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GIS-based Spatial Mapping of the Atmospheric Particulate Pollutant ($PM_{2.5}$ and PM_{10}) at Mymensingh City Corporation Areas of Bangladesh

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Abstract: Particulate matter (PM) pollution poses a significant threat to public health and the environment. This research study investigates to analyze the spatial distribution of $PM_{2.5}$ and PM_{10} concentrations in the Mymensingh City Corporation (MCC) areas in Bangladesh. A GIS-based spatial mapping approach was utilized to assess the distribution patterns and potential sources of PM pollution. Data was collected from 48 sampling points across the study area during different times of the day. The results revealed varying concentrations of $PM_{2.5}$ and PM_{10} with higher levels observed during the afternoon and evening hours. The maps generated through spatial mapping techniques provided valuable insights into the pollution hotspots and areas of concern. The study identified several potential sources of PM pollution, including traffic emissions, construction activities, industrial processes, brick kilns, road dust, biomass burning, waste burning, and residential sources. The health risks associated with elevated $PM_{2.5}$ and PM_{10} pollution were also highlighted, emphasizing the need for mitigation strategies. Based on the findings, several recommendations were proposed to mitigate PM pollution. This research contributes to the understanding of PM pollution in the MCC area and provides a foundation for developing targeted interventions to safeguard public health and improve air quality. Further research is warranted to explore additional sources and long-term trends in PM pollution.

1. Introduction

Air pollution is a matter of utmost global concern, presenting a critical and pressing challenge that disrupts the environment and affects human health (Ghorani-Azam *et al.,* 2016). The air we breathe can often conceal a danger known as particulate matter pollution (Kim *et al.,* 2015; Chetouani *et al.*, 2017). In the age of growing urbanization and industrialization, air quality has grown to be a major global problem. Air pollution is a complex blend of gases and particles, both of which have harmful effects on human health (Hamanaka and Mutlu, 2018). Scientific investigations commonly reveal that particulate matter (PM) pollution has a more pronounced impact on health compared to gaseous pollutants (Jubaer *et al.,* 2022). Extensive research conducted worldwide consistently demonstrates that air pollution significantly contributes to higher rates of illness and death (Hossain, 2019). Particulate matter (PM) is a critical constituent of ambient air, which significantly influences human health and overall air quality (Hassan et *al.,* 2022). PM_{10} and $PM_{2.5}$ are of special concern because they offer severe health concerns when inhaled (Rastgeldi, 2010; Medjahed *et al.,* 2020). These aerosol pollutants are commonly acknowledged to be the most dangerous components of airborne particulates. PM stands out as an extremely potent and widespread air contaminant in metropolitan settings (Razib *et al.,* 2020). Exposure to particulate matter (PM) has been associated with a range of health effects, including respiratory conditions such as asthma and bronchitis, reduced lung function, cardiovascular diseases, and various chronic ailments that contribute to premature mortality when exposed for prolonged periods of time (Brunekreef and Holgate, 2002; Gozzi *et al.,* 2017). Notably, higher levels of ambient $PM_{2.5}$ have been identified as a leading cause of premature deaths, which is approximately 7.6% globally. Approximately 59% of such early fatalities take place in East and South Asia, placing a heavy burden on the population that is at risk (Iqbal *et al.,* 2020). Air quality monitoring data in Bangladesh is limited, but surveys conducted by the Department of Environment (DOE) indicate that the levels of Suspended Particulate Matter (SPM) exceed the country's air quality guidelines (Ashraful Haque *et al.,* 2017). Emissions from automobiles are a significant contributor to the pollution issue in Bangladesh (Begum *et al.,* 2013). Research suggests that particle emissions from coal and biomass burning, particularly in brickfields, may contribute to the haze observed in urban and semi-urban areas of Bangladesh (Hasan *et al.,* 2020). Previous studies have found that meteorological factors, such as atmospheric circulation, planetary boundary layer height, air temperature, relative humidity, wind speed, and wind direction, have a significant influence on the concentration of $PM_{2.5}$ (Xu and Chen, 2021). The Mymensingh City Area, situated in the north-central region of Bangladesh, has witnessed significant growth in urban infrastructure and industrial activities in recent years, contributing to the deterioration of air quality (Salam *et al.,* 2008). The combination of uncontrolled population growth, haphazard land use development, and poor traffic management have led to severe strain on the Mymensingh road network, resulting in significant air pollution from transportation (Sarker *et al.,* 2018). Numerous researchers have explored various aspects of particulate matter, including people's perceptions of air pollution in both rural and urban areas of the Mymensingh region but there is a scarcity of reports (Mondol *et al.,* 2021). The green landscapes and heavy rainfall during the monsoon season in Mymensingh city help alleviate air pollution, but the negative impact of land use changes and human activities has intensified the degradation of air quality in recent times (Rouf *et al.,* 2012). The atmospheric particulate pollutant levels, specifically $PM_{2.5}$ and PM_{10} in the Mymensingh City Areas of Bangladesh have been influenced by rapid urbanization and industrial growth (Ruba *et al.,* 2021). The combined impact of vehicle emissions, industrial pollutants, and other activities has worsened the air quality of this region (González *et al.,* 2017), highlighting the urgent need for a thorough understanding of the issue and the implementation of effective solutions. The main objectives of this study are-

- To determine the spatial distribution patterns of $PM_{2.5}$ and PM_{10} pollutants across different regions within the Mymensingh City Area.
- To identify and characterize potential pollution hotspots and sources of $PM_{2.5}$ and PM_{10} pollutants in the Mymensingh City Area using GIS techniques.

- To analyze the concentration levels of $PM_{2.5}$ and PM_{10} pollutants and evaluate their adherence to both national and international air quality standards.

Rapid urbanization, industrial activities, and transportation emissions contribute to the accumulation of particulate matter (PM) in the atmosphere (Alizadeh-Choobari *et al.,* 2016). The high concentration of particulate matter in the air has detrimental effects on human health, particularly respiratory and cardiovascular systems (Manisalidis *et al.,* 2020). In view of this, understanding the spatial distribution of particulate matter pollution in the Mymensingh City Corporation area is crucial for effective pollution control and mitigation strategies.

2. Materials and Methods

To achieve the aim of this study, a GIS-based spatial mapping approach was employed to identify and analyze the distribution of $PM_{2.5}$ and PM_{10} concentrations across the Mymensingh City area in Bangladesh. A methodical approach was followed during this study that involved study area selection, data collection, data preprocessing, data analysis, map projection and visualization.

2.1 Study Area

Mymensingh City Corporation, located in the north-central region of Bangladesh, was selected as the study area to conduct the research (Figure 1). This city is situated on the northern bank of the old Brahmaputra. Mymensingh is the divisional capital and an important industrial and commercial hub. With a population of approximately 0.45 million, the city is home to a significant number of people who are at risk of being exposed to hazardous air pollutants. Various factors contribute to the city's air pollution, including transportation, emissions from brick kilns, and construction activities. As a result, the air quality of Mymensingh City has been declining over time, posing a significant threat to the health and well-being of its residents.

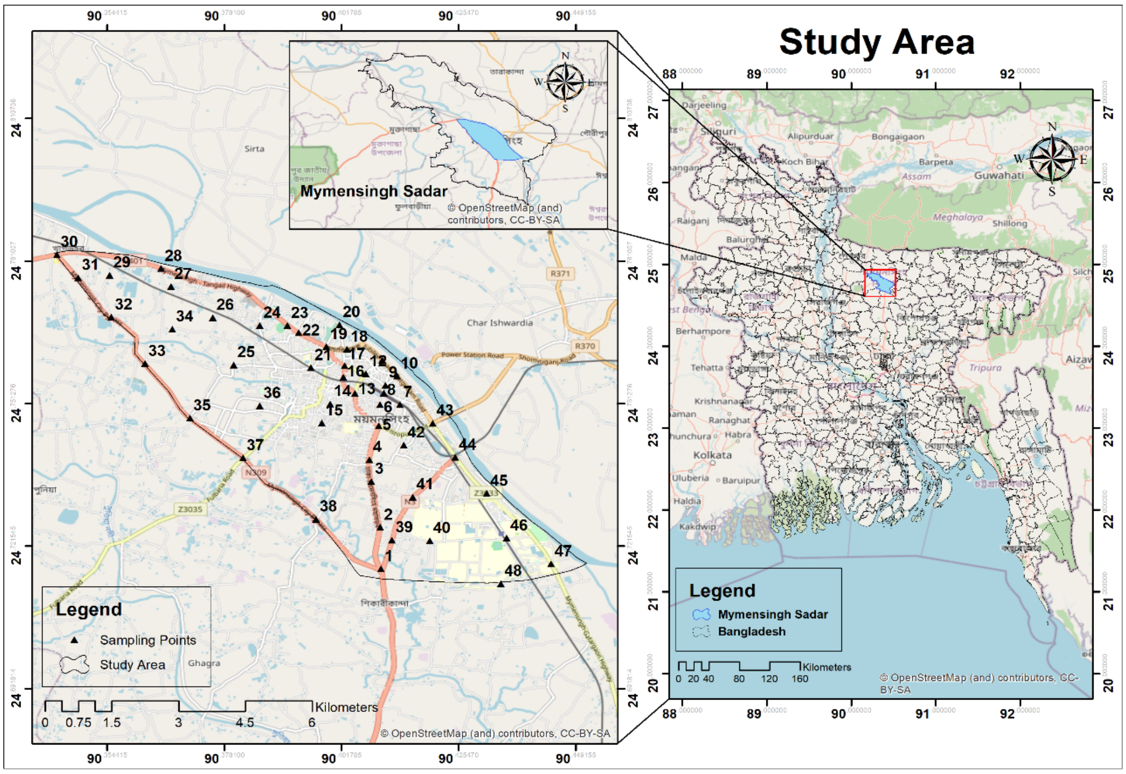

Figure 1: Locator map of the study area (Mymensingh City Corporation)

2.2 Sampling Instrument

In this study, the Airveda $PM_{2.5}$-PM_{10} Air Quality Monitor was employed as the primary instrument to measure particulate matter (PM) concentrations in the study area. The Airveda PM monitor is a reliable and portable device designed to accurately assess air quality and provide real-time data on $PM_{2.5}$ and PM_{10} pollutants (Figure 2). The Airveda PM monitor is equipped with advanced sensor technology that enables it to capture fine particulate matter with a diameter of 2.5 micrometers ($PM_{2.5}$) and coarse particulate matter with a diameter of 10 micrometers (PM_{10}). These pollutants are known to be critical indicators of air pollution and have significant impacts on human health and the environment. The table 1 provides the features and specifications of the sampling instrument.

Figure 2: Airveda PM2.5 PM10 Air Quality Monitor

Table 1: General specifications of the Airveda $PM_{2.5}$ PM_{10} Air Quality Monitor.

Specifications	Description
Measurement Parameters	$PM_{2.5}$ (Fine Particulate Matter) in µg/m³ PM_{10} (Coarse Particulate Matter) in µg/m³
Measurement Range	$PM_{2.5}$= (0 – 999) µg/m³ PM_{10}= (0 – 1999) µg/m³
Measurement Accuracy	±10 µg/m³ or ±10% of reading, whichever is greater
Response Time	< 10 seconds
Data logging	Real-time data logging with timestamp
Calibration	Factory calibrated; no user calibration required
Dimensions	(116*116*60) mm

Source: www.airveda.com

By utilizing the Airveda $PM_{2.5}$ PM_{10} Air Quality Monitor in this study a robust dataset was obtained, enabling comprehensive spatial mapping and analysis of $PM_{2.5}$ and PM_{10} concentrations in the study area. The use of this advanced instrument contributed significantly to the accuracy and reliability of the research findings, providing valuable insights for effective pollution management and public health protection measures.

