Original Research Article

Evaluating Particulate Matter (PM□.□ and PM□□) Concentrations in Educational Institutions within South City Corporation, Dhaka, Bangladesh

ABSTRACT

Dhaka is widely recognized as the most polluted city in Bangladesh due to its high levels of dust. Most of the educational buildings in Dhaka South City Corporation are situated alongside the main road.The objective of this study is twofold. First and foremostly, it aims to identify the status of air pollution within educational institutions located in the Dhaka South City Corporation. Secondly, it seeks to assess the relationships among different zones and various air quality parameters, specifically focusing on particulate matter levels of PM□.□ and PM□□. This study was conducted in 37 locations of Dhaka metropolitan, by using Aeroqual s500. This research study is found that the average concentrations of PM□.□ and PM□□ in all the selected places of the study area were 68.82 and 113.95 µg/m³ respectively. The mean concentration of particulate matter (PM□.□ and PM□□) in all the zones had been observed to be more than one times higher than the acceptable level of concentration set by the National Ambient Air Quality Standards (NAAQS) level. It had been measured that the average value of PM□.□/PM□□ was 60.41%. Additionally, the study demonstrated that as the P values are less than 0.05, the concentrations of PM□.□ may vary significantly between and among zones. The outcome of this research is arranged in descending order based on the average concentration of PM□.□ which follows as Zone-5 (Chak Bazar, Bangshal, Kotwali) > Zone-2 (Dhanmondi) > Zone-6 (Sutrapur, Gendaria, Jatra Bari) > Zone-3 (Ramna, Shahbagh) > Zone-1 (Hazaribagh) > Zone-4 (Lalbagh, New Market) > Zone-7 (Kadamtali).

Keywords— Air Pollution, Particulate Matter, Educational Institution, Dhaka South City Corporation, Bangladesh.

1. INTRODUCTION

Air pollution has risen to the status of a major environmental health concern in many nations throughout the globe. Human exposure is the most obvious consequence of pollution, but the hidden cost to society from these contaminants' impacts on people's health and the ecosystem is also significant[1]. Particulate Matter has a harmful effect not only on human health but also on the environment and can raise respiratory problems and global warming, respectively [2]. However, the inventory of air pollutants is declining in Europe and the USA, while in Asia, the situation is worsening in real-time [3]. Bangladesh has the foulest air in South Asian countries

and each year 21% of all deaths in the country are caused due to a long-time exposure of high PM contain air [4]. Dhaka, the most populated city in the world and the capital of Bangladesh was identified as the fifth most polluted capital city in the world [5]. The level of air pollution in Dhaka city is now a quite concerning issue, with the AQI concentrations ranging from "Unhealthy" to "Extremely Unhealthy" for two-thirds of the year [6]. The city has grown increasingly crowded during the previous ten years. The land use with the highest average concentrations was the commercial area followed by residential, mixed, industrial, and sensitive area in Dhaka city [7].The municipal infrastructure is being built, locals are building high-rise residential and commercial developments to accommodate the city's growing population [8] which helps to increase air pollution. The massive and uncontrolled increase of emissions from industrial activities and transportation specifically, personal vehicles in Dhaka city deteriorates the air quality [9]. These two parts use a great amount of fuel that resulted in significant increases in emissions as well as economic losses [10]. Vulnerable groups like school going children are the major exposures and sufferers of PM because their immune and whole-body systems are under developing stage at this age [11]. In addition to having an adverse effect on children's physical and mental growth, air pollution aggravates respiratory diseases including asthma and seasonal allergic rhinitis (SAR), better known as hay fever, which is most frequent in schoolchildren [12, 13]. The proximity of educational institutions to major roads and busy traffic areas exacerbates the exposure of students and staff members to harmful pollutants. The levels of PM□.□ near schools in Dhaka City exceeded the World Health Organization's (WHO) recommended guidelines, posing a significant health risk to the vulnerable population, especially children [14].

2. OBJECTIVES

The objectives of the Studies are:

1. To identify the status of air pollution in educational institution of Dhaka South City Corporation.
2. To assess the relationship among Zones and parameters (PM□.□ and PM□□).

