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Research Paper

Comparative evaluation of post-monsoon crossroads air quality variations in major cities of the Greater Dhaka region

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ABSTRACT

This study investigates the escalating problem of urban air pollution in Dhaka and its surrounding areas in the post-monsoon period. Using Aeroqual Series 500 air quality monitors, concentrations of NO_2, SO_2, CO_2, CH_4, $PM_{2.5}$, and PM_{10} were measured at 24 selected sites in Dhaka, Narayanganj, and Gazipur. The findings reveal elevated NO_2 levels in several areas, exceeding the standard threshold of 0.053 ppm, with Gulistan, Mirpur 10, Gabtuli Darus-salam, Farmgate, and Savar showing the highest concentrations. Gulistan also showed a marked SO_2 peak of 0.3 ppm. Areas adjacent to the Buriganga River, specifically Lalbagh and Kadamtuli, were identified as heavily polluted, with strong odour and poor air quality. High concentrations of CH_4 and CO_2 were detected at New Market, Zinda Park, and Jirani Bazar. The average Air Quality Index (AQI) across the sites was 186.8, with a peak of 395 at Joydebpur Rail Station and a low of 110 at Panam City. The study underscores the need for enhanced air quality monitoring and control strategies in Greater Dhaka, highlighting the health risks posed by industrial and vehicular emissions in rapidly urbanizing regions.

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1. INTRODUCTION

Air quality refers to the purity of the air in a defined area and reflects the concentrations of diverse pollutants and contaminants in the atmosphere, which can originate from natural and anthropogenic

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sources [1]. The concentrations of $PM_{2.5}$, PM_{10}, ground-level O_3, NO_2, CO, SO_2, and volatile organic compounds are pivotal in determining air quality, which significantly influences public health, climate, and overall quality of life [2]. $PM_{2.5}$ denotes fine particles 2.5 µm or less in diameter, while PM_{10} denotes particles 10 µm or less in diameter [3]. Urban population growth and land-use change are key factors in the worsening air quality of cities worldwide [2], and air quality in urban areas is worse than in rural areas because of higher emissions from vehicles and industries. Air pollution has become a major environmental challenge in Asia and globally [4]. Weather parameters such as sunshine, temperature, wind direction, air pressure, and rainfall affect how air pollutants are emitted, dispersed, transformed, and deposited [5].

Bangladesh has poor air quality and ranks low on the Environmental Performance Index [6], and Dhaka, the crowded capital, has been reported as one of the most polluted megacities in the world [7]. Air pollution harms the health and environment of urban populations [5], [8]. Industry, urban activity, and vehicles are the main sources of air pollution in Greater Dhaka, and reducing it is an urgent challenge.

2. RELATED WORKS

Air pollution is a severe health threat in many developing countries; cities such as Bangkok, Cairo, Delhi, Mexico City, and Dhaka have pollutant levels well above WHO standards [9], harming many people, especially the vulnerable, at great cost. Dhaka was estimated to release about 50 tons of lead each year, mainly in the dry season, when airborne particulate matter exceeded 463 $\mu g/m^3$ [10]. Pollutants from gasoline engines, such as CO, hydrocarbons, NO_x, SO_2, lead, and carbon, are abundant in Dhaka's air [6]. The EPA and WHO have identified six criteria air pollutants—carbon monoxide, lead, ozone, particulate matter, nitrogen dioxide, and sulphur dioxide—with different sources and effects on health and the environment [11]. Dhaka is heavily polluted, and its surrounding areas, notably Gazipur and Narayanganj, are strongly affected by the same sources. Dhaka, the capital and predominant commercial hub of Bangladesh, is surrounded by industries such as garments, chemicals, and brick kilns and has a large population and heavy traffic, which worsen air quality [12]. Construction and biomass and waste burning also contribute, and energy consumption rises with economic growth. Concentrations of volatile organic compounds, CO_2, CO, SO_2, NO_x, suspended particulate matter, $PM_{2.5}$, and PM_{10} have increased substantially in Dhaka [11], where air pollution is caused mainly by smoke, dust, gases, and fumes from industries and vehicles [13].

3. METHODOLOGY

3.1 Study Area

Bangladesh has a tropical and subtropical climate, with a hot, rainy summer monsoon and a dry winter; the monsoon lasts from June to October, and the post-monsoon season comprises October and November [14]. Monsoon rain affects air pollution in Dhaka, and seasonal weather changes the concentrations of air pollutants [15]; the pre-monsoon and post-monsoon seasons have different meteorological conditions that affect pollution levels [16]. Meteorological variables such as temperature, humidity, wind, and rain influence the emission, transport, and transformation of air pollutants [5], [15], so meteorology is essential for understanding the spatial patterns of air pollution [17], [18]. The primary focus areas are the Dhaka North and Dhaka South City Corporations, together with Gazipur and Narayanganj (Figure 1), both characterized by heavy industry and high population density. The northern part of Narayanganj, a fringe area of the Dhaka South City Corporation, is an emerging urban region where intense economic activity in a congested setting accelerates air pollution.