2.3 $PM_{2.5}$ and PM_{10} Standard

The table below shows the Bangladeshi standard of $PM_{2.5}$ and PM_{10}.

Table 2: Standard level of $PM_{2.5}$ and PM_{10}

Particulate Matter Standard		
Category	**$PM_{2.5}$ (µg/m3)**	**PM_{10} (µg/m3)**
Good	0-50	0-50
Moderate	51-100	51-100
Caution	101-150	101-150
Unhealthy	151-200	151-200
Very Unhealthy	201-300	201-300
Extremely Unhealthy	301-500	301-500

Source: Department of Environment (DoE), Bangladesh 2018

2.4 Research Design

This study utilized a cross-sectional research design to collect data on the spatial distribution of $PM_{2.5}$ and PM_{10} pollutants in the study area. This design allowed for simultaneous data collection from multiple sampling locations, ensuring comprehensive coverage across the study area. By using a cross-sectional design, the study was able to provide a snapshot of the air quality in the study area at a specific point in time, which can be used to inform future policies and interventions aimed at reducing air pollution and protecting public health.

2.5 Sample Site Selection

The selection of sampling sites was a crucial aspect of this study. In this study, the selection of sampling sites was carefully planned and executed. The aim was to ensure that the data collected was both accurate and representative of the study area. Proximity to known sources of pollution, such as busy roads, industrial areas, and construction sites, was taken into consideration when selecting the sampling sites. The sampling sites were also strategically chosen to cover different areas of the study area, which was essential to achieve a representative sample. This ensured that the data collected was reflective of the most polluted areas in the city.

2.6 Data Collection

In this study, the primary data was collected using the reliable and portable Airveda $PM_{2.5}$ PM_{10} Air Quality Monitor. This instrument is known for its high accuracy and portability, making it the ideal choice for field data collection. To ensure comprehensive data collection, the monitors were placed at various locations within the study area, and readings were taken at multiple time points throughout the day. Additionally, before each use, the monitors were calibrated, and readings were taken at the same time to ensure consistency in the data collected. The data collection process for this project started on 27.03.2023 and continued up to 02.04.2023. To ensure that the data collection adhered to recommended guidelines, the supervisor provided detailed instructions on data collection and analysis. This approach ensured that the data collected was both robust and of high quality, enabling accurate and comprehensive analysis.

2.7 Data Processing and Cleaning

After the data was collected, it was crucial to process it to ensure that it was of high quality and ready for analysis. To achieve this, the data was cleaned to remove any errors or inconsistencies that could have occurred during the data collection process. Quality checks were also performed to ensure that the data met the necessary standards and was fit for analysis. Additionally, the data was transformed into a suitable format that could be analyzed efficiently. For data preprocessing, MS Excel was used, which provided a range of tools and functions for data manipulation, filtering, and aggregation. This step was critical to ensure the accuracy and reliability of the results obtained from the analysis. The data processing stage was conducted under the guidance of the supervisor, who ensured that the process was in accordance with recommended guidelines for data analysis.

2.8 Spatial Analysis and Map Projection

The processed data was then imported into the ArcGIS software for further processing and analysis. This software is commonly used for mapping and analyzing spatial data, making it an ideal tool for the study. The digital map created by ArcGIS allowed us to easily visualize the data in a spatial context, giving us a better understanding of the distribution of pollutants in the Mymensingh City Corporation area. We utilized the inverse distance weighting (IDW) interpolation technique, which is a widely used method for spatial analysis. This technique allowed us to generate continuous maps of $PM_{2.5}$ and PM_{10} concentrations across the study area, making it easier to interpret and analyze the data. The use of ArcGIS software and the IDW interpolation technique allowed us to effectively visualize and analyze the spatial distribution of $PM_{2.5}$ and PM_{10} pollutants, providing valuable insights into the air quality of the study area.

3. Result and Discussions

In this section, the results of the particulate matter (PM) distribution analysis in the Mymensingh City Corporation area based on the collected data are presented. All the interpreted results are presented according to the objectives of the study.

3.1 Data Analysis

The analysis includes the concentration levels of $PM_{2.5}$ and PM_{10} at various sampling points during different times of the day. Particulate Matter data was collected from a total of 48 sampling points in the MCC area. The data collection process consisted of three shifts each day: Morning, Afternoon, and Evening.

3.1.1 Sampling Points and Coordinates

Table 3 provides essential details regarding the specific locations where the sampling for Particulate Matter (PM) concentration data took place within the Mymensingh City Corporation (MCC) area. The table presents information about the sampling points, including their local names, latitude, longitude coordinates along with their zonal characteristics. This table serves as a comprehensive reference, allowing for easy identification of the precise locations where the data collection occurred.

2.9 Research Framework

The Framework for the project process is given in **Figure 3.**

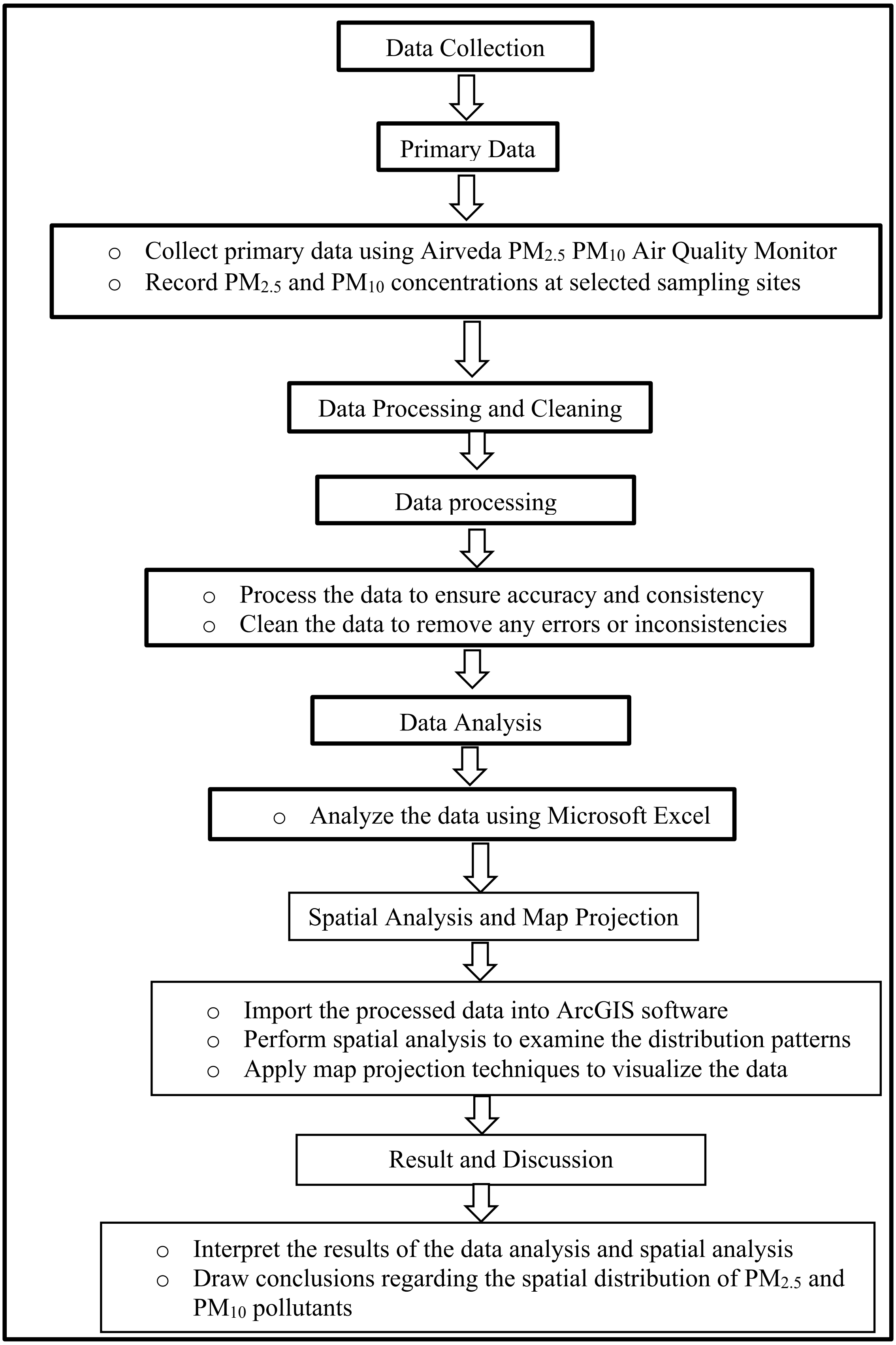

Figure 3: Framework for the project process

Table 3: Sampling points of $PM_{2.5}$ and PM_{10} in the Mymensingh City Corporation area.

Sample No.	Locations	Latitude	Longitude	Zone
1	Dhaka-Mymensingh Bypass	24.716739	90.409776	Traffic
2	Digharkanda	24.725382	90.409658	Mixed
3	Mashkanda	24.734988	90.407865	Mixed
4	Mymensingh Polytechnic Institute	24.73953	90.407465	Residential
5	Chorpara	24.746589	90.409352	Commercial
6	Brahmmapolli	24.750999	90.409608	Residential
7	Baghmara	24.751005	90.41361	Residential
8	Mymensingh Railway Junction	24.753434	90.410351	Traffic
9	Station Mor	24.755059	90.410679	Commercial
10	Moharaja Road	24.756976	90.413058	Commercial
11	Bipin Park	24.760328	90.410064	Mixed
12	Traffic Signal, Ganginar Par	24.757455	90.406767	Commercial
13	Trishal Bus-stand	24.753346	90.404503	Commercial
14	Noumohol	24.751172	90.399518	Residential
15	Aqua Morolpara	24.747173	90.397829	Residential
16	Boundary Road	24.756723	90.402211	Commercial
17	Traffic Signal, Notun Bazar	24.759175	90.402422	Traffic
18	Shoshi Lodge	24.762568	90.402922	Traffic
19	Townhall	24.763089	90.39874	Commercial
20	Bat Ball Chottor	24.767703	90.40138	Traffic
21	Shankipara bazar	24.758745	90.395599	Commercial
22	Kachijhuli	24.766026	90.393137	Commercial
23	Tangail Bus-Stand	24.767514	90.390881	Traffic
24	Bou Bazar	24.76755	90.385272	Commercial
25	Gohailkandi	24.759306	90.380042	Residential
26	Amin Bazar	24.769172	90.375797	Commercial
27	Mymensingh Road Station	24.775665	90.367306	Traffic
28	Khagdohor Bazar	24.779437	90.365319	Commercial
29	Khagdohor Moddhopara	24.778041	90.354888	Residential
30	Rohomotpur Bypass	24.782316	90.34423	Traffic
31	Zamia Kasimia	24.777515	90.348537	Residential
32	Bagherkanda	24.769285	90.355238	Residential
33	Badekolpa Moddhopara	24.759598	90.362039	Residential
34	Khagdohor Dokkhinpara	24.766761	90.367588	Residential
35	Gondropa Bypass Mor	24.748197	90.371143	Traffic
36	Chukaitala Bazar	24.750789	90.385299	Commercial
37	Aqua Bypass Mor	24.739887	90.381906	Traffic
38	Moddho Barera	24.727104	90.396672	Residential
39	Hridoyer mor	24.722756	90.412018	Traffic
40	Fishari Mor, BAU	24.722615	90.419655	Residential

41	Moynar mor	24.731713	90.41623	Residential
42	Vatikashor Bazar	24.742539	90.414409	Commercial
43	Patgudam Bridge mor	24.747131	90.420271	Commercial
44	Kewatkhali Bypass mor	24.740017	90.424841	Traffic
45	KB College	24.732481	90.43119	Residential
46	Jabbarer Mor, BAU	24.723188	90.435224	Commercial
47	Sesh Mor, BAU	24.717781	90.444184	Commercial
48	Pagla Bazar, BAU	24.713642	90.434042	Commercial

3.1.2 Temporal Variation of $PM_{2.5}$ Concentration

Table 4 shows the concentration of $PM_{2.5}$ at different times of the day within the Mymensingh City Corporation (MCC) area. The data collection process involved measuring $PM_{2.5}$ levels during three different time periods: morning (7 a.m. - 9 a.m.), afternoon (12 p.m. - 2 p.m.), and evening (5 p.m. - 7 p.m.). This table provides an overview of the temporal variation in $PM_{2.5}$ concentrations throughout the day within the MCC area.