3. METHODOLOGY

a. Study Area

The study was conducted in Dhaka South city corporation. Data of Particulate matter concentration (PM□.□& PM□□) were recorded continuously 1-min for the average concentrations. Aeroqual monitors were used for data collection and placed tripods at ~1.5 m

elevation above the ground which were positioned horizontally. The monitoring location was nearest to the road with no other primary pollutant sources nearby. We divided the study area into seven zones based on thanas of Dhaka South City Corporation area according to Dhaka City Thana Map of Bangladesh which include in total thirty-six educational institution locations. The zones are divided as following, Hazaribagh area; Zone-(1), Dhanmondi area; Zone-(2), Ramna and Shahbagh area includes in Zone-(3), than Lalbagh and New Market area consisted in Zone-(4), Chak Bazar, Bangshal and Kotwali resided in Zone-(5), after that Sutrapur, Gendaria and Jatra Bari area involves in Zone-(6) and lastly Kadamtali area; Zone-(7).

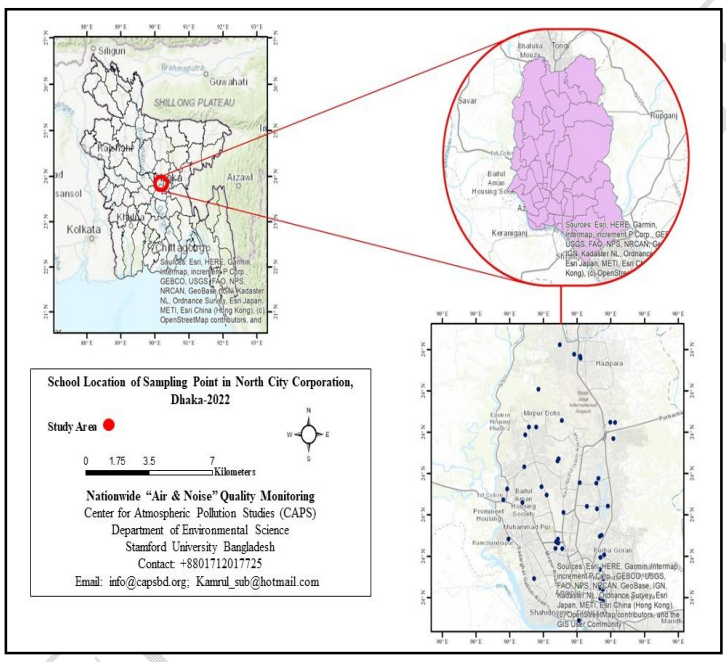


Fig. 1: Study Area (Dhaka South City Corporation and Data Collection Locations Point)

b. Data collection

Aeroqual portable monitors (Model: S500) were employed to collect air quality data. These monitors were positioned horizontally on tripods at a height of approximately 1.5 meters above ground level. The monitors were deliberately positioned alongside the road near the educational institution, away from other major sources of pollution, in order to obtain precise measurements. The Aeroqual monitors were configured to measure and record the average concentrations of particulate matter (PM) for a period of 1 minute. In order to commence the monitoring process, the device was activated by pressing and holding the power button until the screen became operational. Prior to commencing data collection, the sensors necessitated a

3-minute warm-up period to eradicate any impurities. A distinct Location ID was allocated to each monitoring site for the purpose of identification.

The sensor autonomously gathered and stored air quality data following the initialization period. Data retrieval was expedited by establishing a connection between the device and a personal computer using a USB cable. The data can be readily downloaded and exported to Excel format using the provided software.