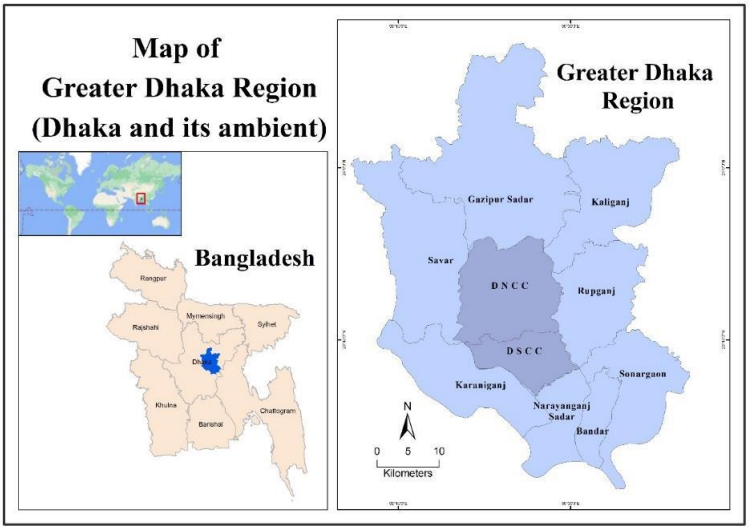

Figure 1. Greater Dhaka Region

3.2 Objective of the Study

This study aims to evaluate the air quality of the Dhaka city corporations and their surrounding regions.

3.3 Site Selection

Air quality data, including NO_2, SO_2, CO_2, CH_4, $PM_{2.5}$, and PM_{10}, were acquired in the post-monsoon season at 24 sites across Gazipur, Dhaka, and Narayanganj (Figure 2), grouped into five zones:

- **Emerging Urban Areas:** Developing areas of Greater Dhaka combining new high-rise buildings, offices, and roads, attracting professionals and families seeking modern living outside the crowded centre.
- **Market Areas:** Hubs of commerce ranging from traditional bazaars to modern malls.
- **Recreational Sites:** Parks, lakes, and cultural centres offering residents a respite from urban life.
- **Areas near Industry:** Less residential areas housing numerous factories that are vital to Dhaka's economy.
- **Transportation Hubs:** Major bus, rail, and metro nodes linking parts of Dhaka and beyond.

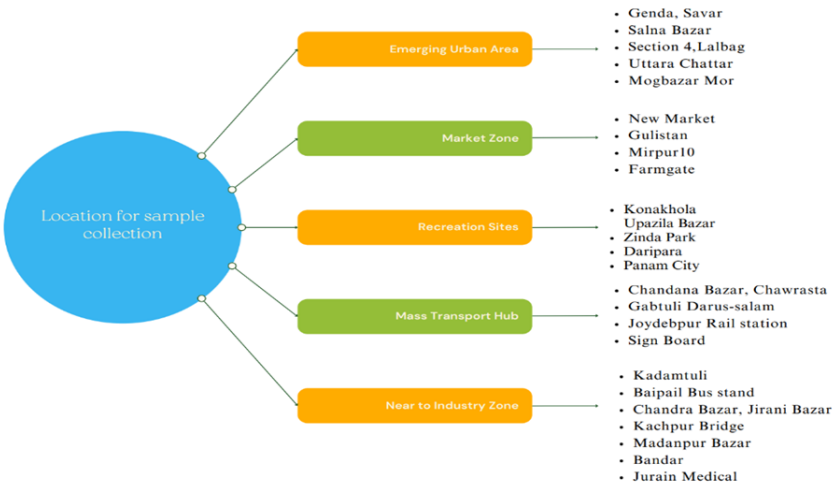

Figure 2. Locations of Sample Collection

3.4 Data Collection Instrument

Data were collected with a portable Aeroqual Series 500 air quality monitor, which measures pollutants such as NO_2, SO_2, CO_2, CH_4, $PM_{2.5}$, and PM_{10} in real time, making it suitable for environmental monitoring in areas with potential air quality problems.

3.5 AQI Scoring Method

The sub-index of each pollutant was calculated using Equation (1), and the AQI was taken as the maximum of the sub-indices (Equation 2):

$$I_{si} = [(C_obs - C_min)(I_max - I_min) / (C_max - C_min)] + I_min \quad (1)$$

$$AQI = max(I_{si}, NO_2, I_{si}, SO_2, I_{si}, PM_{2.5}, I_{si}, PM_{10}) \quad (2)$$

Where I_{si} is the sub-index of the observed pollutant, C_obs is the observed pollutant concentration, C_max and C_min are the upper and lower concentration limits of the AQI category containing C_obs, and I_max and I_min are the AQI values corresponding to C_max and C_min. The maximum operator method was chosen because it avoids the eclipsing and ambiguity problems that affect other aggregation methods; moreover, because the synergistic effects of pollutant combinations are not well understood, a health-based index that combines or weights different pollutants is not feasible. The research workflow is shown in Figure 3.

