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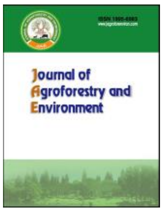

Spatial Distribution and Health Risk Assessment of $PM_{2.5}$ and PM_{10} in the Tejgaon Industrial Area in Dhaka, Bangladesh

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Abstract: Hazardous particles released into the atmosphere from natural and anthropogenic sources severely affect human health, particularly those near the Tejgaon Industrial Area. This study aimed to understand the spatial distribution patterns of $PM_{2.5}$ and PM_{10}, identify their sources, and assess the health risk associated with exposure in 26 sampling points within the area studied. The concentrations of both $PM_{2.5}$ and PM_{10} varied depending on the location and time of day. The highest concentration of $PM_{2.5}$ was 327 $\mu g/m^3$, and PM_{10} was 443 $\mu g/m^3$, both recorded in the evening at site S-16 (104, Shahed Tajuddin Ahmed Avenue). On the other hand, the lowest levels were found in the afternoon at site S-8 (373, Tejgaon), where $PM_{2.5}$ was 38 $\mu g/m^3$ and PM_{10} was 79.7 $\mu g/m^3$. The hazard quotient (HQ) for $PM_{2.5}$ and PM_{10} was consistently >1 at all sites, indicating significant non-carcinogenic risk. The HQ values ranged from 2.5 - 14 for $PM_{2.5}$, and 2.1 - 8.9 for PM_{10}, respectively. The estimated lifetime cancer risk (ELCR) for $PM_{2.5}$ was estimated at 1.90×10^{-4} - 8.21×10^{-4} for children and 6×10^{-5} - 2.63×10^{-4} for adults, exceeding the acceptable threshold of 1×10^{-6} - 1×10^{-4}. The highest ELCR was observed at S-16 (104, Shahed Tajuddin Ahmed Ave). Particulate matter concentrations were highest in high-traffic areas, with potential sources including vehicle emissions, road dust, construction, industrial activities, and open garbage dumping. $PM_{2.5}$ and PM_{10} levels in the Tejgaon Industrial Area exceeded the WHO and DoE recommended limits. The study highlighted a clear link between rising vehicle numbers, industrial expansion, and constructional activists increased air pollution in the Tejgaon Industrial area.

Keywords: Particulate Matter (PM); Spatial distribution; Health risk assessment; Hazard quotient (HQ); Lifetime cancer risk (ELCR).

INTRODUCTION

As time progresses, the world has faced numerous environmental challenges, including the rise of harmful pollutants. One such issue is "particulate matter," a pollutant that disrupts ecosystems and negatively impacts life. The sources and regulation of particulate matter have changed over time and have become a significant regional and global concerns (Kumar *et al.*, 2024). Atmospheric PM has several detrimental effects, including reduced visibility, worsened human health, and direct and indirect influences on weather and climate (Zhao *et al.*, 2023). Alarmingly, over 95% of the global population is exposed to unhealthy air, highlighting the widespread nature of this pollutant and its serious effects on the natural environment, climate, and human body (Moyebi *et al.*, 2023; Yousefi *et al.*, 2023).

Particulate matter (PM) consists of tiny solid particles and liquid droplets, and it contains organic and inorganic chemicals, metals, acids, and dust or soil (Anderson *et al.*, 2012). Atmospheric Particulate Matter can be broadly classified into 2 classes, including fine particulates (known as $PM_{2.5}$, which are smaller than 2.5 µm) and coarse particulates (also known as PM_{10}, and whose sizes are between 2.5 and 10 µm) (Subramanian and Khatri, 2018). Generally, the sources of such particulates are vehicular emissions, industrial activities, power plants, and construction activities (Xiao et al., 2025). Chemical reactions between nitrogen oxides and sulfur dioxide in the

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upper atmosphere also produce particulates (Correa *et al.*, 2023; Lala *et al.*, 2023; Song *et al.*, 2023). Urban areas in developing countries experience severe air pollution, which is strongly linked to health problems, especially respiratory diseases (Hossen, 2018). Globally, air pollution causes approximately 9 million deaths each year, with 235 million people living with asthma and 64 million suffering from COPD, according to World Health Organization estimates (Ahmed and Rahman, 2020; Mullick, 2021). The Eastern and South Asian regions are vulnerable to atmospheric pollution, as approximately 59% of premature deaths caused by air pollution occur in these areas (Hossain *et al.*, 2023). Additionally, approximately 91% of people live in highly polluted areas where the air quality exceeds WHO recommended air quality threshold (Henning, 2023). Among the most polluted countries, Bangladesh stands out because of its large population, with its capital city, Dhaka, often ranking among the most polluted cities worldwide (Pavel *et al.*, 2021). Between 2018 and 2022, Bangladesh has experienced alarming levels of air pollution, ranking among the world's most affected countries in terms of $PM_{2.5}$ concentration (Roy *et al.*, 2023; Rahman et al., 2024). Rapid population growth, industrialization, and a shift from agriculture to industry, combined with extensive industrial and commercial activities, have significantly worsened the country’s air quality (Zarin and Esraz-Ul-Zannat, 2023).