Table 4: Concentration of $PM_{2.5}$ at different locations of Mymensingh City Corporation area.

Sample No.	**Locations**	**$PM_{2.5}$ (µg/m^3)**		
		Morning (7 – 9) a.m.	**Afternoon (12 – 2) p.m.**	**Evening (5 – 7) p.m.**
1	Dhaka-Mymensingh Bypass	76	159	278
2	Digharkanda	68	145	167
3	Mashkanda	81	197	256
4	Mymensingh Polytechnic Institute	69	146	179
5	Chorpara	78	181	246
6	Brahmmapolli	68	214	232
7	Baghmara	62	155	178
8	Mymensingh Railway Junction	59	127	142
9	Station Mor	66	159	239
10	Moharaja Road	57	103	97
11	Bipin Park	64	118	119
12	Traffic Signal, Ganginar Par	69	164	197
13	Trishal Bus-stand	67	187	216
14	Noumohol	56	129	121
15	Aqua Morolpara	62	133	119
16	Boundary Road	59	137	147
17	Traffic Signal, Notun Bazar	64	147	184
18	Shoshi Lodge	59	116	128
19	Townhall	66	141	156

20	Bat Ball Chottor	54	92	85
21	Shankipara bazar	65	129	141
22	Kachijhuli	62	134	148
23	Tangail Bus-Stand	78	189	208
24	Bou Bazar	67	98	109
25	Gohailkandi	57	95	103
26	Amin Bazar	68	117	129
27	Mymensingh Road Station	56	115	138
28	Khagdohor Bazar	61	123	142
29	Khagdohor Moddhopara	57	91	82
30	Rohomotpur Bypass	74	156	221
31	Zamia Kasimia	66	137	122
32	Bagherkanda	63	84	76
33	Badekolpa Moddhopara	61	91	84
34	Khagdohor Dokkhinpara	56	86	78
35	Gondropa Bypass Mor	60	87	76
36	Chukaitala Bazar	62	112	134
37	Aqua Bypass Mor	71	136	145
38	Moddho Barera	64	82	73
39	Hridoyer mor	53	88	93
40	Fishari Mor, BAU	61	83	74
41	Moynar mor	55	82	71
42	Vatikashor Bazar	64	109	121
43	Patgudam Bridge mor	129	392	442
44	Kewatkhali Bypass mor	92	212	292
45	KB College	56	119	84
46	Jabbarer Mor, BAU	66	132	148
47	Sesh Mor, BAU	63	127	136
48	Pagla Bazar, BAU	59	104	94

3.1.3 Temporal Variation of PM_{10} Concentration

Table 5 shows the concentration of PM_{10} at different times of the day within the Mymensingh City Corporation (MCC) area. The data collection process involved measuring PM_{10} levels during three different time periods: morning (7 a.m. - 9 a.m.), afternoon (12 p.m. - 2 p.m.), and evening (5 p.m. - 7 p.m.). This table provides an overview of the temporal variation in PM10 concentrations throughout the day within the MCC area.

Table 5: Concentration of PM_{10} at different locations of Mymensingh City Corporation area.

Sample No.	Locations	PM_{10} (µg/m^3)		
		Morning (7 – 9) a.m.	**Afternoon (12 – 2) p.m.**	**Evening (5 – 7) p.m.**
1	Dhaka-Mymensingh Bypass	99	335	375
2	Digharkanda	87	277	245
3	Mashkanda	119	358	445
4	Mymensingh Polytechnic Institute	93	256	365
5	Chorpara	112	376	455
6	Brahmmapolli	98	305	345
7	Baghmara	78	312	255
8	Mymensingh Railway Junction	74	185	219
9	Station Mor	82	310	350
10	Moharaja Road	64	302	209
11	Bipin Park	76	284	276
12	Traffic Signal, Ganginar Par	105	342	412
13	Trishal Bus-stand	115	375	388
14	Noumohol	83	295	362
15	Aqua Morolpara	76	189	132
16	Boundary Road	89	245	244
17	Traffic Signal, Notun Bazar	96	321	272
18	Shoshi Lodge	71	221	214
19	Townhall	87	258	241
20	Bat Ball Chottor	61	177	135
21	Shankipara bazar	69	175	171
22	Kachijhuli	66	178	198
23	Tangail Bus-Stand	106	362	348
24	Bou Bazar	76	122	159
25	Gohailkandi	59	134	118
26	Amin Bazar	74	159	167
27	Mymensingh Road Station	63	169	184
28	Khagdohor Bazar	79	186	176
29	Khagdohor Moddhopara	65	192	108
30	Rohomotpur Bypass	110	327	334
31	Zamia Kasimia	91	247	192
32	Bagherkanda	94	196	202
33	Badekolpa Moddhopara	97	232	129
34	Khagdohor Dokkhinpara	85	148	126
35	Gondropa Bypass Mor	82	168	178
36	Chukaitala Bazar	73	179	148
37	Aqua Bypass Mor	78	183	222
38	Moddho Barera	69	156	102

39	Hridoyer mor	73	361	245
40	Fishari Mor, BAU	79	203	176
41	Moynar mor	81	231	133
42	Vatikashor Bazar	78	177	134
43	Patgudam Bridge mor	213	842	782
44	Kewatkhali Bypass mor	174	610	665
45	KB College	59	168	113
46	Jabbarer Mor, BAU	83	221	197
47	Sesh Mor, BAU	79	213	188
48	Pagla Bazar, BAU	68	164	136

3.2 Spatial Distribution of $PM_{2.5}$ and PM_{10} in the MCC Area

In this study, the focus lies in understanding the spatial distribution of particulate matter concentrations through the implementation of GIS-based spatial mapping techniques. Spatial mapping allows for the visualization and analysis of the geographical patterns of particulate matter pollution, providing valuable insights into its dispersion and the areas most affected. The maps generated in this research display the spatial distribution of $PM_{2.5}$ and PM_{10} concentrations during different time periods, specifically in the morning, afternoon, and evening hours of the days. Collecting data during these specific timeframes allows for the capture of diverse variations in PM levels associated with various human activities and environmental factors. Each map presented in this study is accompanied by a detailed legend, which serves as a comprehensive guide for interpreting the depicted data. These map legends play a crucial role in facilitating the understanding of the pollution levels in different areas by providing essential information about the color scales used to represent PM (particulate matter) concentrations. The legend also indicates the range of PM concentrations, highlighting the highest and lowest levels observed within the study area. Additionally, the map legends incorporate the standard Air Quality Index (AQI) categories and range corresponding to different values of $PM_{2.5}$ and PM_{10}, as defined by the Department of Environment (DoE), Bangladesh.

3.2.1 Spatial Distribution of $PM_{2.5}$ (Morning)

The map depicts the spatial distribution of $PM_{2.5}$ concentrations in the MCC area during the morning hours (7 a.m. to 9 a.m.) (Figure 4). It is divided into distinct zones, each represented by a unique color or shading, indicating different levels of particulate pollution. Analysis of the collected data shows $PM_{2.5}$ concentrations ranging from 53 to 129 μg/m³ across the studied locations. The highest $PM_{2.5}$ concentration of 129 μg/m³ is observed at "Patgudam Bridge mor," while the lowest concentration of 53 μg/m³ is found at "Hridoyer mor." The legend accompanying the map provides a color scale for interpreting pollution levels. Lighter colors represent cleaner air, while darker colors indicate higher $PM_{2.5}$ concentrations and potential health risks. Furthermore, the map includes labels indicating specific measurement points within the Mymensingh City Area, offering a comprehensive understanding of the air pollution scenario. Notable areas with considerable $PM_{2.5}$ concentrations include "Aqua Bypass Mor" with a concentration of 71 μg/m³, "Mashkanda" with 81 μg/m³, and "Dhaka-Mymensingh Bypass" with 76 μg/m³.

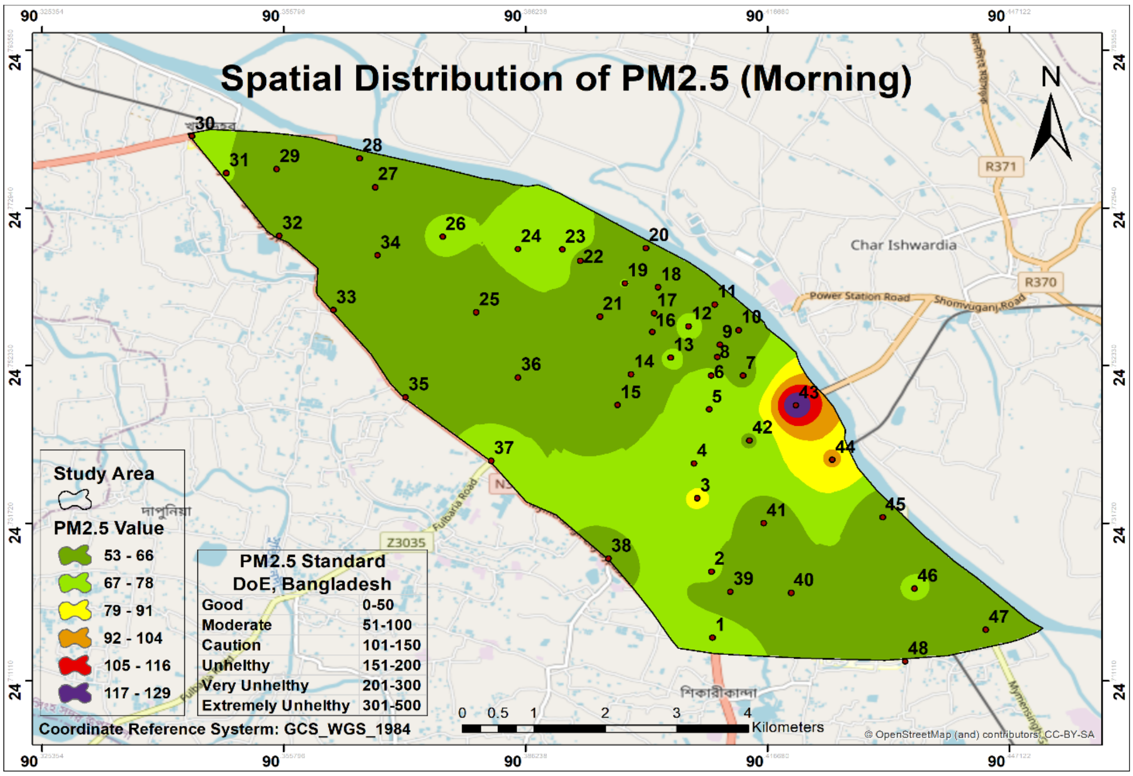

Figure 4: Spatial Distribution of $PM_{2.5}$ (Morning) in Mymensingh City Corporation area

3.2.2 Spatial Distribution of $PM_{2.5}$ (Afternoon)

The spatial map represents the distribution of $PM_{2.5}$ concentrations in the Mymensingh City Area during the afternoon hours (12 p.m. to 2 p.m.). Analysis reveals $PM_{2.5}$ concentrations ranging from 82 to 392 µg/m³ across the studied locations (Figure 5).