Figure 2: Portable Air Quality Monitor

c. Data processing & Interpretation of Results

The collected data were processed using IBM SPSS V20 and MS Excel 2020. These tools were employed for data input, analysis, and visualization. A variety of graphs, tables, diagrams, and box-whisker plots were created in order to comprehend the properties of the data. Descriptive statistics were utilized to evaluate the spread of each land use characteristic, while ANOVA tests were employed to ascertain the statistical significance of the results. The air quality data is displayed in a thorough manner using an array of graphs, charts, and tables

4. RESULT & DISCUSSION

a. Status of Air Pollution Studies in EducationalInstitutions Area of South Dhaka City Corporation

The status of air pollution in educational institution zone area of South Dhaka City Corporation were shown in figure 3 (a, b, c, d, e, f, g and h). While there should always be less pollution in sensitive areas, in Dhaka city, there was a significant amount of pollution in these areas [7].Study found that in zone 1 (fig. 3 (a)) out of four places in Hajaribag area, the three highest average concentration of PM□.□ and PM□□ were in front of Shahid Sheikh rasel

Govt. High School, outside of Hajaribag Model Town High School and Hajaribag Ideal School & College with the concentration of 73 and 146 µg/m³; 71 and 96 µg/m³ and 34 and 103 µg/m³ respectively. On the other hand, the least PM□.□concentration was found in front of Hajaribag Girl's High School (31 µg/m³) and PM□□ concentration was found outside of Hajaribag Model Town High School (96 µg/m³). It also found that the most polluted place was 1.12folds higher than NAAQS levelland 5.84 and 2.92 folds higher than WHO standard. Where, the Bangladesh NAAQS level is 65 µg/m³ set by the Department of Environment (DoE) for concentrations of PM□.□. Also, the Air Quality Standard (24-hour) set by the WHO for PM□.□andPM□□ are 25 and 50 µg/m³ respectively.The primary cause of the severe dust pollution in the sensitive area of Dhaka city is vehicle emission [15]

Figure 3 (b) illustrated that among four places in Dhanmondi area, the three highest average concentration of PM□.□was in front of Dhaka City College (108 µg/m³), outside of Daffodil University (101 µg/m³) and Stamford College (84 µg/m³). Comparatively less polluted place was in front of Dhaka College (77 µg/m³). The average concentration of PM□□found higher outside of Daffodil University (206 µg/m³), Dhaka City College (116 µg/m³) and Stamford College (105 µg/m³) respectively and least polluted place was in front of Dhaka College (91 µg/m³). The study also indicated that the most polluted place were 1.66 and 1.36 times higher than the national standards. The study estimated that PM□.□ was found in PM□□ in Zone-2 was 76.69%.The comparison of the average concentration of PM□.□and PM□□ of zone-3 area was demonstrated through figure 3 (c). Within seven places in Ramna and Shahbagh area, the three highest average concentration of PM□.□was University of Dhaka (DU) area (80 µg/m³), outside of BTCL Ideal School and College (73 µg/m³) and Sher-E-Bangla School & College (56 µg/m³) and the least contaminated place was in front of Ibrahim Medical College (32 µg/m³). The average concentration of PM□□found higher outside of BTCL Ideal School and College (152 µg/m³), University of Dhaka (DU) (121 µg/m³) and in front of Siddeswari Girls College (109 µg/m³) respectively and comparatively least contaminated place was in front of Ibrahim Medical College (52 µg/m³). The most polluted place were 1.23 and 1.01 times higher than the national standards (NAAQS).

The figure 3 (d) presented that out of four places of zone-4 in Lalbagh and New Market area, the highest average concentration of PM□.□were in front of MadrashaRahmaniaHafijia (68 µg/m³) and outside of Govt. laboratory High School (66 µg/m³) and comparatively less contaminated place was Dhaka Ideal High School (27 µg/m³). On the other hand, the average concentration of PM□□ found higher outside of Govt. laboratory High School (133 µg/m³),

MadrashaRahmaniaHafijia (113 µg/m³) and in front of Dhaka Ideal High School (70 µg/m³) respectively. The least contaminated place was Lalbagh Govt. Model School & College (58 µg/m³). Study observed that the most polluted place was 1.05 times higher than the NAAQS and 2.72 and 2.66 times higher than WHO standard. The study estimated that the ratio of PM□.□ /PM□□ was 50.02% in Zone-4.

In figure 3 (e) zone-5 indicated that in Chak Bazar, Bangshal and Kotwali area, out of six places the highest average concentration of PM□.□and PM□□ were in front of Haybot Nagar Govt. Primary School (232 and 232 µg/m³), outside of Armanitola Govt. Primary School (120 and 186 µg/m³) and Suritola Model Govt. Primary School (117 and 119 µg/m³)respectively. Moreover, the least contaminated place was outside of Darul Huda Madrasa with PM□.□and PM□□ concentration of 50.00 and 88.00 µg/m³ respectively. However, study found that the most polluted places were 3.60 and 1.55 folds higher than the NAAQS level.