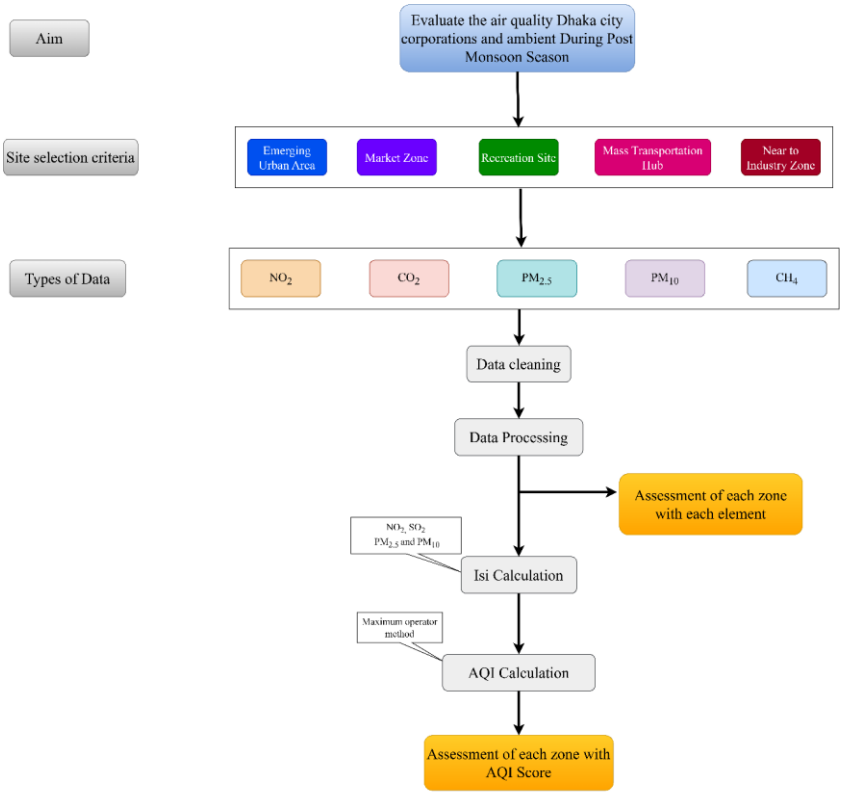

Figure 3. Research Workflow

4. RESULTS AND DISCUSSION

4.1 Emerging Urban Areas

Dhaka suffers from severe air pollution that affects public health; air pollution reached its worst level in the winter of 1996–97, when the city had more lead in the air than any other place in the world [19]. The emerging urban areas studied are Section 4 (Lalbagh), Uttara Chattar, Mogbazar Mor, Salna Bazar, and Genda (Savar) (Figure 4). Industries are concentrated in major urban areas such as Dhaka, Rajshahi,

Chittagong, Khulna, and Narayanganj [6]. The standard permissible value for NO_2 is 0.053 ppm. NO_2 is a reddish-brown toxic gas with a strong, unpleasant odour that forms during high-temperature combustion and lightning [20]; it is a major air pollutant, and NO_x harm health in various ways, including eye, head, and lung problems [21]. The reference range used for CO_2 is 400–1000 ppm.