The decline in air quality has had severe consequences, with deaths related to air pollution in Bangladesh increasing from 123,000 in 2017 to 173,500 in 2019 (Rahman and Kabir, 2023). Dhaka, a densely populated capital with more than 22.4 million residents (Sarkar, 2023), faces critical environmental challenges, especially air pollution. Unplanned urbanization and emissions from large construction projects are major contributors to this issue (Majumder *et al.*, 2023). Primarily, particulate matter comes from automobiles (diesel and gasoline powered), and brick kilns, which pose a serious risk to human health and visual aesthetics in Dhaka (Rahman and Kabir, 2023). Worryingly, particulate matter levels in Dhaka and nearby areas exceed the Bangladesh National Ambient Air Quality Standard (BNAAQS) (Gupta *et al.*, 2020).

The Tejgaon Industrial Area in Dhaka, Bangladesh, began its development as an industrial zone in the 1950s under the Tejgaon Development Initiative led by the Public Works Department (Das *et al.*, 2015). However, the Detailed Area Plan (DAP) of 2010 identified a significant challenge, as the evolving land use patterns in the city core have hindered improvements and expansion efforts (The Daily Star, 2014). While the rapid economic growth in Tejgaon signifies progress, it has also led to deteriorating air quality due to continuous construction, bustling industrial activities, and high population density. This creates a complex challenge at the intersection of economic development and environmental preservation. Despite these pressing issues, there remains a notable research gap in understanding air quality within this specific area. To date, no detailed studies have been conducted on how $PM_{2.5}$ and PM_{10} are spread out in the Tejgaon industrial area, where these pollutants originate, or the associated health risks due to PM exposure in the study area. This research aims to fill this gap and address these unexplored areas by examining spatial patterns, identifying pollution sources, and assessing health risks related to particulate matter concentrations in 26 different locations within Tejgaon.

MATERIALS AND METHODS

Study Area

The Tejgaon Industrial Area is situated within Dhaka North City Corporation ward number 24, which is located at approximately 23°25' north latitude and 90°25' east longitude. Tejgaon records an average annual precipitation of approximately 741 mm and exhibits elevated thermal conditions, with maximum summer temperatures reaching 36.5°C. The region demonstrates a pronounced seasonal rainfall distribution, characterized by intense monsoonal precipitation and minimal rainfall during the winter months. $PM_{2.5}$ and PM_{10} have been measured at twenty-six (26) locations in the Tejgaon Industrial Area, as shown in Fig. 1. Data on $PM_{2.5}$ and PM_{10} were collected during three shifts on working days between July and August 2023: morning, afternoon, and evening.

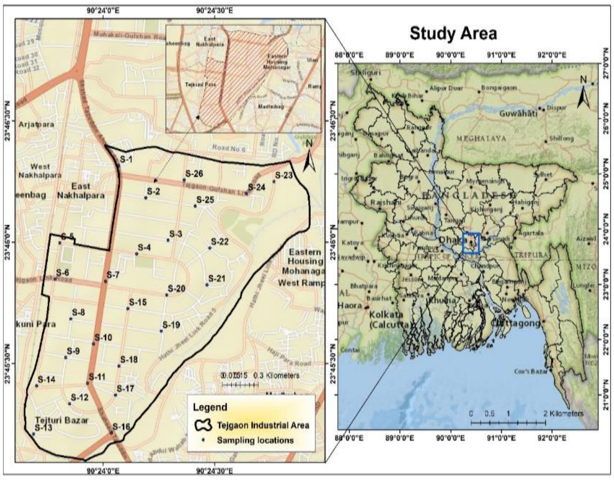

Figure 1: Twenty-six sampling locations were chosen for PM sampling in the Tejgaon Industrial Area

Sampling of $PM_{2.5}$ and PM_{10}

In this study, an Airveda $PM_{2.5}$-PM_{10} air quality monitoring instrument was used to measure the levels of particulate matter (PM). The Airveda PM monitor is a portable and validated instrument designed to provide accurate measurements of ambient air quality parameters, particularly particulate matter concentrations. Equipped with advanced sensor technology, this monitor can detect $PM_{2.5}$ matter with a 2.5-micrometer diameter and larger particles with a 10-micrometer diameter (PM_{10}).