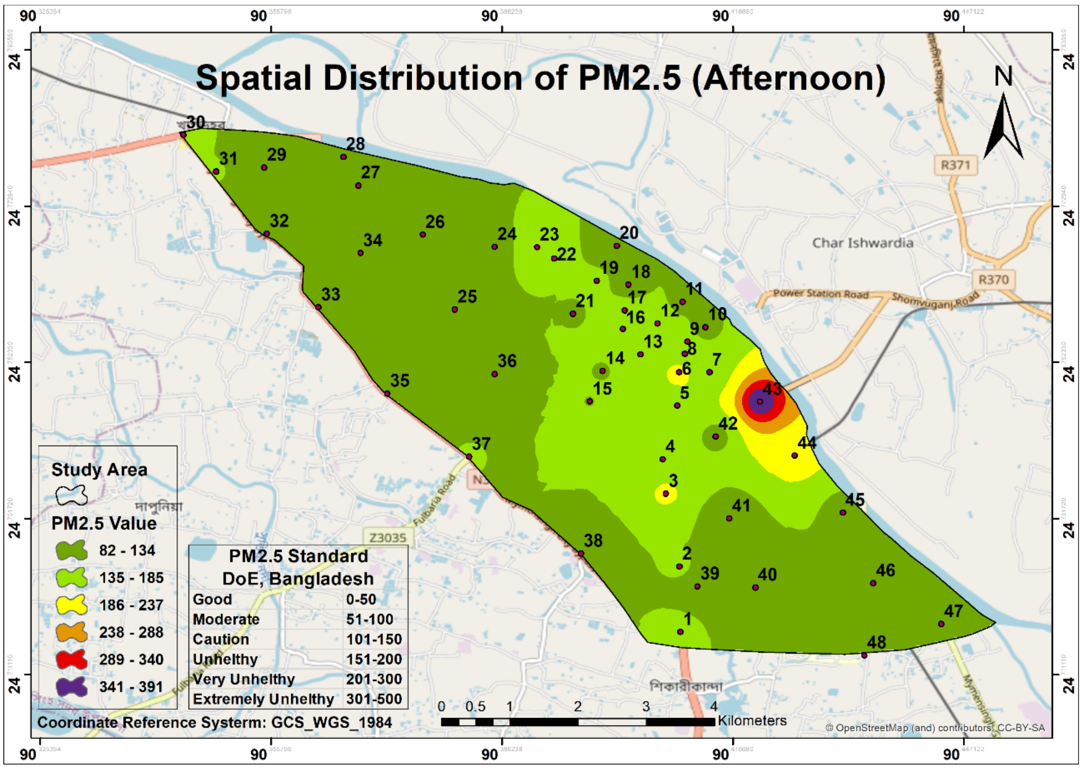

Figure 5: Spatial Distribution of $PM_{2.5}$ (Afternoon) in Mymensingh City Corporation area

The highest $PM_{2.5}$ concentration of 392 μg/m³ is observed at "Patgudam Bridge mor," while the lowest concentration of 82 μg/m³ is found at "Moynar mor," and "Moddho Barera." Notable areas with relatively high $PM_{2.5}$ concentrations include "Mashkanda" with a concentration of 197 μg/m³, "Brahmmapolli" with 214 μg/m³, and "Chorpara" with 181 μg/m³.

3.2.3 Spatial Distribution of $PM_{2.5}$ (Evening)

The spatial map represents the distribution of $PM_{2.5}$ concentrations in the Mymensingh City Area during the evening hours (5 p.m. to 7 p.m.). The map is divided into distinct zones, each designated by a unique color or shading, indicating varying levels of pollution (Figure 6). Analysis of the collected data shows $PM_{2.5}$ concentrations range from 71 to 442 μg/m³ across the studied locations during the evening hours. The highest recorded $PM_{2.5}$ concentration of 442 μg/m³ is observed at "Patgudam Bridge mor," while the lowest recorded concentration of 71 μg/m³ is found at locations "Moynar mor" and "Moddho Barera." Notable areas with relatively high $PM_{2.5}$ concentrations during the evening hours include "Mashkanda" with a concentration of 256 μg/m³, "Brahmmapolli" with 232 μg/m³, and "Chorpara" with 246 μg/m³.

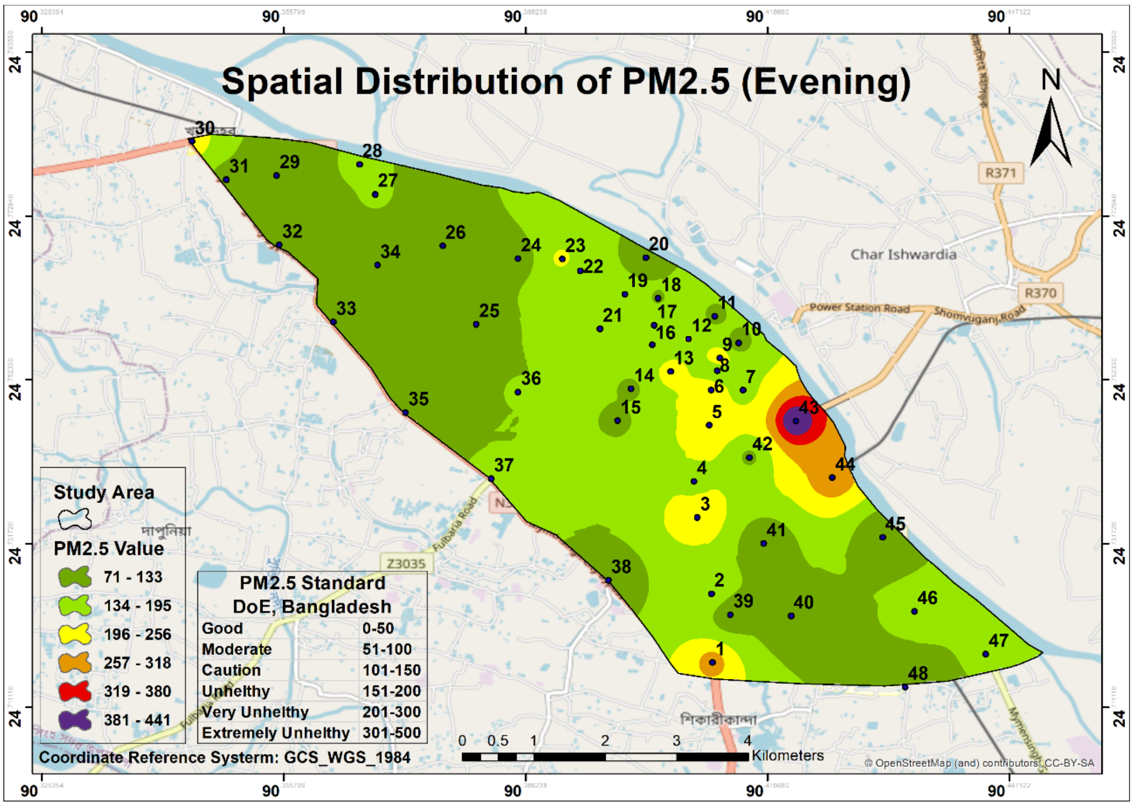

Figure 6: Spatial Distribution of $PM_{2.5}$ (Evening) in Mymensingh City Corporation area

3.2.4 Spatial Distribution of PM_{10} (Morning)

The spatial map illustrates the distribution of PM_{10} concentrations in the Mymensingh City Area during the morning hours (7 a.m. to 9 a.m.). The map is divided into distinct zones, each designated by a unique color or shading, representing different levels of pollution (Figure 7). Analysis of the collected data shows PM_{10} concentrations range from 59 to 213 μg/m³ across the studied locations during the morning hours. The highest recorded PM_{10} concentration of 213 μg/m³ is observed at "Patgudam Bridge mor," while the lowest recorded concentration of 59 μg/m³ is found at

"Gohailkandi." Notable areas with relatively higher PM_{10} concentrations during the morning hours include "Mashkanda" with a concentration of 119 μg/m³, "Dhaka-Mymensingh Bypass" with 99 μg/m³, and "Chorpara" with 112 μg/m³.

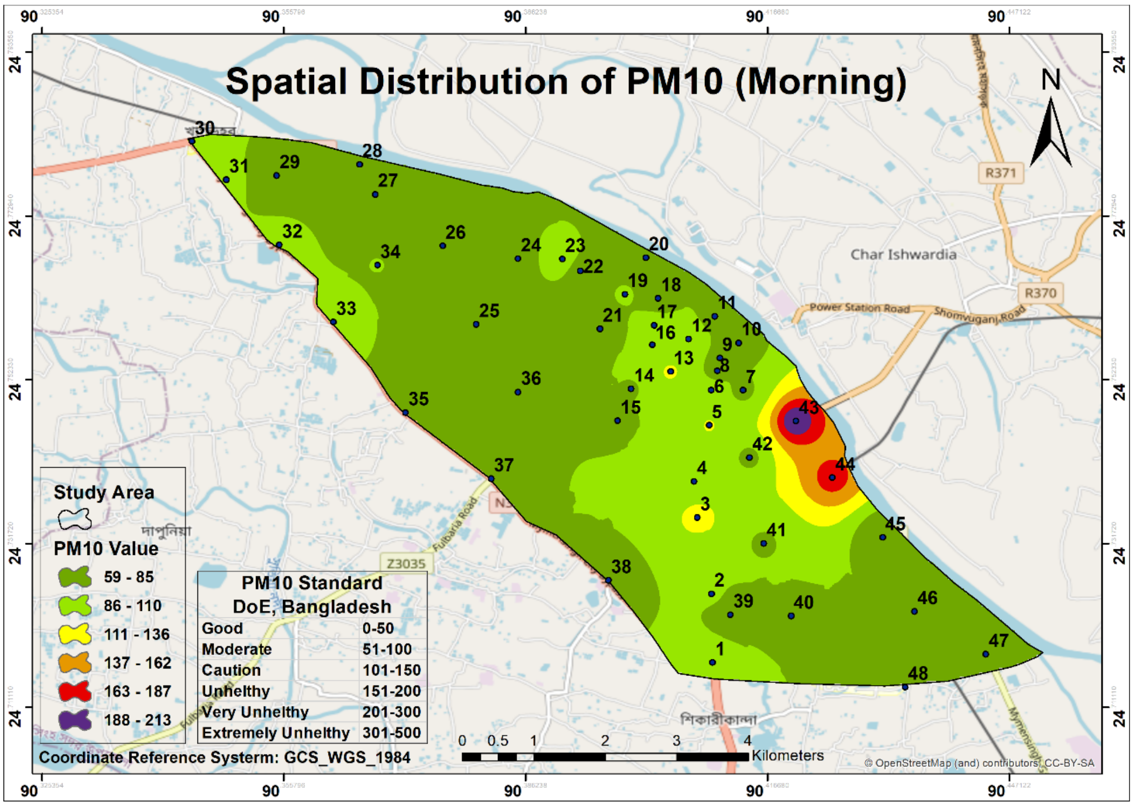

Figure 7: Spatial Distribution of PM_{10} (Morning) in Mymensingh City Corporation area

3.2.5 Spatial Distribution of PM_{10} (Afternoon)

The spatial map represents the distribution of PM_{10} concentrations in the Mymensingh City Area during the afternoon hours (12 p.m. to 2 p.m.). The map is divided into distinct zones, each marked by a specific color or shading, indicating varying levels of pollution (Figure 8). Analysis of the collected data shows PM_{10} concentrations range from 122 to 842 μg/m³ across the studied locations during the afternoon hours. The highest recorded concentration of 842 μg/m³ is observed at "Patgudam Bridge mor," while the lowest recorded concentration of 122 μg/m³ is found at "Bou Bazar." Noteworthy areas with relatively higher PM_{10} concentrations during the afternoon hours include "Trishal Bus-stand" with a concentration of 375 μg/m³, "Chorpara" with 376 μg/m³, and "Mashkanda" with 358 μg/m³.