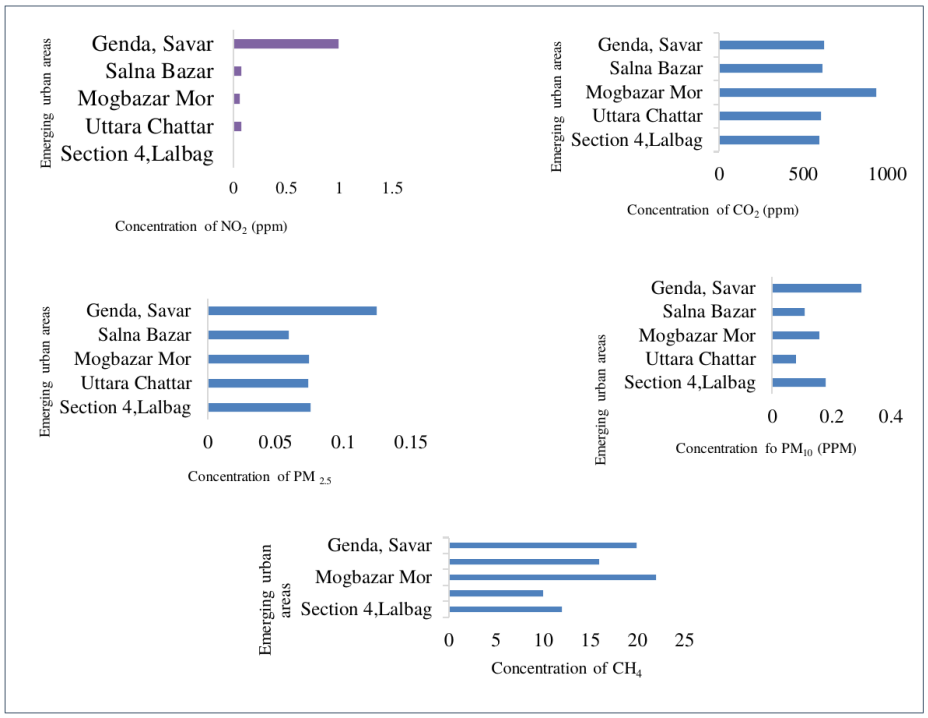

Figure 4. Air quality of Emerging Urban Areas in Greater Dhaka

Genda (Savar), an urban area with numerous brick kilns, factories, and vehicles, recorded the highest levels of NO_2, $PM_{2.5}$, and PM_{10}, with NO_2 peaking at 0.99 ppm. In contrast, the lowest pollutant levels were recorded in Section 4 (Lalbagh), a more organized residential area with minimal traffic, with the lowest CO_2 value of 599 ppm. Uttara Chattar had the lowest CH_4 level (10 ppm), attributed to its status as a newer, planned area with lower waste production. Salna Bazar, near the dusty and busy Mymensingh Highway in Gazipur, exemplifies air pollution from heavy vehicular movement. Savar, a key economic and communication hub north of Dhaka, suffers significantly from air pollution, especially near brickfields that elevate CO_2 levels and affect residents' respiratory health. Mogbazar recorded the highest CO_2 concentration (938 ppm) and CH_4 level (22 ppm), indicating dense population and extensive waste disposal.

4.2 Market Areas

Crowded market areas such as Farmgate and Mirpur 10 in the Dhaka North City Corporation (DNCC) and New Market and Gulistan in the Dhaka South City Corporation (DSCC) face significant pollution (Figure 5). Farmgate, both a market area and a transportation hub, records exceptionally high pollution: NO_2 reaches 0.09 ppm, almost twice the standard limit, and PM_{10} reaches 0.497, posing serious health risks to residents.