Data Processing and Map Projection

After data collection, we performed quality checks to identify and correct errors. Microsoft Excel was used to clean the dataset by removing incorrect and missing values. The cleaned data were then imported into ArcGIS for

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spatial analysis. The Inverse Distance Weighting (IDW) interpolation technique was employed to generate continuous spatial distribution maps of $PM_{2.5}$ and PM_{10} concentrations across the study area. This deterministic method estimates values at unsampled locations by weighing nearby measured data points inversely proportional to their distance, thereby facilitating the visualization of particulate matter dispersion patterns.

Evaluation of Health Risks

An in-depth assessment of health risks is essential for comprehending the possible negative consequences of exposure to hazardous pollutants by humans. It acts as a predictive tool, estimating the effects of particular pollutants on human health on the basis of exposure data (Morakinyo *et al.*, 2017). Within this framework, both carcinogenic and noncarcinogenic risks associated with contaminants are evaluated, providing a holistic perspective on potential health hazards (US National Research Council, 1983). To evaluate the carcinogenic and noncarcinogenic risks associated with $PM_{2.5}$ exposure, we used the USEPA's (2009) recommended methodology in our research. For PM_{10} exposure, only noncarcinogenic health risks were taken into consideration.

To estimate the cancer risk posed by fine particles, we conducted dose-response assessments utilizing slope factors (SFs). These SFs indicate the degree of carcinogenicity of the contaminant and are crucial for understanding the potential risk when individuals are exposed to the pollutant. The Integrated Risk Information System (IRIS) of the U.S. Environmental Protection Agency (USEPA) calculates key dose-response values for each substance using Equation (1). This helps provide a clear understanding of the potential risks to public health and safety (USEPA, 2011).

$$SF=UR/(BW\times IR)\text{……… ………………}(1)$$

Equation (1) is related to the unit risk (UR) in µg m^{-3}, body weight (BW) in kg, and inhalation rate (IR) in m^3 h^{-1}, offering insights into the potential cancer risk associated with pollutant exposure.

In addition, the lifetime average daily dose (LADD) was computed as part of our exposure assessment in order to estimate the lifetime exposure of the residents to pollutants. Equation (2) was instrumental in this calculation (Kim *et al.*, 2018).

$$LADD= (CA\times IR\times ED\times EF)/(BW\times AT)\text{ ………}(2)$$

Equation (2) takes into account the contaminant concentration (CA) in µg m^{-3}, inhalation rate (IR) in m^3 h^{-1}, exposure duration (ED) in years, exposure frequency (EF) in days $year^{-1}$, body weight (BW) in kg, and average time for a lifetime (AT) in days, providing a comprehensive understanding of exposure levels.

Finally, to estimate the Estimated Lifetime Cancer Risk (ELCR), which represents the probability of developing cancer during one's lifetime, we utilized Equation (3) (Kim et al., 2018).

$$ELCR=SF\times LADD\text{……………………}(3)$$

ELCR is expressed as one cancer incidence per one million people, with its reference value set at 3.14×10^3, allowing for a nuanced assessment of cancer risks associated with pollutant exposure.

The calculation of the HQ for noncarcinogenic risk was based on Equation (4), incorporating the reference exposure level (REL) (Morakinyo *et al.*, 2017).

$$HQ=LADD/REL\text{……………………}(4)$$

REL serves as the threshold at which adverse health effects may occur, with 50 µg m^{-3} for $PM_{2.5}$ and 75 µg m^{-3} for PM_{10} taken from relevant literature (Matooane and Diab, 2003; Othman *et al.*, 2020).

Additionally, for $PM_{2.5}$, a standard unit risk of 0.008 per µg m^{-3} was adopted, whereas no specific unit risk value was available for PM_{10}. This approach aligns with previous studies highlighting the significance of HQ values greater than 1 as indicative of potential noncarcinogenic effects (Morakinyo *et al.*, 2017; Othman *et al.*, 2019).

Notably, an ELCR value within the range of 1.0E-06 to 1.0E-04 is generally considered acceptable (Othman *et al.*, 2018), providing a benchmark for evaluating cancer risks associated with pollutant exposure. The variables utilized in this study are outlined in Table 1, and were adapted from previous research and USEPA guidelines, facilitating a comprehensive assessment of health risks.

Table 1. Input data for health risk assessment for different ages.

Factors	Children (6-12 years)	Adults (21-70 years)
Inhalation rate (m^3/day)	13.5	16
Body weight (kg)	45.3	80
Exposure frequency (days)	350	350
Exposure duration (years)	12	30
Average time (days)	4380	10950
Unit risk for ($PM_{2.5}$) (µg m^{-3})	-	0.008

We further estimated cancer incidence per lifetime for both children and adults based on Equation (5), considering the cancer risk probability derived from our analysis (Chalvatzaki *et al.*, 2019).

$$I=N\times ELCR\text{…………………………}(5)$$

With the help of equation (5), cancer incidences can be estimated while accounting for population demographics and the cancer risk probability found in this investigation. With the all factors considered, these techniques and computations offer insightful information about the possible health hazards linked to PM exposure, assisting stakeholders and legislators in putting into practice efficient mitigation measures.