The study estimated that in Zone-5, 73.45% PM□.□was found into PM□□ . Study found that in Sutrapur, Gendaria and Jatra Bari area Zone-6, the maximum average concentration of PM□.□was in front of Central Women's College (91 µg/m³), outside of Narindra Govt. High School (79 µg/m³) and Dhaka MahanagarMohila College (74 µg/m³) and the average concentration of PM□□ found higher outside of Narindra Govt. High School (151 µg/m³), Dhaka MahanagarMohila College (142 µg/m³) and in front of Central Women's College (140 µg/m³) respectively.

Furthermore, the least concentration of PM□.□ and PM□□ was found in front of Salimullah College (45 and 73 µg/m³). In addition to the study found that the most polluted place were 3.60 and 1.55 times higher than the NAAQS. Study found in zone-7 (Kadamtali area), the most average concentration of PM□.□ was in front of Muradpur Govt. Primary & High School (55 µg/m³), outside of Bangladesh bank Adarsha High School (45 µg/m³) and relatively less contaminated place was Syampur Govt. Primary School and in front of Shyampur Ideal High School (44 µg/m³). However, the average concentration of PM□□ found higher outside of Bangladesh bank Adarsha High School (143 µg/m³), in front of Syampur Govt. Primary School (87 µg/m³) and Muradpur Govt. Primary & High School (71 µg/m³) respectively. Comparatively less contaminated places less polluted places were in front of Muradpur Govt. Primary & High School (71 µg/m³). Moreover, the most polluted place were 2.2 and 2.86 times higher than WHO standard. The study estimated that the ratio of PM□.□ /PM□□ was 53.63% in Zone-7.Finally the comparison of the average concentration of PM□.□ and PM□□ of seven zones in Dhaka South City Corporation. The average concentration of PM□.□ was higher in the Chak Bazar, Bangshal and Kotwali area (Zone-5), Dhanmondi area (Zone-2) and Ramna

and Shahbagh area (Zone-3) with the values of 116.00, 92.50 and 69.38 µg/m³ respectively. It was also observed that the average concentration of PM□□ was higher in the Chak Bazar, Bangshal and Kotwali area (Zone-5), and Dhanmondi area (Zone-2) with the values of 154.50, and 129.50 µg/m³ respectively with the highest concentration of PM□.□ and PM□□ in the Zone-5.It was also noticed that the concentrations of PM□.□ and PM□□ found in the most polluted Zone were 1.78 and 1.03 times higher than the national standards. The concentration of PM was found relatively lower in industrial area, residential area and sensitive area. Moreover, the average concentration of PM□.□ (47.00 µg/m³) was found to be least in Kadamtali area (Zone-7) and PM□□ (93.50 µg/m³) were found to be least in Lalbagh and New Market area (Zone-4).

Children in Dhaka cities experience respiratory issues as a result of air pollution [15]. Children's brain structure has been changed by particulate matter, which has an impact on cognitive performance [16].