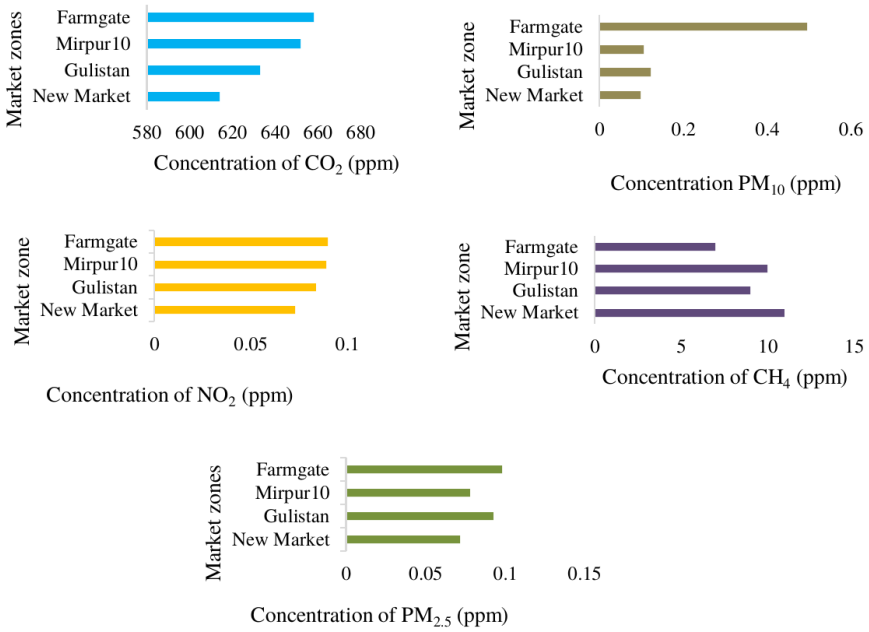

Figure 5. Concentration of Pollutants in Market Areas

4.3 Recreational Sites

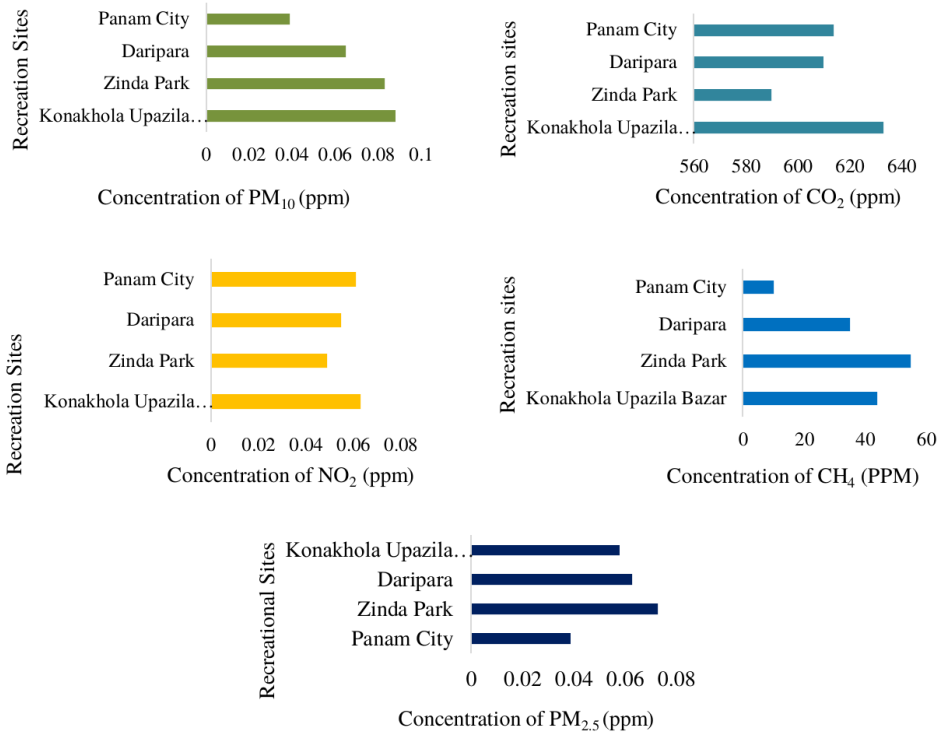

Figure 6. Concentration of Major Pollutants at Recreational Sites

Panam City, Zinda Park, and Konakhola Upazila Bazar are located outside the Dhaka City Corporation, in areas of low population density, and show lower air pollution (Figure 6). The regions surrounding Dhaka are polluted because the city acts as a parent source of pollutants, while the fringe zones are less polluted owing to healthy vegetation cover and fewer anthropogenic activities; recreational sites around Greater Dhaka are less polluted than the other categories. Konakhola Upazila Bazar (0.063 ppm)

and Panam City (0.061 ppm) have relatively high NO_2 concentrations. Panam City has the lowest PM_{10} and CH_4 levels (0.039 and 10 ppm, respectively). Zinda Park has the highest $PM_{2.5}$ level (0.073), followed by Daripara (0.063), Konakhola Upazila Bazar (0.058), and Panam City (0.039). Konakhola Upazila Bazar has the highest CO_2 (630 ppm) among recreational sites, and Zinda Park has the highest CH_4 concentration (55 ppm) because it lies beside Shapla Beel, a wetland with abundant biomass residue. These results show that the recreational sites in the periphery of Dhaka are less polluted, while areas in the city core are heavily polluted, with adverse implications for residents' health.

4.4 Transportation Hubs

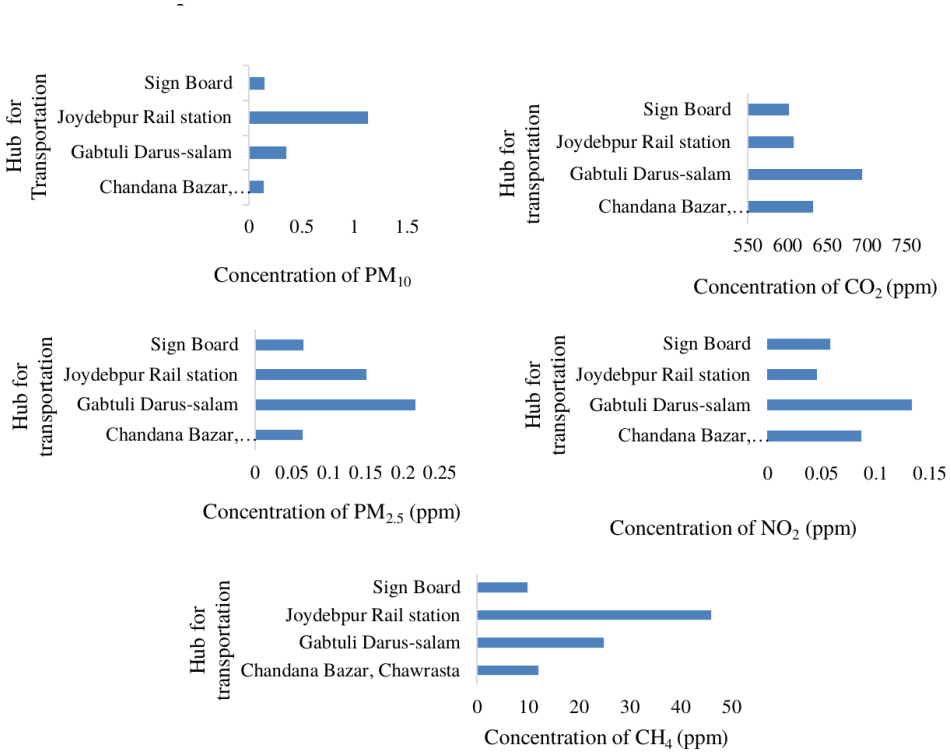

Figure 7. Concentration of Major Pollutants at Transportation Hubs

Gabtuli Darus-salam is a highly congested area with heavy traffic from nearby bus terminals and roads (Table 1). It has some of the worst air quality in the city, with $PM_{2.5}$ levels exceeding national standards most of the time, and its air pollution is also influenced by weather and wind direction, which carry pollutants from other sources [22].