RESULTS

Particulate matter levels vary significantly across different locations, emphasizing the localized nature of air pollution within the Tejgaon Industrial Area. Morning,

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afternoon, and evening measurements show that air quality varies over time. Understanding these differences is critical for determining daily exposure patterns.

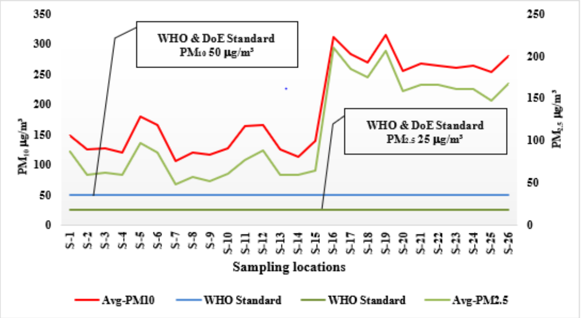

Figure 2: Average PM$_{2.5}$ and PM$_{10}$ Concentrations

Certain locations, such as S-19 (Uttar Begunbari Mosjid), S-16 (104 Shahed Tajuddin Ahmed Ave.), and S-17 (47, Hatir Jheel Link Rd), have notably high concentrations of PM$_{2.5}$ and PM$_{10}$ each at various times of the day, indicating increased pollution levels. Figure-2 clearly shows that the atmosphere throughout the Tejgaon Industrial Area contained higher concentrations of PM$_{10}$ than PM$_{2.5}$. The mean concentration of PM$_{10}$ was 314.3 µg m^{-3}, the highest observed level in S-19 (Uttar Begunbari Mosjid) and 105.7 µg m^{-3} is the lowest at S-7 (Channel 24 Road). The mean concentration of PM$_{2.5}$ was 211 µg m^{-3}, the highest observed level in S-16 (104, Shahed Tajuddin Ahmed Ave) and the lowest 49 µg m^{-3} in S-7 (Channel-24, Road). At all the sampling sites, the concentrations of PM$_{2.5}$ and PM$_{10}$ exceeded the World Health Organization (WHO) guideline limits of 25 µg/m^3 and 50 µg/m^3, respectively, as well as the national guideline limits set by the Department of Environment (DoE), Bangladesh.

Spatial Distribution of PM$_{2.5}$ (Morning)

Figure 3 shows the spatial distribution of morning (7 a.m. to 9 a.m.) PM$_{2.5}$ levels in the Tejgaon Industrial Area. The particulate matter levels vary across different locations. The highest observed level is 194 µg/m^3 at S-19 (Uttar Begunbari Mosjid), whereas the lowest level is 52 µg/m^3 at S-9 (Baitus Salam Jame Masjid Mor). The notable areas include S-11 (Square of Seven Rd.) at 95 µg/m^3, S-17 (47 Hatir Jheel Link Rd.) at 163 µg/m^3, and S-18 (Begunbari Bottola Mor) at 175 µg/m^3, offering insights into spatial distribution.

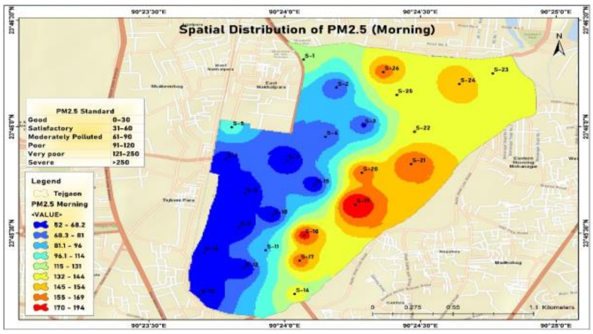

Figure 3: Spatial Distribution of PM$_{2.5}$ (Morning)

Spatial Distribution of PM$_{2.5}$ (Afternoon)

Figure 4 shows that particulate matter levels vary in the Tejgaon Industrial Area during the afternoon hours. The highest concentration is recorded at S-19 (Uttar Begunbari Mosjid) with a value of 264 µg/m^3, whereas the lowest concentration was observed at S-9 (Baitus Salam Jame Masjid Mor) at 38 µg/m^3. Notable areas with elevated particulate matter levels include S-17 (47, Hatir Jheel Link Rd.) at a concentration of 206 µg/m^3 and S-18 (Begunbari Bottola Mor) at 192 µg/m^3.