3.2.6 Spatial Distribution of PM_{10} (Evening)

The spatial map represents the distribution of PM_{10} concentrations in the Mymensingh City Area during the evening hours (5 p.m. to 7 p.m.). The map is divided into distinct zones, each marked by a specific color or shading, indicating varying levels of pollution (Figure 9). Analysis of the collected data shows PM_{10} concentrations range from 102 to 782 μg/m³ across the studied locations during the evening hours. The highest recorded concentration of 782 μg/m³ is observed at "Patgudam Bridge mor," while the lowest recorded concentration of 102 μg/m³ is found at "Moddho Barera." Noteworthy areas with relatively higher PM_{10} concentrations during the evening hours include "Chorpara" with 455µg/m³, "Mashkanda" with 445 µg/m³, and "Trishal Bus-stand" with 388µg/m³.

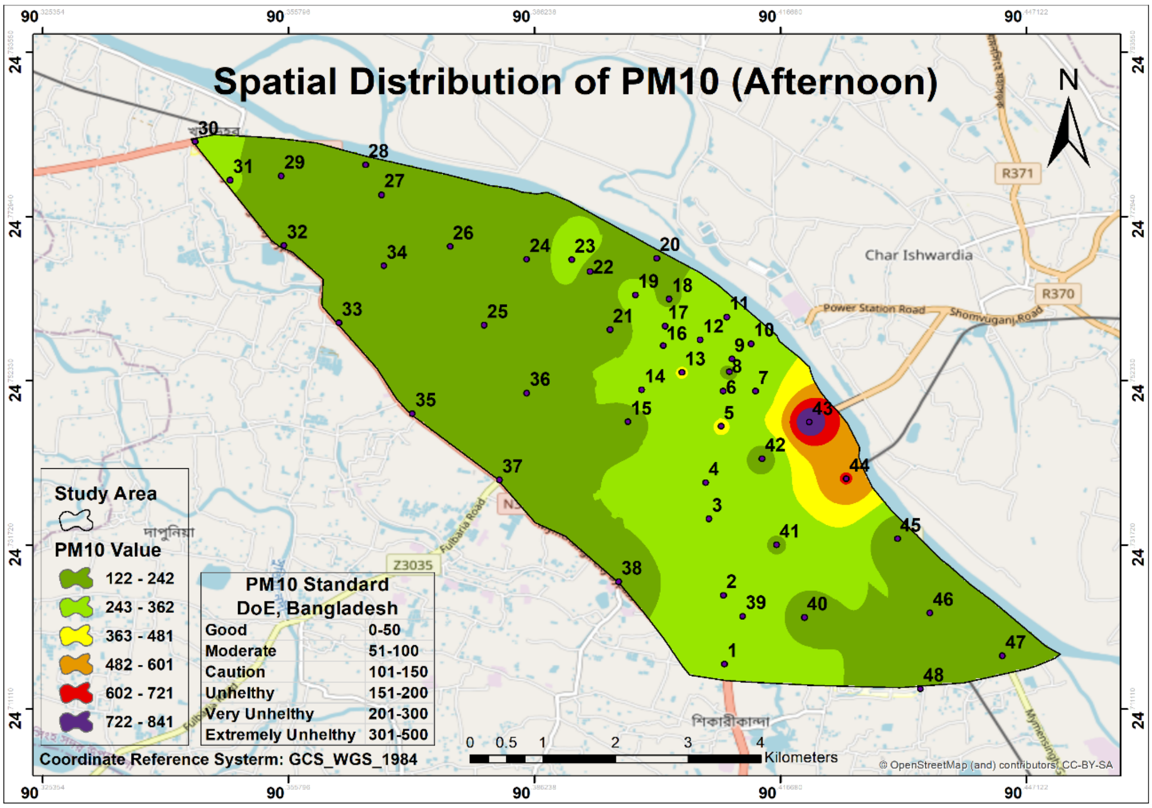

Figure 8: Spatial Distribution of PM_{10} (Afternoon) in Mymensingh City Corporation area

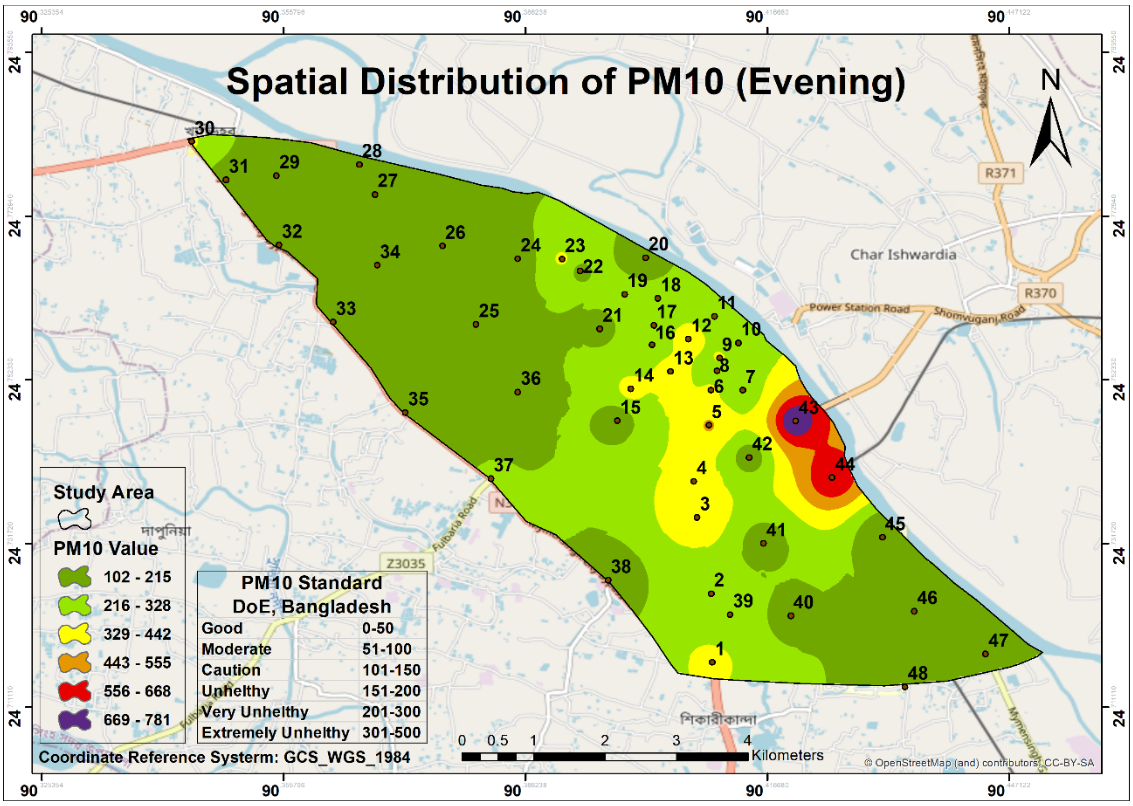

Figure 9: Spatial Distribution of PM_{10} (Evening) in Mymensingh City Corporation area

3.3 Zone-Specific Variations of $PM_{2.5}$ and PM_{10}

This section explores the zone-specific variations of $PM_{2.5}$ and PM_{10} pollution within the study area. The entire study area is categorized into three distinct zones: Commercial, Residential, and Traffic zones. The objective of this analysis is to investigate how air pollution levels differ across these zones and how they fluctuate throughout the day. The categorization into Commercial, Residential, and Traffic zones was based on the varying land-use patterns and predominant human activities observed in each area (Figure 10). Understanding the potential sources of pollution in different zones is crucial for formulating targeted pollution control strategies and designing effective urban planning initiatives to mitigate the adverse impacts of air pollution on public health and the environment. The Commercial zone comprises areas with high commercial and industrial activities, including offices, shopping centers, and business establishments. These areas often witness increased vehicular movement, emissions from industrial activities, and other sources of pollution, which can significantly contribute to elevated $PM_{2.5}$ and PM_{10} levels. The Residential zone primarily encompasses areas characterized by residential buildings, housing complexes, and community spaces. Although traffic emissions and industrial activities may also influence residential areas, the proximity to vehicular traffic, construction activities, and household practices can influence the $PM_{2.5}$ and PM_{10} concentrations in these zones. The Traffic zone focuses on locations with high traffic density, such as major roadways, intersections, and transportation hubs. Vehicular emissions are a prominent contributor to air pollution in traffic zones, making them crucial areas to assess the impact of transportation-related pollutants on air quality. By analyzing the data collected from multiple sampling points within each zone at different time periods (Morning, Afternoon, and Evening), this research aims to obtain valuable insights into the temporal and zone-specific variations of $PM_{2.5}$ and PM_{10} concentrations. These insights will be instrumental in identifying critical pollution sources and potential hotspots that demand targeted interventions. The implications of this study extend to air quality management and urban planning, providing stakeholders with informed knowledge to develop effective strategies that address air pollution in a zone-specific manner. Ultimately, this research endeavors to foster healthier and more sustainable urban environments, benefiting both the public and the ecosystem.

3.3.1 Zone-Specific Variations of $PM_{2.5}$

3.3.1.1 Commercial Zone

This graph represents the zonal variations in $PM_{2.5}$ concentrations in the commercial zone of the study area during different time periods of the day. From the graph, it is evident that, during the morning period, the $PM_{2.5}$ concentration ranges from 57 µg/m³ to 129 µg/m³, with the lowest being recorded at location L10 and the highest at L43. As the day progresses to the afternoon, $PM_{2.5}$ levels increase significantly, varying between 98 µg/m³ and 392 µg/m³ (Figure 10). The highest concentration is observed at L43, indicating a substantial rise in pollution during this period. However, some locations, such as L24 and L48, show relatively lower $PM_{2.5}$ levels in the afternoon. By the evening, $PM_{2.5}$ concentrations slightly decrease from the afternoon levels. The lowest evening concentration is seen at L48 with 94 µg/m³, while the highest remains at L43 with 442 µg/m³, indicating that pollution levels remain elevated even during the Evening period. Across all locations in the commercial zone, the data reveals that the $PM_{2.5}$ concentrations consistently exceed the good air quality threshold (50 µg/m³) set by regulatory standards throughout the day. This suggests the presence of persistent air pollution within the commercial zone, necessitating attention to improve air quality and safeguard public health.