Table 1. Concentration of Pollutants at Gabtuli Darus-Salam

Pollutant	Concentration
NO_2 (ppm)	0.134
CO_2 (ppm)	695
$PM_{2.5}$	0.217
PM_{10}	0.358
CH_4 (ppm)	25

The permitted sulphur content of diesel fuel in Bangladesh was 5000 ppm, with a planned reduction to 500 ppm [23]. Dhaka is surrounded by many textile industries, whose heavy trucks use high-sulphur diesel, adding to SO_2 pollution; the main source of atmospheric SO_2 is the fossil fuel burned in nearby brick kilns [23]. Gazipur is experiencing substantial physical expansion and population growth [24]

and has the highest concentration of brick kilns in the region, followed by Narayanganj and Dhaka; these kilns are major contributors to $PM_{2.5}$, SO_2, and CO emissions [25]. $PM_{2.5}$ levels rise in the post-monsoon season (October–November) [26]. Narayanganj benefits from its location between two rivers, which facilitates the transport of industrial goods by boat and ship, but this also introduces several sources of air pollution, including heavy trucks, coal- and wood-burning brick kilns, long-route bus exhaust, industrial dust [22], and diesel-fuelled water vessels.

4.5 Areas near Industry

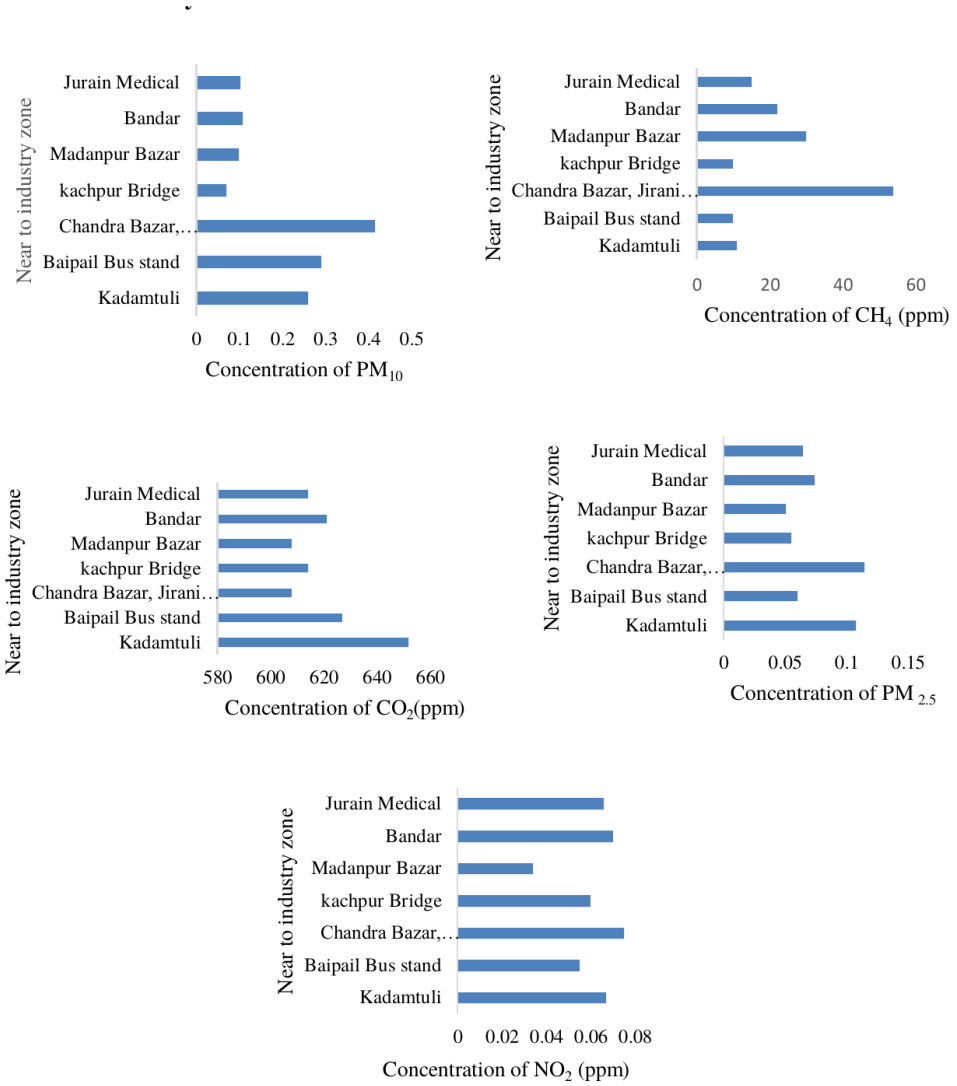

Figure 8. Concentration of Major Pollutants in Areas near Industry

In the areas near industry (Figure *8*), the highest NO_2 concentration was recorded at Chandra Bazar (Jirani Bazar), at 0.075 ppm, and the lowest at Madanpur Bazar, at 0.034 ppm. The average NO_2 level across these locations was 0.061 ppm, higher than the WHO guideline of 0.04 ppm for annual mean exposure. The highest CO_2 concentration was at Kadamtuli (652 ppm) and the lowest at Chandra Bazar (608 