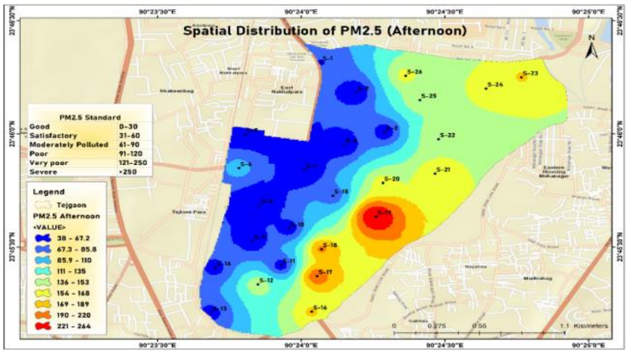

Figure 4: Spatial Distribution of PM$_{2.5}$ (Afternoon)

Spatial Distribution of PM$_{2.5}$ (Evening)

Figure 5 shows that particulate matter levels vary during in the evening hours in the Tejgaon Industrial Area. The highest concentration is recorded at S-16 (104, Shahed Tajuddin Ahmed Ave.) with a value of 327 µg/m^3, whereas the lowest value was observed 48 µg/m^3 at S-9 (Baitus Salam Jame Masjid Mor) at. Notable areas with elevated particulate matter levels include S-22 (DPDC Nakhalpara) with concentration of 200 µg/m^3 and 187 µg/m^3 at S-17 (47 Hatir Jheel Link Rd.).

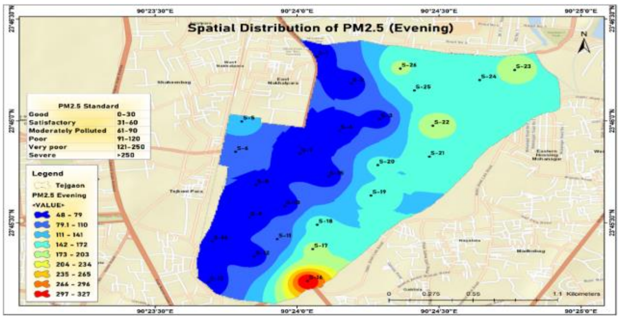

Figure 5: Spatial Distribution of PM$_{2.5}$ (Evening)

Spatial Distribution of PM$_{10}$ (Morning)

Figure 6 shows that particulate matter levels vary in the morning hours within the Tejgaon Industrial Area. The highest concentration was recorded at S-19 (Uttar Begunbari Mosjid) with a value of 290 µg/m^3, whereas the lowest concentration was observed 114 µg/m^3 at S-9 (Baitus Salam Jame Masjid Mor). The notable areas with elevated particulate matter levels include S-17 (47, Hatir Jheel Link Rd.) at 258 µg/m^3 and S-18 (Begunbari Bottola Mor) at 263 µg/m^3. These findings provide information on the spatial

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distribution of particulate matter (PM) concentrations during the morning.

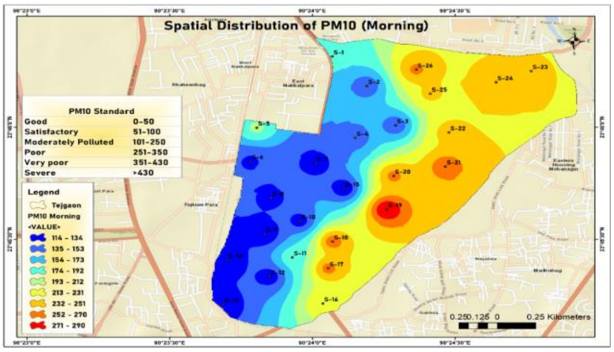

Figure 6: Spatial Distribution of PM_{10} (Morning)

Spatial Distribution of PM_{10} (Afternoon)

Figure 7 shows that particulate matter levels exhibit variation during the afternoon hours in the Tejgaon Industrial Area. The highest concentration was recorded at S-19 (Uttar Begunbari Mosjid) with a value of 384 µg/m³, while the lowest concentration was observed at S-9 (Baitus Salam Jame Masjid Mor) at 80 µg/m³. Notable areas with elevated particulate matter levels include S-17 (47, Hatir Jheel Link Rd.) at 309 µg/m³ and S-18 (Begunbari Bottola Mor) at 294 µg/m³.