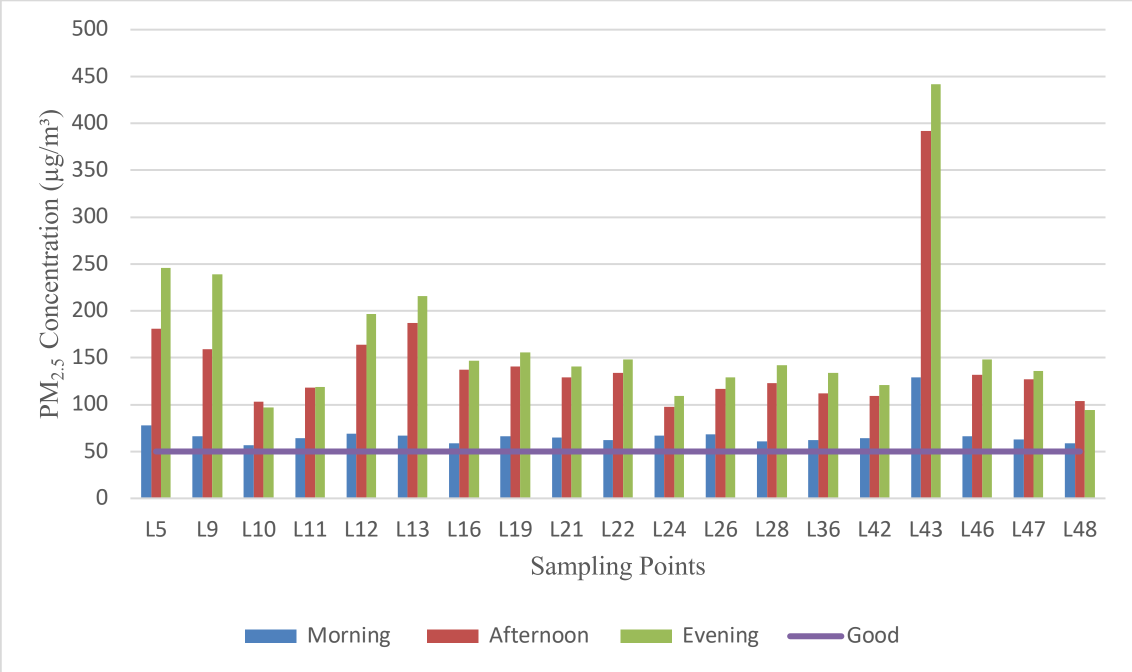

Figure 10: $PM_{2.5}$ Concentration in commercial zones throughout the day

3.3.1.2 Residential Zone

This graph depicts the variations in $PM_{2.5}$ concentrations within the residential zone of the study area during different time periods of the day. From the graph, it is evident that, during the morning period, $PM_{2.5}$ concentrations range from 55 µg/m³ to 69 µg/m³, with the lowest concentration recorded at location L41 and the highest at L4. As the day progresses to the afternoon, $PM_{2.5}$ levels show significant fluctuations, varying between 84 µg/m³ and 214 µg/m³ (Figure 11). Location L6 exhibits the highest concentration during this period, indicating a notable increase in pollution levels. In contrast, L38 and L41 show relatively lower $PM_{2.5}$ levels in the afternoon. By the evening, $PM_{2.5}$ concentrations generally decrease from the afternoon levels. The lowest evening concentration is observed at location L41 with 71 µg/m³, while the highest remains at L6 with 232 µg/m³. Despite the decrease, it is evident that residential areas still experience elevated $PM_{2.5}$ levels during the evening period. Notably, all locations within the residential zone exhibit $PM_{2.5}$ concentrations exceeding the good air quality threshold (50 µg/m³) throughout the day. This highlights the presence of consistent air pollution in residential areas, emphasizing the importance of addressing pollution sources to safeguard the health and well-being of the residents.

3.3.1.3 Traffic Zone

This graph represents the variations in $PM_{2.5}$ concentrations within the traffic zones of the study area during different time periods of the day. From the graph, it is evident that, during the morning period, $PM_{2.5}$ concentrations range from 53 µg/m³ to 92 µg/m³, with the lowest concentration recorded at location L39 and the highest at L44 (Figure 12). As the day progresses to the afternoon, $PM_{2.5}$ levels show significant fluctuations, varying between 87 µg/m³ and 212 µg/m³. Location L44 exhibits the highest concentration during this period, indicating a significant increase in pollution levels due to traffic-related activities.

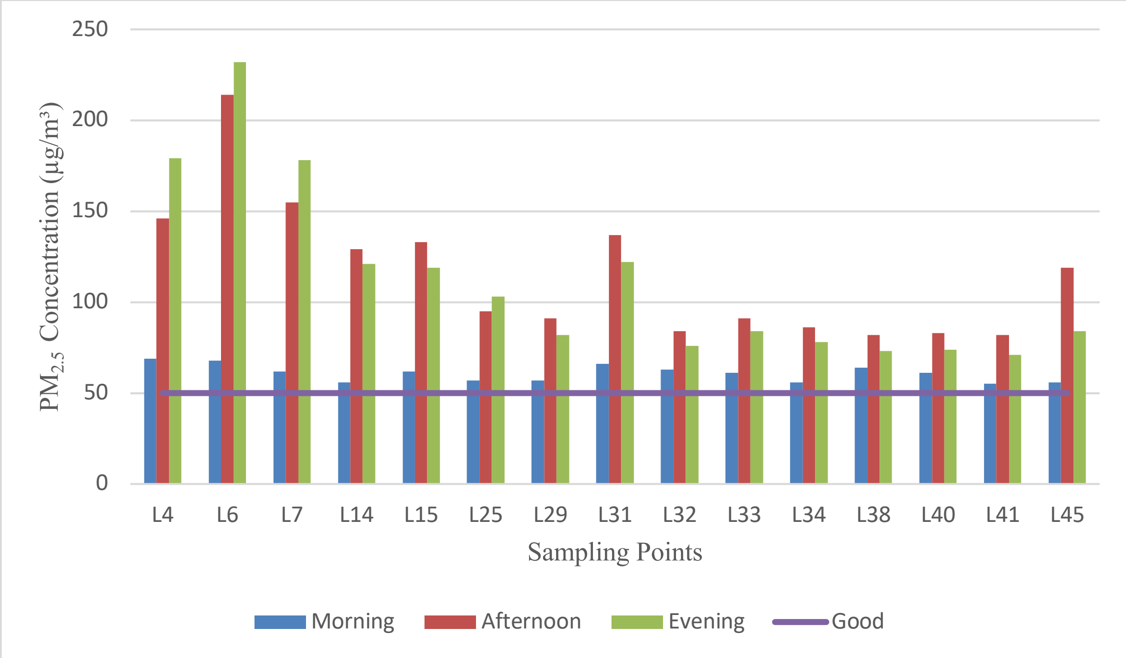

Figure 11: $PM_{2.5}$ Concentration in residential zones throughout the day

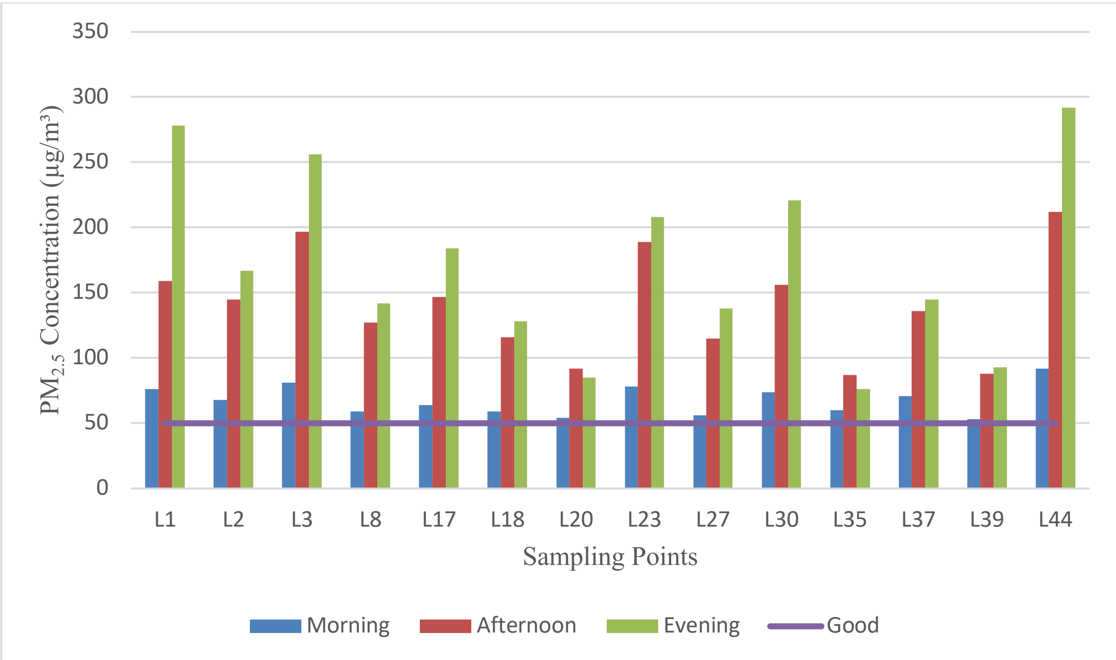

Figure 12: $PM_{2.5}$ Concentration in traffic zones throughout the day

However, L20 and L35 show relatively lower $PM_{2.5}$ levels in the afternoon. By the evening, $PM_{2.5}$ concentrations generally decrease from the afternoon levels. The lowest evening concentration is observed at location L35 with 76 µg/m³, while the highest remains at L44 with 292 µg/m³. Despite the decrease, it is evident that traffic zones still experience elevated $PM_{2.5}$ levels during the evening period. Similar to the other zones, all locations within the traffic zone consistently exhibit PM2.5 concentrations surpassing the good air quality threshold (50 µg/m³) throughout the day. This underscores the presence of persistent air pollution in traffic zones, emphasizing the need to address vehicular emissions and other sources to mitigate the impact on air quality and public health.

3.3.2 Zone-Specific Variations of PM_{10}

3.3.2.1 Commercial Zone

This graph presents the variations in PM_{10} concentrations in the commercial zones of the study area during different time periods of the day. From the graph, it is evident that, during the morning period, PM_{10} concentrations range from 64 µg/m³ to 213 µg/m³, with the lowest concentration recorded at location L10 and the highest at L43 (Figure 13). As the day progresses to the afternoon, PM_{10} levels show significant fluctuations, varying between 122 µg/m³ and 842 µg/m³. Location L43 exhibits the highest concentration during this period, indicating a substantial increase in pollution levels in commercial areas, possibly attributed to heightened economic activities and traffic. By the evening, PM_{10} concentrations generally decrease from the afternoon levels. The lowest evening concentration is observed at location L42 with 134 µg/m³, while the highest remains at L43 with 782 µg/m³. Despite the decrease, it is evident that commercial zones still experience elevated PM_{10} levels during the evening period. Like the previous analyses, all locations within the commercial zone consistently exhibit PM10 concentrations exceeding the good air quality threshold (50 µg/m³) throughout the day. This underscores the presence of persistent air pollution in commercial areas, necessitating effective pollution control measures to safeguard public health and well-being.

