 25 and 50 $\mu g/m^3$ respectively. Moreover, it was estimated that the average ratio of $PM_{2.5}/PM_{10}$ showed that the $PM_{2.5}$ mass was 46.32% of the PM_{10} mass. Based on $PM_{2.5}$ and PM_{10} dispersion, among all those land use the maximum range is found in mixed area where the minimum range is found in the residential area and industrial area. Further found that in $PM_{2.5}$ and PM_{10} dispersion coefficient of variation higher in the mixed area and lower in the residential area and industrial area. Moreover, whisker box graph of $PM_{2.5}$ and PM_{10} show that values are dispersed in the mixed area and industrial area. It also revealed that that the concentrations of the parameters do not change significantly with land use as the p values are greater than 0.05. As because a number of old vehicles largely contribute to declined overall air pollution in Dhaka. to change the scenario, should improvement of public transport system for metropolitan area and need technological upgradation of mass transportation. In addition, unfit vehicles should be restricted. Along with that, citizens ought to uphold the Supreme Court's transportation guidelines for building materials. Furthermore, the Government of Bangladesh should implement Air Pollution Control Rules (2022) to thoroughly combat air pollution.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Majumder, A. K., Nayeem, A. A., Patoary, M. N. A. and Carter, W. S. Temporal Variation of Ambient Particulate Matter in Chattogram City, Bangladesh. *Journal of Air Pollution and Health*. 2020, 5(1): 33-42. https://doi.org/10.18502/japh.v5i1.2857

[2] Harrison, R. M., Pope, F. D. and Shi, Z. Trends in Local Air Quality 1970–2014. *Earth Systems, and Environmental Sciences*. 2014, pp. 1-17. https://doi.org/10.1039/9781782622178-00058

[3] Razib, Nayeem, A. A., Hossain, M. S. and Majumder, A. K. $PM_{2.5}$ concentration and meteorological characteristics in Dhaka, Bangladesh. *Bangladesh J. Sci. Ind. Res*. 2020. 55(2): 89-98. https://doi.org/10.3329/bjsir.v55i2.47629

[4] Hossen, M. A. and Hoque, A. Variation of Ambient Air Quality Scenario in Chittagong City: A Case Study of Air Pollution, *Journal of Civil, Construction and Environmental Engineering*, 2018, 3(1): 10-16. https://doi.org/10.11648/j.jccee.20180301.13

[5] Begum, B. A., Biswas, S. K. and Nasiruddin, M. Trend and Spatial Distribution of Air Particulate Matter Pollution in Dhaka City. *Journal of Bangladesh Academy of Sciences*. 2010, 34(1): 33-48. https://doi.org/10.3329/jbas.v34i1.5490

[6] Nayeem A. A., Hossain M. S., Majumder A. K. and Carter W. S. Spatiotemporal Variation of Brick Kilns and It's Relation to Ground-Level $PM_{2.5}$ Through MODIS Image at Dhaka District, Bangladesh. *Int. J. of Environmental Pollution & Environmental Modelling*, 2019, 2(5): 277-284.

[7] Haque, H. A., Huda, N., Tanu F. Z., Sultana, N., Hossain, M. S. A. and Rahman, M. H. Ambient Air Quality Scenario in and Around Dhaka City of Bangladesh. *Barisal University Journal Part 1* 2017, 4(1): 203-218.

[8] Rana, M. M., Sulaiman, N., Sivertsen, B., Khan, M. F., and Nasreen, S. Trends in atmospheric particulate matter in Dhaka, Bangladesh, and the vicinity. *Environ Sci Pollut Res Int*. 2016; 23(17): 17393-403. https://doi.org/10.1007/s11356-016-6950-4

[9] Nayeem, A. A., Hossain, M. S. and Majumder, A. K. Characterization of Inhalable Ground-Level Ambient Particulate Matter in Dhaka City, Bangladesh. *J. Sci. Res*. 2020, 12 (4): 701-712. https://doi.org/10.3329/jsr.v12i4.45802

[10] Begum, B., Hopke, P. and Markwitz, A. Air Pollution by Fine Particulate Matter in Bangladesh. *Atmospheric Pollution Research*, 2013, 4: 75-86. https://doi.org/10.5094/APR.2013.008

[11] Hossain, M. M., Majumder, A. K, Islam, M., and Nayeem, A. A. Study on Ambient Particulate Matter ($PM_{2.5}$) with Different Mode of Transportation in Dhaka City, Bangladesh. *American Journal of Pure and Applied Biosciences*. 2019, 1 (4): 12-19. https://doi.org/10.34104/ajpab.019.0191219

[12] Motalib, M. A. and Lasco, R. D. Assessing Air Quality in Dhaka City. *International Journal of Science and Research (IJSR)*, 2013, 4(12): 1908-1912. https://doi.org/10.21275/v4i12.sub159291

[13] IQAir. 2020, World Air Quality Report Region & City $PM_{2.5}$ Ranking. https://www.iqair.com/world-most-polluted-cities/world-air-quality-report-2020-en.pdf

[14] Salam, A., Hossain, T., Siddique, M. N. A., and Alam, A. M. S. Characteristics of Atmospheric Trace Gases, Particulate Matter, and Heavy Metal Pollution in Dhaka, Bangladesh. *Air Qual Atmos*, 2008, 1: 101-109. https://doi.org/10.1007/s11869-008-0017-8

[15] International Labor Organization (ILO). *Health hazards of child labour in brick kilns of Bangladesh. Dhaka*. 2014. International Programme on the Elimination of Child Labour (IPEC).

[16] Kim, K. H. Kabir, E. and Kabir, S. A. A review on the human health impact of airborne particulate matter. *Environment International*. 2015, V 74: (136-143). https://doi.org/10.1016/j.envint.2014.10.005

[17] Majumder, A. K., Patoary, M. N. A., Nayeem, A. A., & Rahman, M. T. U. (2023). Air quality index (AQI) changes and spatial variation in Bangladesh from 2014 to 2019. *Journal of Air Pollution and Health*. https://doi.org/10.18502/japh.v8i2.12919

[18] Department of Environment. *Ambient Air Quality in Bangladesh. Dhaka Bangladesh*. 2019. World Bank and Department of Environment (DoE).