ppm). The highest $PM_{2.5}$ (0.115) and PM_{10} (0.415) levels were at Chandra Bazar and the lowest (0.055 and 0.069, respectively) at Kanchpur Bridge. The highest CH_4 level was at Chandra Bazar (54 ppm), and the lowest (10 ppm) at Kanchpur Bridge, Baipail Bus Stand, and Kadamtuli.

4.6 Concentration of SO_2

SO_2 levels varied across locations (Figure 9). Gulistan had the highest SO_2 level (0.3 ppm), followed by Chandana Bazar (Chawrasta) and Fuldi Bazar (0.2 ppm each), whereas 15 locations, including New Market, Kadamtuli, and Farmgate, recorded 0 ppm, the lowest possible reading. The average SO_2 level across the sites was 0.06 ppm, below the national standard of 0.12 ppm. Most of the locations are inside the Dhaka City Corporation, indicating that the city corporation area is polluted by all major air pollutants regardless of land-use category. Brick kilns, which burn coal for energy, are a major contributor to SO_2 emissions in Bangladesh, and addressing such sources is crucial to improving air quality and meeting national standards [22], [27].

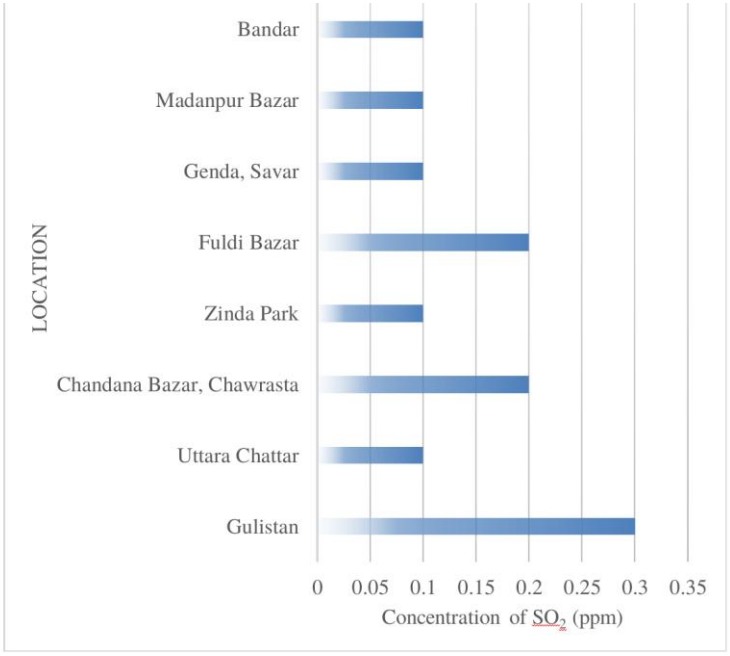

Figure 9. Concentration of SO_2 at the Sampling Locations

4.7 Air Quality Index (AQI)

The Air Quality Index (AQI) indicates how clean or polluted the air is and how it affects human health; it is usually reported daily based on national air quality standards and helps the public understand the health risks of breathing polluted air [28], [29]. The AQI summarizes different pollutants into an overall air quality status and is a useful tool for environmental agencies to inform the public about local air quality [30], [31]. The AQI of the sampling locations is shown in Figure *10*