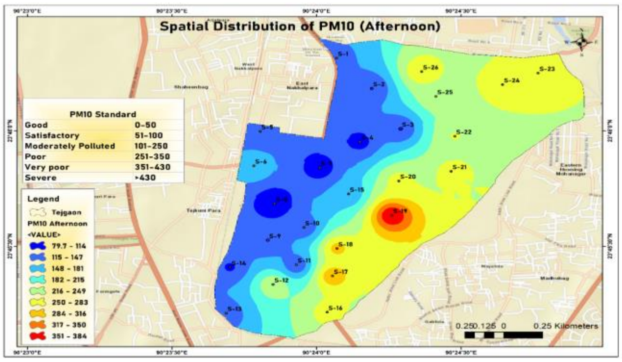

Figure 7: Spatial Distribution of PM_{10} (Afternoon)

Spatial Distribution of PM_{10} (Evening)

Figure 8 shows that there is variability in the evening particulate matter levels in the Tejgaon Industrial Area. With a reading of 443 µg/m³, the highest concentration was recorded at S-16 (104, Shahed Tajuddin Ahmed Ave.). This is mainly due to higher levels of $PM_{2.5}$ and PM_{10}. Moreover, S-8 (373, Tejgaon), here $PM_{2.5}$ and PM_{10} concentrations are noticeably lower with a value of 103 µg/m³, has the lowest concentration. The Significant locations with increased $PM_{2.5}$ and PM_{10} concentrations were 285 µg/m³ at S-17 (47, Hatir Jheel Link Rd.) and 306 µg/m³ at S-22 (DPDC Nakhalpara). These locations highlight the presence of both pollutants.

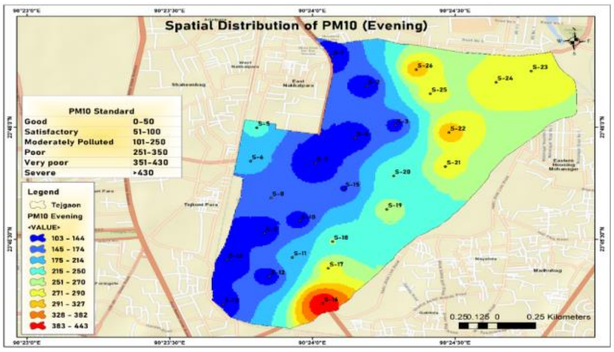

Figure 8: Spatial Distribution of PM_{10} (Evening)

3.7 Source Characterization of $PM_{2.5}$ and PM_{10}

$PM_{2.5}$ and PM_{10} source characterization involves recognizing and understanding the various origins or contributors of these particulate pollutants. This is an essential phase in creating methods for managing air quality standards. The following are typical sources of $PM_{2.5}$ and PM_{10} in the Tejgaon Industrial Area.

- **Sources of Combustion:** The combustion of fossil fuels, including those used in automobiles, power plants, and industries, is the principal source of $PM_{2.5}$ fine particles in this location. The larger particles released by combustion sources such as dust and ash from industrial combustion processes are PM_{10} particles. There are many industrial facilities, including factories and manufacturing plants, in the Tejgaon Industrial Area. Numerous pollutants are discharged into the atmosphere via industrial processes such as combustion, chemical production, and material handling.
- **Emissions from Transportation:** Emissions from vehicle exhaust, comprising diesel and gasoline engines, contribute to both $PM_{2.5}$ and PM_{10} levels. Particulate matter is also released into the air as a result of brake and tire wear. High vehicular traffic in the area, including trucks, buses, private cars, and other vehicles associated with industrial activities, leads to significant emissions of air contaminants.
- **Activities in Industry:** It is possible to emit $PM_{2.5}$ and PM_{10} particles into the atmosphere. by a variety of industrial processes, including manufacturing, construction, and material handling.
- **Construction and Demolition:** Ongoing Mega construction projects such as Metrorail, road construction, and demolition activities in Dhaka City can generate dust and particulate matter, contributing to local air pollution levels.
- **Waste Burning:** Improper waste disposal practices, such as the open burning of solid waste, contribute to the release of hazardous air pollutants**.** The Open burning of waste materials contributes to the presence of particulate matter and toxic gases.
- **Weather Conditions:** Local weather conditions, such as temperature inversions and stagnant air masses, can trap pollutants close to the ground, leading to the

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accumulation of pollutants in the Tejgaon Industrial Area.

- **Lack of Green Spaces:** The scarcity of green spaces and vegetation in Tejgaon Industrial Area. Plants play crucial roles in absorbing pollutants and improving air quality.

Health Risk Assessment due to PM Exposure

In assessing the health risks associated with PM exposure, non-carcinogenic values were calculated using the Hazard Quotient (HQ), providing insight into the potential adverse effects of particulate matter on human health. HQ values for both $PM_{2.5}$ and PM_{10} were determined across various sampling locations, with values indicating the degree of risk posed by exposure to these pollutants. For $PM_{2.5}$, HQ values ranged from 2.6 to 14.0 across the sampling locations. Lower values, such as those observed at S-1 (Mohakhali Bus Terminal) with a value of 2.6 and S-2 (240, Bir Uttam Mir Shawkat Sarak) with a value of 2.5, suggest relatively lower risks of non-carcinogenic effects, while higher values, such as at S-16 (104, Shahed Tajuddin Ahmed Ave.). with a value of 14.0, indicate a potentially significant risk associated with $PM_{2.5}$ exposure.