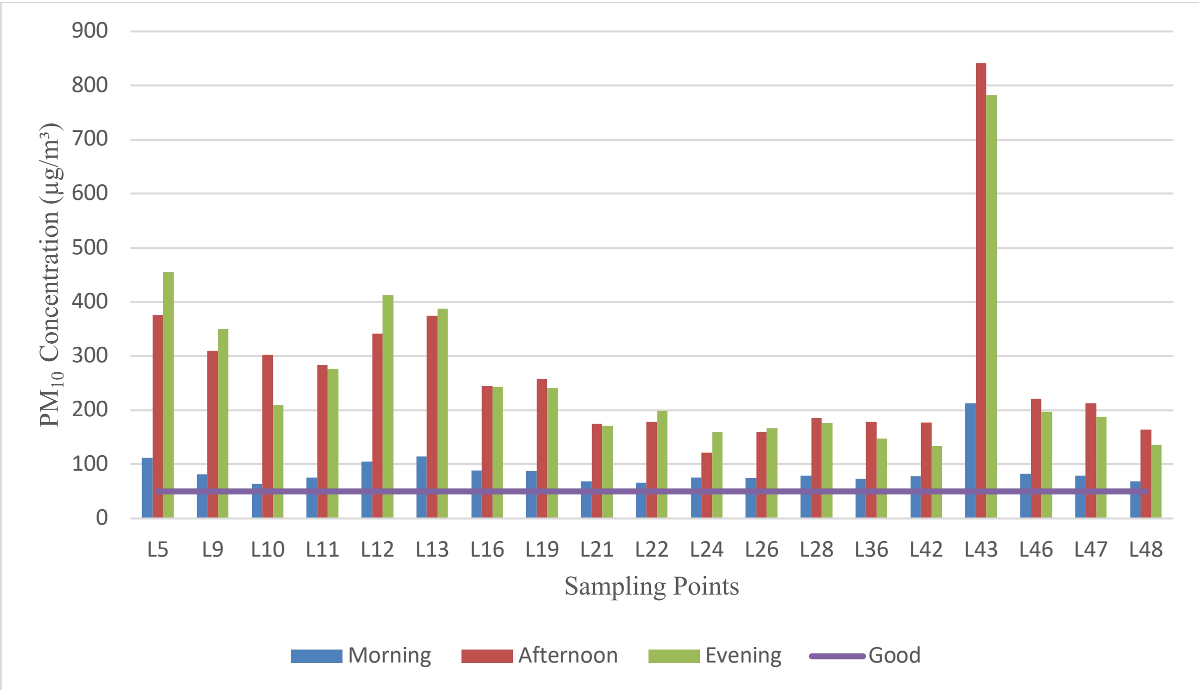

Figure 13: PM_{10} Concentration in commercial zones throughout the day

3.3.2.2 Residential Zone

This graph presents the variations in PM_{10} concentrations in the residential zones of the study area during different time periods of the day. From the graph, it is evident that, during the morning period, PM_{10} concentrations range from 59 µg/m³ to 98 µg/m³, with the lowest concentration recorded at locations L25, L45 and the highest at L6. As the day progresses to the afternoon, PM_{10} levels show significant fluctuations, varying between 134 µg/m³ and 312 µg/m³ (Figure 14). Location L7 shows the highest concentration during this period, indicating a substantial increase in pollution levels in residential areas, possibly associated with traffic and other local sources. By the evening, PM_{10} concentrations generally decrease from the afternoon levels. The lowest evening concentration is observed at location L38 with 102 µg/m³, while the highest is observed at L4 with 365 µg/m³. Despite the decrease, it is evident that commercial zones still experience elevated PM_{10} levels during the evening period. As seen in the other zones, all locations within the residential zone consistently exhibit PM_{10} concentrations exceeding the good air quality threshold (50 µg/m³) throughout the day. This underscores the presence of persistent air pollution in residential areas, necessitating effective pollution control measures to safeguard the health and well-being of the residents.

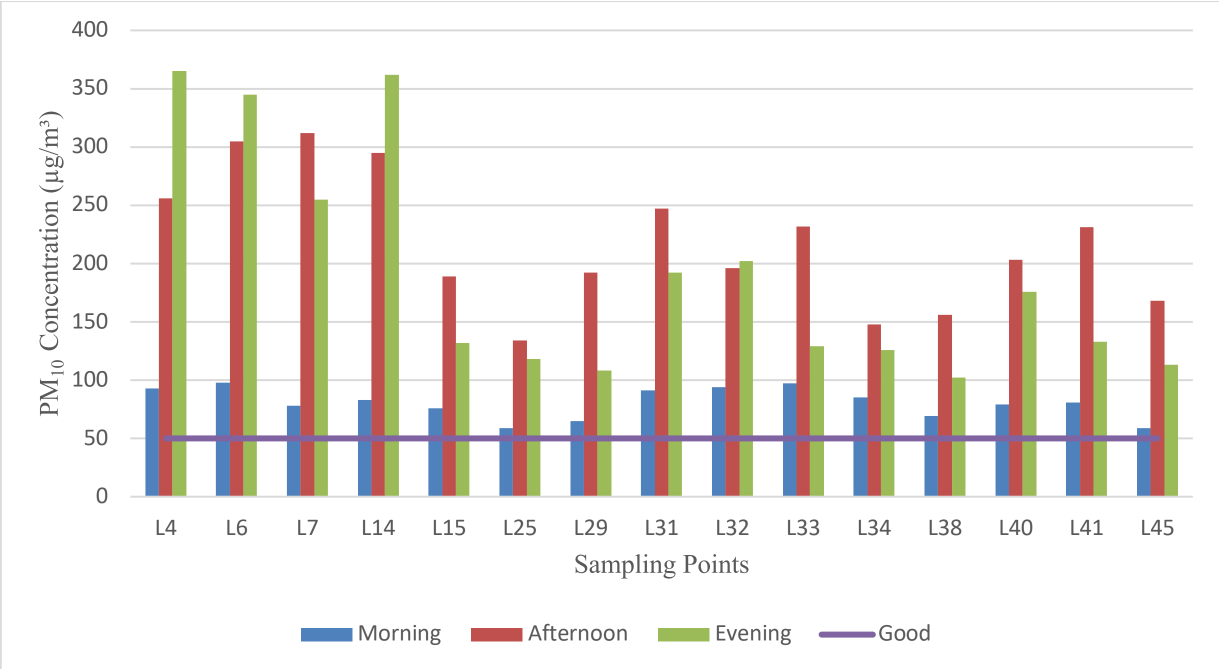

Figure 14: PM_{10} Concentration in Residential zones throughout the day

3.3.2.3 Traffic Zone

This graph presents the variations in PM_{10} concentrations in the traffic zones of the study area during different time periods of the day. From the graph, it is evident that, during the morning period, PM_{10} concentrations range from 61 µg/m³ to 174 µg/m³, with the lowest concentration recorded at locations L20 and the highest at L44. As the day progresses to the afternoon, PM_{10} levels show significant fluctuations, varying between 168 µg/m³ and 610 µg/m³. Location L44 shows the highest concentration during this period, indicating a notable increase in pollution levels in traffic zones, likely due to vehicular emissions and other anthropogenic activities (Figure 15). By the evening, PM_{10} concentrations generally decrease from the afternoon levels. The lowest evening concentration is observed at location L20 with 135 µg/m³, while the highest remains at L44 with 665 µg/m³. Despite the decrease, it is evident that traffic zones still experience elevated PM_{10} levels during the evening period. Similar to the other zones, all locations within the traffic zone consistently exhibit PM_{10} concentrations exceeding the good air quality threshold (50 µg/m³) throughout the day. This emphasizes the presence of persistent air pollution in traffic areas, necessitating effective pollution control measures to reduce PM_{10} emissions and improve air quality for the well-being of the population.

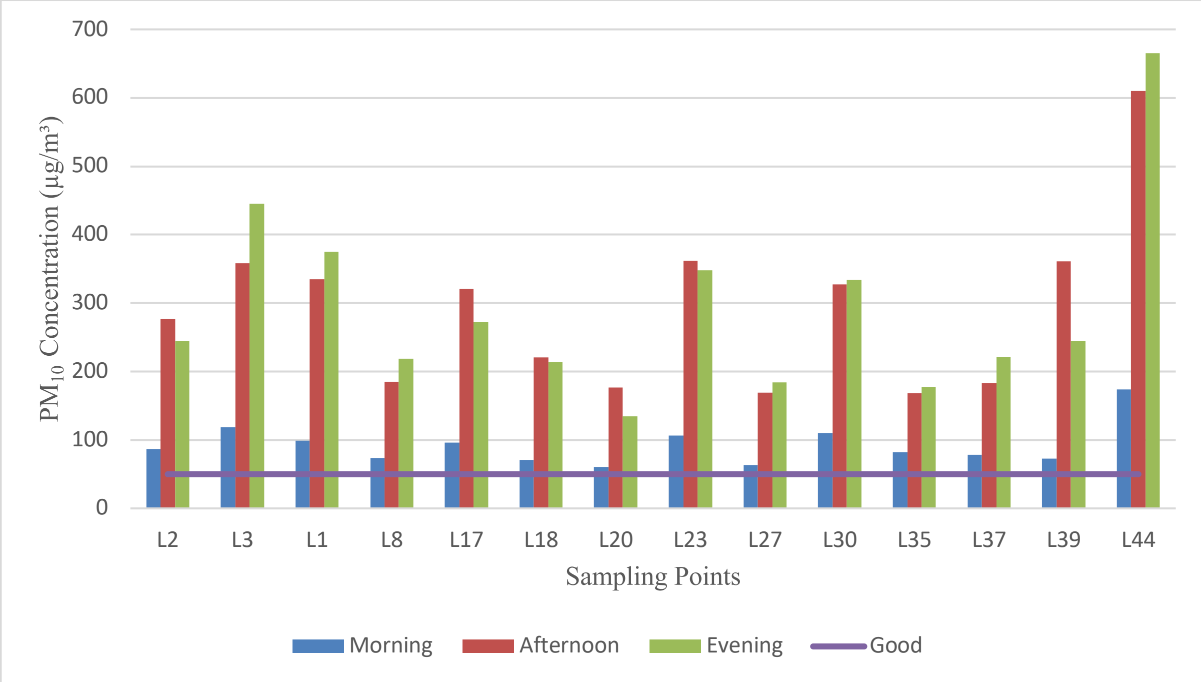

Figure 15: PM_{10} Concentration in traffic zones throughout the day

3.4 Observed and Potential Sources of PM Pollution in the Mymensingh City Corporation Area

The Mymensingh City Corporation (MCC) area is confronted with several potential sources of PM pollution, which contribute to the observed levels of $PM_{2.5}$ and PM_{10}. Identifying the sources of $PM_{2.5}$ and PM_{10} pollution is crucial for understanding the factors contributing to the observed pollution levels in the MCC area. This section discusses the potential and observed sources of particulate matter, shedding light on their role in PM pollution.

3.4.1 Traffic Emissions

Traffic emissions are a significant contributor to $PM_{2.5}$ and PM_{10} pollution in the MCC area. The high volume of traffic in specific locations, such as Dhaka-Mymensingh Bypass, Digharkanda, Mashkanda, Chorpara, Patgudam Bridge Mor, Tangail Bus Stand, Trishal Bus Stand, and others, leads to the combustion of fossil fuels, resulting in the release of particulate matter into the atmosphere. Diesel-powered vehicles emit particulate matter as a byproduct of incomplete combustion. Exhaust emissions from trucks, buses, and other diesel engines can be potential sources of PM pollution, especially in areas with heavy traffic or transportation hubs. These vehicles release fine particles into the air, which can have detrimental effects on air quality and human health. The combustion of diesel fuel generates pollutants, including black carbon and other toxic substances, contributing to the overall particulate matter pollution in the vicinity.

3.4.2 Construction and Demolition

Construction and demolition activities are known to generate significant amounts of dust, thereby contributing to $PM_{2.5}$ and PM_{10} pollution. These activities involve processes such as excavation, material handling, and crushing, which can release a substantial amount of particulate matter into the air. Ongoing construction projects and areas with demolition activities, such as Bipin Park and Notun Bazar Traffic Signal, Ganginar Par, and Brahmmapolli are likely to exhibit higher levels of particulate matter. These areas serve as hotspots for PM pollution, as the dust particles released during construction and demolition activities become suspended in the air and can be easily transported by wind currents. The presence of construction materials, debris, and unpaved surfaces further exacerbates the issue by facilitating the dispersal of dust particles. Consequently, the surrounding areas experience increased concentrations of $PM_{2.5}$ and PM_{10} pollutants.

3.4.3 Industrial and Manufacturing Processes

Within the MCC area, industrial activities and manufacturing processes play a significant role in contributing to particulate matter (PM) pollution. These activities encompass a wide range of sectors and involve diverse manufacturing operations. Metal processing and manufacturing which often involve cutting rods, aluminum, and the production of various metal products can generate particulate matter emissions, including $PM_{2.5}$ and PM_{10}, due to the release of fine particles during cutting, grinding, and other metalworking procedures. Additionally, other industrial sectors within the MCC area may contribute to PM pollution. These sectors encompass manufacturing processes associated with textiles, chemicals, plastics, and more. Such industrial operations can release particulate matter into the atmosphere as a byproduct of their production methods and material handling practices.