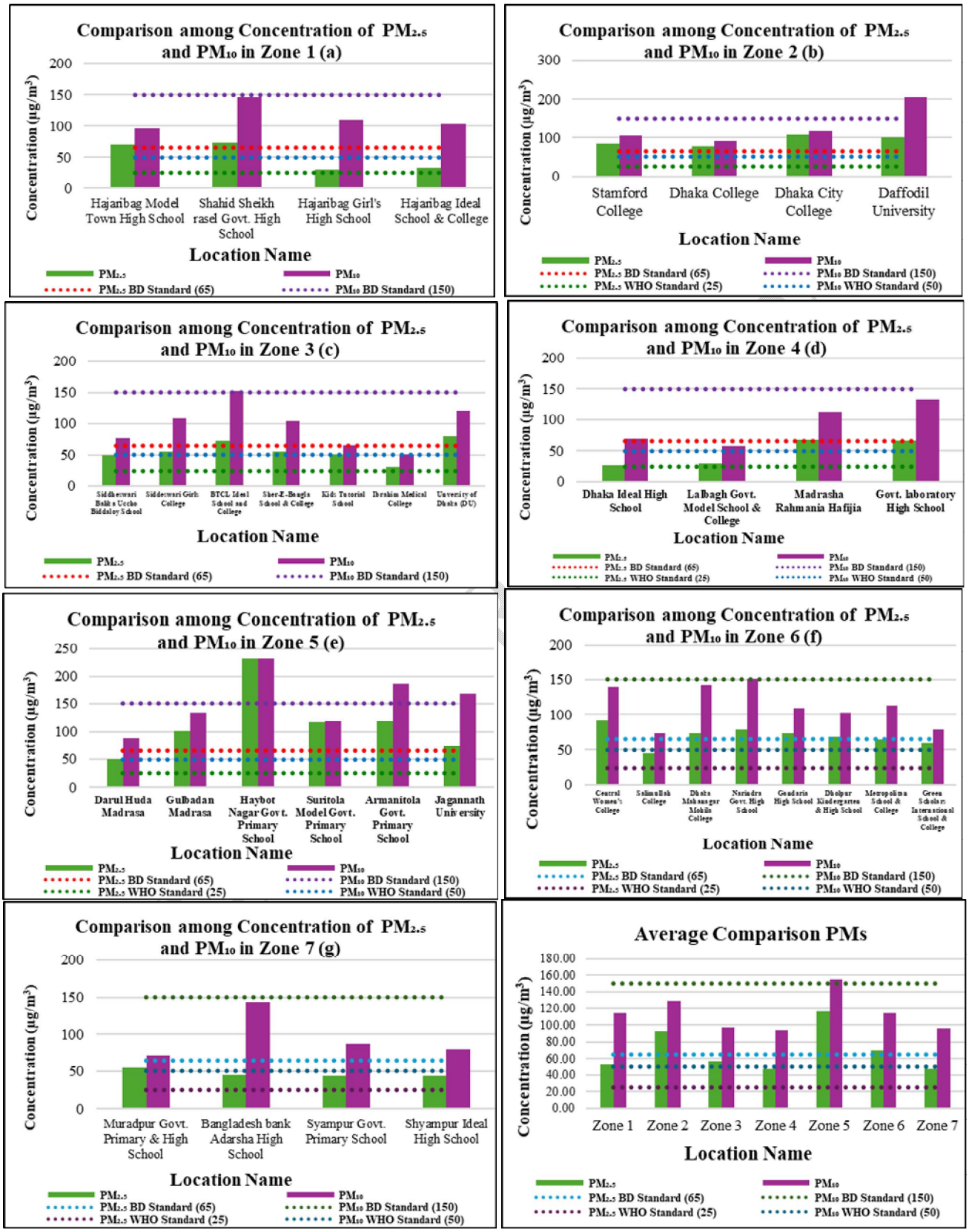


Figure 3: Comparison of Particulate Matters of Educational Institutions in Dhaka South City Corporation Area Based on Zones

b. Dispersion of the Educational Institutions in Dhaka South City Corporation Area Based on Zones