Similarly, for PM_{10}, HQ values ranged from 2.1 to 8.9, with lower values suggesting minimal risk and higher values indicating a greater likelihood of non-carcinogenic effects. Locations such as S-16 (104, Shahed Tajuddin Ahmed Ave.) again demonstrated notably elevated HQ values (8.9), signaling a heightened risk of non-carcinogenic effects linked to PM_{10} exposure. Conversely, sites such as S-7 (Channel 24 Road), and S-13 (7/L OLD BFDC Rd.) recorded lower HQ values (2.1 and 2.6, respectively), indicating a comparatively lower risk of adverse health impacts associated with PM_{10} inhalation.

In this study on the health risks linked to particulate matter (PM) exposure, we focused on evaluating the Excess Lifetime Cancer Risk (ELCR) specifically attributable to $PM_{2.5}$, utilizing an Inhalation Unit Risk (IUR) value of 0.008 per $\mu g\ m^{-3}$. The ELCR values were calculated for both children and adults across various sampling locations, and the results indicate a concerning trend. Across the sampling locations, the ELCR values exceeded the acceptable limit of 1.0E-04 for all age groups, indicating a significant cancer risk associated with $PM_{2.5}$ exposure. Specifically, the ELCR values ranged from 1.9E-04 to 8.2E-04 for children and from 6.1E-05 to 2.6E-04 for adults, with most of the recorded values surpassing the established threshold. It's crucial to acknowledge that ELCR values falling within the range of 1.0E-06 to 1.0E-04 are generally considered acceptable, serving as a benchmark for assessing cancer risks associated with pollutant exposure.

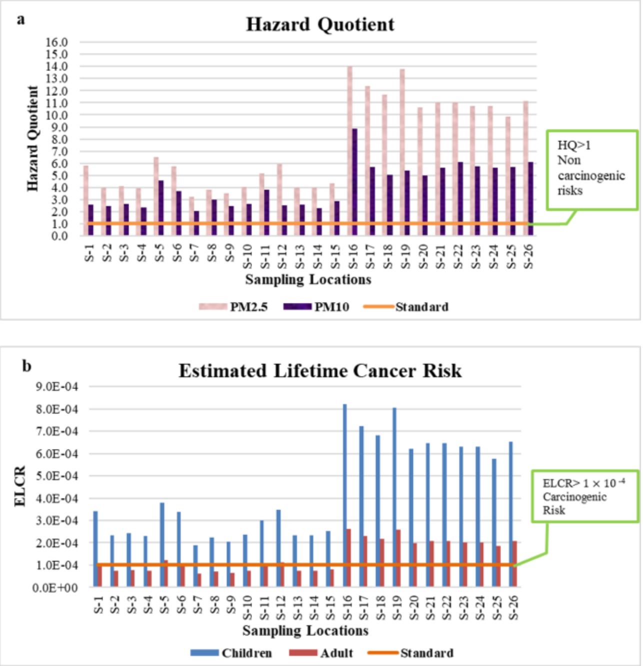

Figure 9: HQs associated with $PM_{2.5}$ and PM_{10} (a) and ELCRs associated with $PM_{2.5}$ (b) at the twenty-six sampling locations for three different age groups.

However, most of the obtained ELCR values exceeded this acceptable threshold, indicating a pronounced cancer risk posed by $PM_{2.5}$ exposure in the investigated regions. Comparatively lower values of ELCR ($PM_{2.5}$) were found in the adults. Children have faced greater health risk compared to adults.

DISCUSSION

The results reveal alarming levels of particulate pollutants ($PM_{2.5}$ and PM_{10}) across the Tejgaon Industrial Area, far exceeding both WHO and Bangladesh's Department of Environment (DoE) guidelines. $PM_{2.5}$ and PM_{10} concentrations were consistently high in all sampling locations, with some areas such as S-19 (Uttar Begunbari Mosjid) and S-16 (104, Shahed Tajuddin Ahmed Ave.) showing extreme pollution levels. This indicates severe air quality degradation, which poses serious health risks to residents and workers in the area. Similar trends have been observed in other Bangladeshi cities, where construction operations, industrial activities, and vehicular emissions contribute heavily to air pollution (Haque *et al.*, 2024; Khan *et al.*, 2023).

The spatiotemporal variations in PM concentrations highlight the influence of local pollution sources. Morning hours showed higher $PM_{2.5}$ levels, likely due to increased industrial and traffic activity at the beginning of the day. Afternoon peaks, such as at Uttar Begunbari Mosjid (264 $\mu g/m^3$), may be linked to industrial operations and vehicle emissions. Evening pollution spikes, particularly at S-16 (104 Shahed Tajuddin Ahmed Ave) (327 $\mu g/m^3$), could result from a combination of traffic congestion, waste burning, and reduced atmospheric dispersion. Such patterns

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align with studies in Dhaka and Khulna, where similar sources have been identified (Begum *et al.*, 2013; Kumar *et al.*, 2024).