3.4.4 Brick Kilns

Brick kilns, which are prevalent in the MCC area, are known sources of PM pollution. These kilns, which are widely prevalent in the region, rely on the combustion of solid fuels like coal or biomass in the brick-making process. As a result, substantial amounts of particulate matter are released into the atmosphere, contributing to air pollution. The emissions from brick kilns contain a variety of fine particulate matter, including ash, soot, and other combustion byproducts. These particles can have detrimental effects on air quality and human health when inhaled. Brick kilns typically operate continuously, emitting pollutants throughout their operational hours, which can significantly impact the surrounding areas.

3.4.5 Road Dust

Unpaved roads and road construction activities can lead to the generation of substantial amounts of dust, which contributes to the presence of $PM_{2.5}$ and PM_{10} pollutants in the air. The movement of vehicles, especially on unpaved roads, can agitate the loose soil, gravel, and other particles present on the road surface, resulting in the emission of dust particles into the surrounding atmosphere. Additionally, road construction activities involving excavation, grading, and other earth-moving operations can disturb the soil and release fine particles, further contributing to PM pollution.

3.4.6 Biomass Burning

The burning of biomass for cooking or heating purposes is a significant source of particulate matter (PM) pollution in the MCC area. Many households in the region rely on biomass fuels such as wood, agricultural residues, and animal dung for their daily cooking and heating needs. During the combustion of these biomass fuels, fine particles and smoke containing $PM_{2.5}$ and PM_{10} are emitted into the air. Household-level biomass burning practices, especially in areas where they are prevalent, contribute to the local concentration of particulate matter, impacting the air quality and potentially posing risks to public health.

3.4.7 Waste Burning

Improper waste management practices can contribute to particulate matter (PM) pollution in the MCC area. Inadequate waste disposal facilities, including dumping sites and open burning of waste, can release significant amounts of particulate matter into the air. Dumping sites and areas with inadequate waste disposal facilities may experience elevated levels of PM pollution. Open burning of waste, a common practice in areas with inadequate waste management infrastructure, also contributes to PM pollution. When waste is burned openly, it releases smoke and fine particles containing $PM_{2.5}$ and PM_{10} into the air. These particles can travel over long distances, impacting the air quality of nearby residential areas and posing health risks to the population.

3.4.8 Residential Sources

Residential areas within the MCC area have been identified as potential sources of particulate matter (PM) pollution, particularly in households where solid fuel combustion is commonly used for cooking and heating purposes. These residential sources contribute to the release of $PM_{2.5}$ and PM_{10} particles into the surrounding environment. Incomplete burning and inefficient stoves produce smoke and particulate emissions, which can harm respiratory health when inhaled (Lai *et al.,* 2021).

3.4.9. Relation between Particulate Matter (PM) Pollution and Water

Particulate Matter (PM) pollution and water are two distinct environmental issues, but they can have interconnected effects in some cases. Particulate matter refers to tiny solid particles and liquid droplets suspended in the air. PM pollution is a significant concern because these particles can have adverse effects on human health, the environment, and various natural processes. Particulate Matter (PM) pollution and water are intricately linked in ways that impact both the environment and human health (Mandija *et al.,* 2013; Alaqarbah *et al.,* 2001). PM consists of fine particles suspended in the air, originating from sources like vehicle emissions, industrial processes, and natural activities. These particles can settle onto water surfaces, introducing contaminants and altering water quality. When it rains, PM-laden surfaces contribute to runoff that carries pollutants into water bodies, affecting aquatic ecosystems. PM pollution also affects cloud formation and precipitation patterns. Particles serve as nuclei around which water vapor condenses, influencing cloud properties and potentially altering local weather patterns. Fine PM particles can contain toxic substances like heavy metals and organic compounds (Elbaz *et al.,* 2019). When these particles enter water bodies, they leach pollutants, negatively affecting aquatic life and potentially rendering water unsafe for consumption or recreation. Furthermore, PM pollution exacerbates erosion and sedimentation, where soil particles enriched with PM enter water bodies, leading to habitat disruption and reduced water clarity.

3.5 Health Risks Associated with Elevated $PM_{2.5}$ and PM_{10} Pollution

Particulate matter pollution, comprising fine particles ($PM_{2.5}$) and coarse particles (PM_{10}), is known to be highly detrimental to human health (Marcazzan *et al.,* 2001). These tiny particles, suspended in the air we breathe, can penetrate deep into our respiratory system, causing a range of health problems. Exposure to high concentrations of $PM_{2.5}$ and PM_{10} can have severe consequences for our well-being. Fine particles ($PM_{2.5}$) can infiltrate the deepest parts of our lungs, while coarse particles (PM_{10}) can settle in our upper respiratory tract (Bodor *et al.,* 2022). Long-term exposure to these pollutants can cause a variety of health concerns, including asthma, heart problems, and an increased risk of respiratory infections such as pneumonia, bronchitis, and respiratory syncytial virus (RSV) infections (Wan Mahiyuddin *et al.*, 2023). Understanding the potential health risks associated with elevated levels of $PM_{2.5}$ and PM_{10} pollution in the Mymensingh City Corporation (MCC) area is crucial for addressing public health concerns. This section discusses the health implications observed in relation to the measured pollution levels. The findings highlight the importance of addressing these risks and implementing appropriate measures to safeguard public health. Exposure to high concentrations of $PM_{2.5}$ and PM_{10} particles can have detrimental effects on respiratory health. Fine particulate matter ($PM_{2.5}$) can penetrate deep into the lungs, potentially causing or exacerbating respiratory conditions such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) while coarse particulate matter (PM_{10}) can also contribute to respiratory symptoms and respiratory tract inflammation (Maio *et al.,* 2023). This study observed an association between elevated $PM_{2.5}$ and PM_{10} levels and an increased prevalence of respiratory health issues among the population in the MCC area. Studies have demonstrated a link between long-term exposure to $PM_{2.5}$ and PM_{10} pollution and cardiovascular health effects. Fine particulate matter can enter the bloodstream, triggering inflammation, oxidative stress, and systemic inflammation, which can contribute to the development or progression of cardiovascular diseases (Thangavel *et al.,* 2022). Additionally, these pollutants could potentially cross the blood-brain barrier and sometimes contribute to neurodevelopmental disorders, cognitive impairments, and an increased risk of neurodegenerative diseases. Chronic exposure to particulate matter is associated with an increased risk of developing respiratory and cardiovascular diseases over time. Emerging research suggests potential links between particulate matter exposure and other health outcomes, including adverse birth outcomes, neurological effects, and certain cancers (Li *et al.,* 2022). The MCC area, with its elevated levels of $PM_{2.5}$ and PM_{10} pollution, may pose an increased risk of cardiovascular conditions such as heart attacks, strokes, hypertension, and arrhythmias. Extensive research has consistently demonstrated a strong association between long-term exposure to $PM_{2.5}$ and its impact on human health. These studies have demonstrated that an increase of $10 \mu g/m^3$ in $PM_{2.5}$ levels is associated with a significant rise of approximately 7.3% in all-cause mortality rates (Combes and Franchineau, 2019). What's particularly concerning is that this increased risk persists even at levels below the current standards established by the National Ambient Air Quality Standard. Certain population groups may be more susceptible to the health effects of $PM_{2.5}$ and PM_{10} pollution. Infants, children, the elderly, and individuals with pre-existing respiratory or cardiovascular conditions are particularly vulnerable. Pregnant women, in particular, face an increased risk of adverse birth outcomes when exposed to high levels of these pollutants. Particulate matter can cross the placental barrier, affecting fetal development and contributing to higher rates of preterm birth, low birth weight, and developmental issues in children (Chen *et al.,* 2021). The MCC area, with its diverse population, may have a higher frequency of vulnerable individuals. It is crucial to consider these groups when assessing the health risks associated with elevated particulate matter pollution and developing targeted interventions to protect their well-being. While the observed relationships between $PM_{2.5}$ and PM_{10} pollution and health risks in the MCC area are notable, it is important to acknowledge that further research and comprehensive studies are needed to gain a deeper understanding of the underlying mechanisms and establish definitive causality (Hassanzade *et al.,* 2019).

4. Recommendations and Conclusion

4.1 Recommendations

As the research study highlights the spatial distribution patterns and significant impact of Particulate Matter (PM) pollution in the Mymensingh City Corporation (MCC) area, it is crucial to outline suitable recommendations to mitigate this environmental challenge. The following recommendations aim to address PM pollution, safeguard public health, and improve the overall air quality in the MCC area.

- Incorporate green spaces and urban vegetation into city planning by increasing urban tree planting programs, encouraging the establishment of green roofs, and implementing vertical gardens.
- Enhance traffic management strategies by promoting the use of public transportation and cycling as alternative modes of transport to optimize traffic flow and minimize vehicle emissions.
- Develop innovative green transportation solutions, such as hydrogen fuel cell-powered vehicles or autonomous electric transport systems, to reduce emissions and promote sustainable mobility.
- Strengthen emission control measures for industries, including the implementation of cleaner technologies and regular monitoring to ensure compliance with emission standards.
- Encourage energy-efficient practices and support the use of renewable energy sources in households, businesses, and public institutions by promoting energy conservation measures, such as efficient lighting and appliances to reduce reliance on fossil fuels and lower emissions.
- Promote the use of clean cooking stoves, such as electric or induction cookers, in households to minimize the release of particulate matter from traditional biomass or coal-based cooking methods.
- Improve waste management practices by promoting recycling, composting, and proper waste disposal methods.
- Implement measures to reduce dust emissions from construction and demolition activities by enforcing dust control strategies, such as water spraying and covering of construction materials, and promote the use of eco-friendly construction practices and materials.
- Promote the utilization of satellite imagery and remote sensing technologies to identify pollution hotspots and monitor pollution trends on a larger scale, aiding in the identification of areas requiring targeted interventions.
- Conduct further research on local pollution sources and their impact, supporting studies that identify specific contributors to pollution by analyzing pollution trends, patterns, and source apportionment to better understand the local pollution profile.
- Implement a comprehensive continuous air monitoring system in the Mymensingh City Corporation area with strategically located monitoring stations, advanced air monitoring technologies, a real-time data transmission system, and regular maintenance for effective pollution control.

4.2 Conclusion

Particulate matter (PM) pollution is a serious issue that needs to be addressed right away to protect both the environment and human health. After conducting a spatial distribution study in the Mymensingh City Corporation (MCC) region, alarming levels of $PM_{2.5}$ and PM_{10} concentrations were found. The study explored the spatial distribution patterns of $PM_{2.5}$ and PM_{10} pollutants, identified potential pollution sources, and highlighted the associated health risks. The results underscore the urgent need for comprehensive measures to mitigate PM pollution and protect public health. The identified pollution hotspots, such as places with heavy traffic, industrial zones, and building sites, need concentrated efforts to reduce particulate matter emissions and lessen their negative impacts on public health. Additionally, vulnerable population groups including newborns, kids, the elderly, and those with pre-existing medical conditions face increased hazards, needing particular consideration and specialized protective tactics for them. This research emphasizes the need for immediate action to mitigate PM pollution and safeguard public health in the MCC area. By implementing the recommended measures, policymakers, urban planners, and environmental agencies can make informed decisions to improve air quality, reduce health risks associated with PM pollution, and promote sustainable development. It is crucial to collaborate across sectors, engage stakeholders, and raise awareness among the public to achieve long-term success in combating PM pollution and ensuring a healthier environment for the residents of the Mymensingh City Corporation area.

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