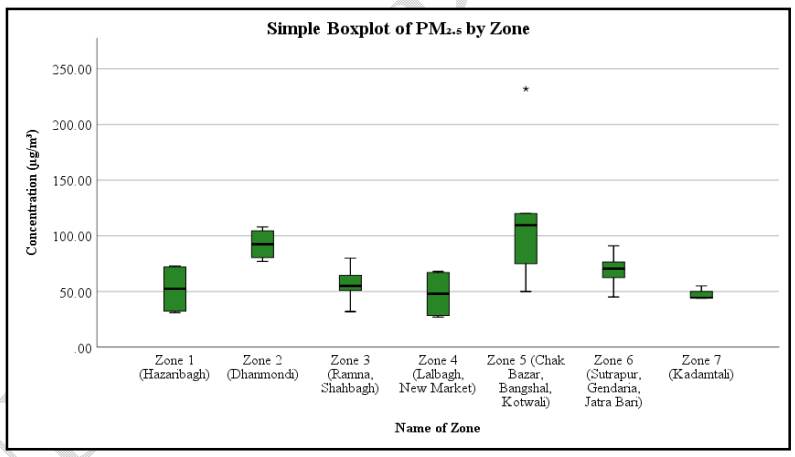
Table 1 presents the descriptive statistics for PM□.□ and PM□□ across seven different zones. For PM□.□, the highest concentration range was observed in Zone-5 at 182 µg/m³, followed by Zone-2 at 74 µg/m³, while the lowest was in Zone-7 at 11 µg/m³. The minimum concentration of PM□.□ across all zones was 27 µg/m³ in Zone-4, and the maximum was 232 µg/m³ in Zone-5. The highest mean PM□.□ concentration was in Zone-5 at 116.00 µg/m³, and the lowest was in Zone-7 at 47.00 µg/m³. Zone-5 also had the highest standard deviation of 62.78 µg/m³, whereas Zone-7 had the lowest at 5.35 µg/m³. The coefficient of variation for PM□.□ was highest in Zone-5 at 54.12% and lowest in Zone-7 at 11.39%.For PM□□, Zone-5 exhibited the highest range at 144 µg/m³, followed by Zone-2 at 115 µg/m³, and the lowest range was in Zone-1 at 50 µg/m³. The minimum PM□□ concentration was 52 µg/m³ in Zone-3, with the maximum again in Zone-5 at 232 µg/m³. The highest mean PM□□ concentration was found in Zone-5 at 154.50 µg/m³, and the lowest was in Zone-4 at 93.50 µg/m³. The standard deviation was highest in Zone-2 at 52.02 µg/m³ and lowest in Zone-1 at 22.20 µg/m³. The coefficient of variation for PM□□ was highest in Zone-2 at 40.17% and lowest in Zone-1 at 19.47%.

Table 1: Descriptive statistics table for PM□.□ and PM□□.

S. N.	Land Use	Number of Land use	PM□.□				PM□□			
			Range (µg/m³) (Min-max)	Mean (µg/m³)	Std. Deviation (µg/m³)	Coefficient of Variation (%)	Range (µg/m³) (Min-max)	Mean (µg/m³)	Std. Deviation (µg/m³)	Coefficient of Variation (%)
1.	Zone-1 (Hazaribagh)	4	42	52.25	22.85	43.74	50	114.00	22.20	19.47
2.	Zone-2 (Dhanmondi)	4	31	92.50	14.43	15.60	115	129.50	52.02	40.17
3.	Zone-3 (Ramna, Shahbagh)	7	48	56.86	15.75	27.71	100	97.29	34.59	35.56
4.	Zone-4 (Lalbagh, New Market)	4	41	47.75	22.28	46.65	75	93.50	35.37	37.83
5.	Zone-5 (Chak Bazar,	6	182	116	62.78	54.12	144	154.50	51.68	33.45

	Bangshal, Kotwali)									
6.	Zone-6 (Sutrapur, Gendaria,Jatra Bari)	8	46	69.38	13.62	19.63	78	113.63	29.16	25.66
7.	Zone-7 (Kadamtali)	4	11	47.00	5.35	11.39	72	95.25	32.50	34.12

The whisker box plot shows the average of PM□.□and PM□□ concentrations in seven zones in figure 4. Following whisker box plot of PM□.□ revealed that Zone-5 had the highest dispersion with extremely negative skewed distribution which contradicted with descriptive statistics where Zone-5 showed highest values along with one lower outlier; followed by Zone-4 and Zone-1 with normally skewed values with normally distributed values. This episode was found in front of Dhaka College. Moderate distribution was seen in Zone-2 with normal skewness and Zone-3 with positive skewness. These situations were found upper outlier in front of Haybot Nagar Govt. Primary School and lower outlier found outside of Darul Huda Madrasa in Zone-5. Less moderate distribution was seen in Zone-6 with negatively skewed values. Zone-7 had the most clustered concentration with extremely positive distributed values.