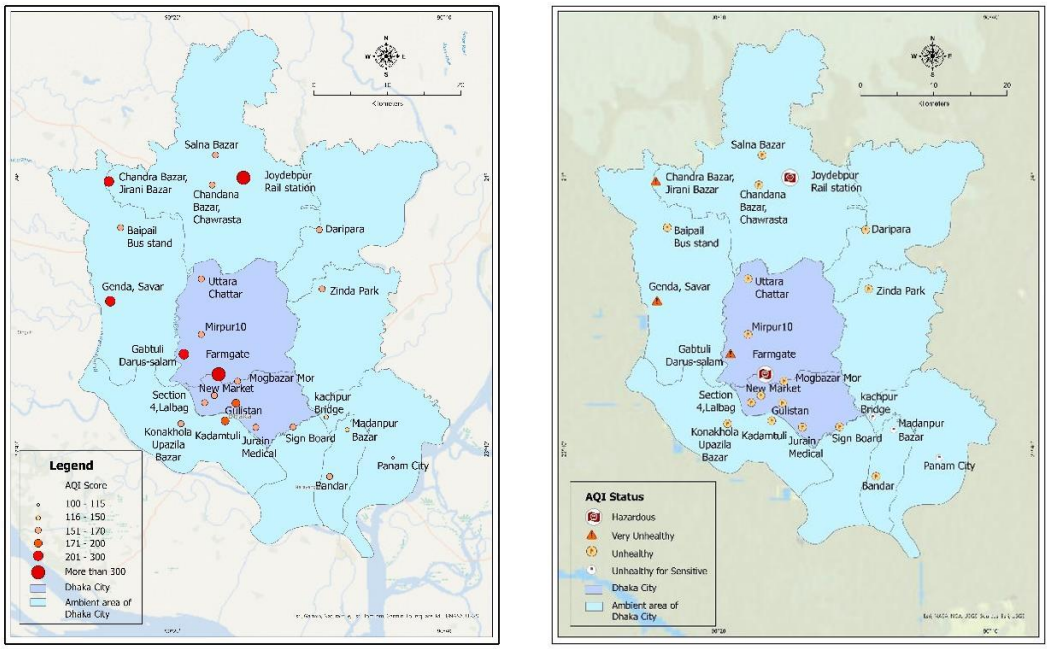

Figure 10. AQI of the Sampling Locations

Air pollution can cause temporary problems such as irritation of the eyes, throat, nose, and skin, wheezing, coughing, chest tightness, and breathing difficulties, some of which can be severe, such as asthma, pneumonia, bronchitis, and increased risk of heart attack; it can also cause headaches, nausea, and dizziness. Long-term exposure can damage the lungs, nerves, and reproductive organs and cause cancer and death [32]. Many large industrial cities have high concentrations of dust and nitrogen oxides [33], and air quality is affected by population density and economic activity [34]. The AQI ranges from 0 to 500, with higher values indicating worse air quality, and is classified into six categories with different health implications (Table 2).

Table 2. Air Quality Index Categories

Level	AQI Value
Good	0–50
Moderate	51–100
Unhealthy for sensitive groups	101–150
Unhealthy	151–200
Very unhealthy	201–300
Hazardous	301–500

The AQI in Greater Dhaka was unhealthy at most locations, with an average of 186.8, indicating serious health risks to the population. The highest AQI was recorded at Joydebpur Rail Station (395), followed by Farmgate (391); both fall in the hazardous category and are major transportation hubs with heavy traffic and prominent business activity (Figure *11*). The lowest AQI was recorded at Panam City (110), followed by Madanpur Bazar (139), both unhealthy for sensitive groups. Air quality varies across locations with the sources and levels of pollution: locations with heavy traffic congestion, such as Gulistan, Mogbazar Mor, and Farmgate, tend to have higher AQI values because of vehicle emissions; locations with industrial activity, such as Gabtuli Darus-salam, Chandra Bazar, and Genda, also have higher AQI values; and locations with agricultural activity, such as Konakhola Upazila Bazar and Zinda Park, tend to have lower AQI values.



Figure 11. AQI Score of Different Zones

5. CONCLUSION

Air pollution is a severe problem in urban areas, especially for health, caused by human activities that emit pollutants, and it is worse in developing than in developed countries [36]–[38]. Air quality in cities is deteriorating rapidly, affecting people's health and the weather and climate of surrounding areas [39]. This study of Greater Dhaka revealed alarming pollutant levels that pose risks to public health and the environment, varying by location and human activity. Because of brick kilns and factories, densely populated areas such as Genda and Savar showed high NO_2, CO_2, $PM_{2.5}$, and PM_{10} levels, whereas more organized zones such as Lalbagh had lower levels. Market areas such as Farmgate and Gulistan showed elevated NO_2 and particulate matter, while New Market showed higher CH_4 concentrations. Recreational sites were comparatively less polluted, although some showed concerning NO_2, CO_2, and PM_{10} levels. Air pollution is increasing with industrialization, urbanization, and construction, and the primary sources are vehicles, industries, and waste burning; traffic and industry worsen air quality in Darus-salam and Greater Dhaka, and sources such as textile-industry transport and diesel increase SO_2 levels. Individuals can use less and smarter transport, but government action is essential. The study shows how human activities, industrialization, and geography affect air quality and calls for policies and actions to reduce air pollution and protect health and the environment.

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Authors Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
S. M. Sium	✓	✓	✓		✓	✓		✓	✓		✓		✓	
Afrin Sharabony				✓	✓	✓		✓		✓				
Kazi Md. Fazlul Haq	✓						✓			✓		✓		✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Conflict of Interest Statement

No conflict of interest.

Informed Consent

Not Applicable.

Ethical Approval

Not Applicable.

Data Availability

This study draws on publicly available data. No new datasets were created.

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