The health risk assessment further underscores the severity of the issue. The Hazard Quotient (HQ) values for $PM_{2.5}$ and PM_{10} were well above safe limits, indicating a high risk of non-carcinogenic health effects. The Excess Lifetime Cancer Risk (ELCR) values also exceeded acceptable thresholds, with children facing greater risks than adults, a trend consistent with previous research (Hassan *et al.*, 2022). This heightened vulnerability in children is concerning, as prolonged exposure to PM can lead to respiratory diseases, cardiovascular problems, and impaired lung development (WHO, 2021).

Major pollution sources in Tejgaon include industrial emissions, vehicular exhaust, construction dust, and open waste burning (Nargis *et. al.*,2022). Brick kilns, a significant contributor in Bangladesh (Ahmad *et al.*, 2022), likely add to the PM load, along with heavy traffic and ongoing infrastructure projects like the Metrorail. The lack of green spaces exacerbates the problem, as vegetation helps absorb pollutants and improve air quality (Kulsum and Moniruzzaman, 2021).

Additionally, it was found that air pollution in Tejgaon is dangerously high, with $PM_{2.5}$ and PM_{10} concentrations exceeding safety limits. Both children and adults face health risks, but children are more vulnerable. The cancer risk from $PM_{2.5}$ is 2-8 times higher than safe levels for children. Similar studies in Khulna found high $PM_{2.5}$ risks, especially for children and the elderly (Saju *et al.*, 2023). Research on toxic metals in $PM_{2.5}$ also shows children are at greater risk than adults (Sakunkoo *et al.*, 2022). Another study found that household PM exposure increases cancer risks more in children (Sidibe *et al.*, 2022).

Addressing this crisis requires urgent policy interventions. Stricter enforcement of emission regulations, promotion of cleaner and sustainable manufacturing technologies, and expansion of green infrastructure are essential. Public awareness campaigns and real-time air quality monitoring can also help mitigate exposure. Without immediate action, the health and environmental costs will continue to rise, mirroring the air pollution challenges seen in other rapidly urbanizing South Asian cities (Roy and Singha, 2021; Anwar *et al.*, 2021).

CONCLUSIONS

The purpose of this study was to provide a spotlight on the complicated nature of air pollution in the Tejgaon Industrial Area of Dhaka, Bangladesh, providing important information on the scope of the issue and its effects on public health. The findings of this study revealed significant spatial and temporal variations in particulate matter ($PM_{2.5}$ and PM_{10}) concentrations across twenty-six locations and times of the day within the studied zone. From the analysis, it is evident that both $PM_{2.5}$ and PM_{10} levels exceed the standard particulate matter concentration established by the World Health Organization (WHO), with the highest recorded value of $PM_{2.5}$ and PM_{10} reaching 210.6 μg/m³ and 314.3 μg/m³, respectively. Both these values were recorded at S-16 (104, Shahed Tajuddin Ahmed Ave.), in the evening. The lowest value for $PM_{2.5}$ and PM_{10} was recorded as 38 μg/m³ and 79.7 μg/m³, respectively, from S-8 (373, Tejgaon) in the afternoon. These findings highlight the widespread nature of air pollution in the study area and emphasize the need for targeted interventions to reduce its harmful impacts. Furthermore, the Hazard Quotient (HQ) values associated with $PM_{2.5}$ and PM_{10} indicated varying degrees of non-carcinogenic risks across different sampling locations. Notably, HQ values ranged from 3.2 to 14 and 2.1 to 8.9 for children and adults, respectively, with higher values signaling increased risk of adverse health effects. Additionally, the estimated lifetime cancer risk (ELCR) values for $PM_{2.5}$ exceeded acceptable thresholds, indicating a substantial cancer risk associated with $PM_{2.5}$ exposure. Specifically, ELCR values for $PM_{2.5}$ were estimated to be 1.90×10^{-4} - 8.21×10^{-4} for children and 6×10^{-5}- 2.63×10^{-4} for adults, with most values surpassing the established threshold. Several potential sources of PM pollution were found in the study, including traffic emissions, road dust, construction activities, industrial processes, and open garbage dumping. These findings underscore the urgent need for concerted efforts to address air pollution in the Tejgaon Industrial Area. Effective strategies should focus on reducing emissions from industrial activities, promoting cleaner transportation alternatives, enhancing monitoring and enforcement measures, and fostering public awareness about the health risks posed by air pollution.

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Conflict of Interest

There are no conflicts of interest declared by the authors.

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