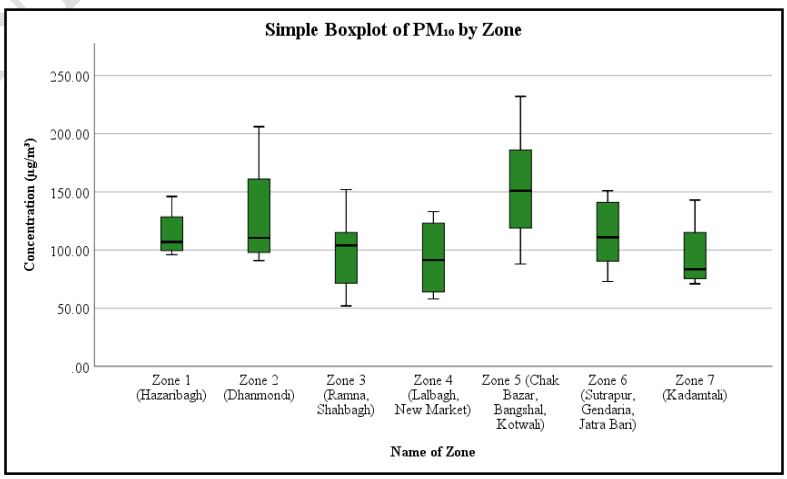


Figure 4: Whisker-box plot showing the concentration of PM□.□and PM□□ in Different Zones

This whisker box plot of PM□□ revealed that the highest concentration that was seen in Zone-5 with positively skewed distribution followed by Zone-2, Zone-4 and Zone-6 with positive to normal skewed values. Moderate distribution was seen in Zone-7 with positively distributed values. Less Moderate distribution was seen in Zone-1 with extremely positive skewness, which was found in front of Shahid Sheikh Rasel Govt. High School. Enforcing stricter vehicle emissions laws and promoting the use of public transportation are essential to addressing the particulate matter problem in the Dhaka Metropolitan Area [7].

c. Significance Test

The table 2 of 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 4.052 for PM□.□ and 1.840 for PM□□ where P value of PM□.□ and PM□□ were 0.004 and 0.125. The following table shows that the concentrations of PM□.□ change significantly between and within in the land uses as the P values are less than 0.05. However, PM□□ do not change significantly as the P values are greater than 0.05.

Table 2: Significance Test

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
PM□.□	Between Groups	21281.957	6	3546.993	4.052	0.004
	Within Groups	26259.232	30	875.308		
	Total	47541.189	36			

PM□□	Between Groups	15825.257	6	2637.543	1.840	0.125
	Within Groups	43001.554	30	1433.385		
	Total	58826.811	36			

d. Land Use Based Cluster Analysis

Figure 5 illustrates the dendrogram plots resulting from cluster analyses of PM□.□ and PM□□ concentrations, with Z-score normalization applied. The PM□.□ analysis identified four distinct clusters. The first cluster includes Zone-4, Zone-7, Zone-1, and Zone-3. This cluster merges with the second cluster, which comprises Zone-6, at an approximate distance of 10. Subsequently, the combined group joins the third cluster, which includes Zone-2. Finally, the fourth cluster, consisting of Zone-5, merges with the third cluster to form a single cohesive cluster at an approximate distance of 25.

For PM□□ concentrations, three clusters were identified. The first cluster comprises Zone-1, Zone-6, and Zone-2. This cluster merges with the second cluster, which includes Zone-4, Zone-7, and Zone-3, at a distance of approximately 13. The merged clusters then join with the third cluster, which includes Zone-5, forming a unified cluster at an approximate distance of 25.

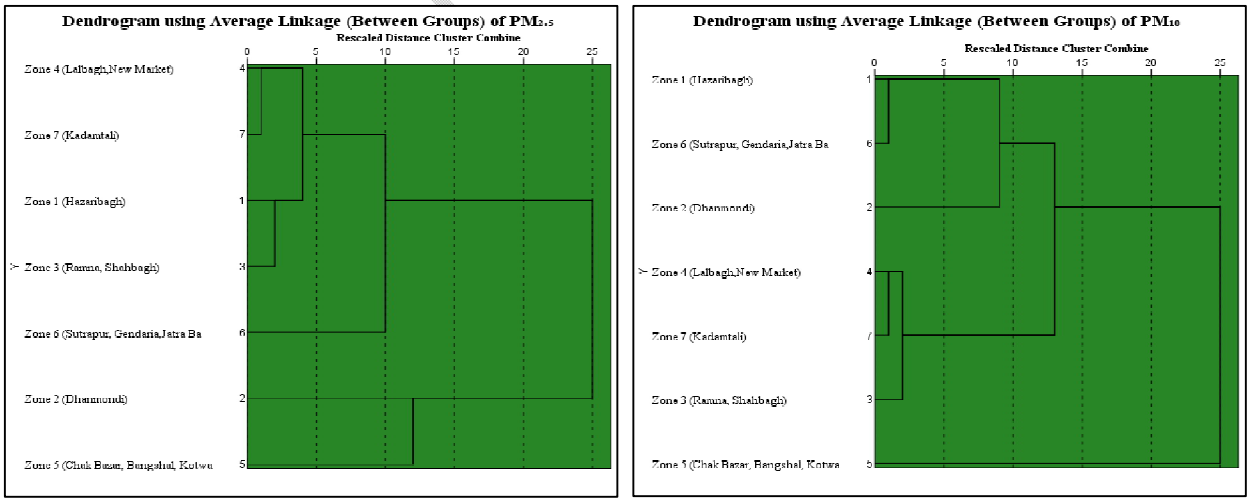


Figure 5: Rescaled Distance Cluster Combine for PM□.□ and PM□□ in Different Zones

5. CONCLUSION

The study determined that the average concentrations of PM□.□ and PM□□ at 37

educational institutions within the Dhaka South City Corporation were 68.82 µg/m³ and 113.95 µg/m³, respectively. The results show variations in PM□.□ levels across different zones, ranked in descending order as follows: Zone-5 (116.00 µg/m³), Zone-2 (92.50 µg/m³), Zone-6 (69.38 µg/m³), Zone-3 (56.86 µg/m³), Zone-1 (52.25 µg/m³), Zone-4 (47.75 µg/m³), and Zone-7 (47.00 µg/m³). Additionally, PM□.□ and PM□□ concentrations were found to be 1.78 and 1.03 times higher than the NAAQS levels of 65 µg/m³ and 150 µg/m³, respectively.

The study also found that PM□.□ and PM□□ dispersion varied by land use, with Zone-5 showing the maximum range, followed by Zone-2, while Zone-7 and Zone-1 had the lowest ranges. The coefficient of variation for PM□.□ and PM□□ was highest in Zone-5 and Zone-4, respectively, and lowest in Zone-7 and Zone-1. Whisker-box plots revealed that Zone-4 exhibited the highest dispersion of PM□.□ with a normally skewed distribution, whereas Zone-5 had the highest PM□□ values with a positively skewed distribution.Priorities the implementation of consistent air quality monitoring systems at educational institutions, particularly in areas with high levels of PM□.□ and PM□□ concentrations, to effectively monitor pollution patterns and trends. Implementing more stringent restrictions and improving pollution control systems can effectively decrease the release of particulate matter, especially in heavily polluted areas like Zone-5 and Zone-2. In addition, the implementation of more green spaces in the vicinity of educational institutions can contribute to the absorption of pollutants and enhance the overall air quality. It is crucial to increase awareness among students, faculty, and the community on the health hazards linked to air pollution. This will promote the adoption of practices that reduce exposure, especially during periods of high pollution. Finally, further investigation is required to determine the origins of particulate matter and comprehend the influence of various land uses on air quality. This will facilitate the creation of focused interventions and policies.

6. LIMITATIONS OF THE STUDY

The research's geographical scope, focusing on South City Corporation educational institutions, limits its generalizability to other Dhaka or Bangladesh areas due to potential variations in particulate matter concentrations. The study need more and longtime data to capture the seasonal variations in PM□.□ and PM□□ concentrations. The study couldn't able to focus all health risk factors related to PM exposure as a result, it couldn't explain the overall public health impacts on the studied populations.The study emphasizes the need for more

investigation to completely understand particulate matter pollution's effects on health in cities like Dhaka.

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