World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

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Meteorological influence on particulate matter levels: A case study of Bonpara, Natore

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World Journal of Advanced Research and Reviews, 2025, 25(03), 1632-1644

Publication history: Received on 14 February 2025; revised on 21 March 2025; accepted on 24 March 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.25.3.0916

Abstract

This study analyzed PM2.5 and PM10 levels in Bonpara, examining their correlation with meteorological factors. Data was collected from 10 selected stations within a 3 km radius of the Bonpara Bypass, covering three directions: northeast, southeast, and west. Measurements were taken at 500m, 1km, and 3km from the center during both dry and wet seasons, with each station providing 14 data points. Results showed the highest particulate matter concentrations at the Bonpara Bypass center, particularly during the dry season. Average PM2.5 and PM10 levels were 156 μg/m^3 and 169 μg/m^3, exceeding Bangladesh Gazette standards (65 μg/m^3 for PM2.5 and 150 μg/m^3 for PM10). In contrast, stations with less traffic recorded 95 μg/m^3 (PM2.5) and 104 μg/m^3 (PM10). The study attributes this to heavy vehicular movement in the bypass area.

In the wet season, frequent rainfall and higher humidity reduced particulate matter levels. At the bypass center, PM2.5 and PM10 dropped to 50 μg/m^3 and 56 μg/m^3, while other stations recorded 35 μg/m^3 and 42 μg/m^3, staying within standard limits. Wind direction also played a key role, with higher PM concentrations downwind of the bypass. Additionally, construction at Stations 07 and 08 in the dry season resulted in PM2.5 and PM10 levels of 113 μg/m^3 and 126 μg/m^3, respectively, exceeding the PM2.5 standard. The study highlights the impact of humidity, rainfall, and human activities on air quality. Expanding monitoring locations and raising public awareness are essential to mitigate PM pollution in Bonpara.

Keywords: Air pollution; Construction dust; Traffic dust; Sustainable development; Environmental pollution

1. Introduction

The pollution of air has been one of the biggest issues of eco-environmental problems in the world [1]. There are five different types of air pollutants, such as carbon monoxide (CO), ground-level ozone (O3), nitric oxide (NO), Sulphur dioxide (SO2), and particulate matter (PM10 and PM2.5) [2]. Particulate matter (PM10 and PM2.5) is one of the alarming issues for the world because Human health issues are associated with particulate matter [3]. Several studies have shown that both particle size has a significant negative impact on human health [4]. The last 20 years have seen a decline in air quality which is frequently attributed to the exponential growth in anthropogenic activity brought on by increasing urbanization which is mostly over more densely populated urban areas [5]. Major cities in Bangladesh are worried about air pollution [6].

Many research has highlighted the significant impact of meteorological factors on air pollution levels. A study by demonstrated a strong correlation between wind speed, wind direction, and precipitation patterns with variations in $PM_{2.5}$ and PM_{10} concentrations which These findings underscore the importance of considering meteorological conditions when assessing and mitigating air pollution [7]. Particulate matter emissions are further exacerbated by an increase in vehicle traffic where older or poorly maintained cars are more harmful [8]. In The cities of Europe, automobile traffic increases PM concentration, and traffic-generated emissions make for over half of all PM emissions

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and automobile traffic accounts for almost 80% of PM emissions in London, UK, and 66.5% in Athens, Greece [8]. PM2.5 and PM10 particles are typically released from sources like automobiles, material handling, crushing and grinding operations, and windblown dust [9]. A study conducted in Taiwan which showed that the PM2.5, PM10 concentrations increased during an Asian dust storm (ADS) and the PM10 concentrations were approximately 2–3 times higher than when there were no ADS [10].

Building upon these existing studies, this research aims to investigate the specific relationship between meteorological factors and $PM_{2.5}$ and PM_{10} concentrations in the vicinity of Bonpara Bypass Bus Stop, Natore. By analysing data on wind speed, wind direction, precipitation, and PM levels, this study seeks to contribute to a deeper understanding of the factors influencing air quality in this region. The findings of this research will have important implications for developing effective air pollution mitigation strategies and improving public health outcomes in Natore and other regions facing similar challenges. The discharge of particulate matter into the atmosphere is mostly caused by industrial emissions from nearby companies and continuous building constructions produce dust where particularly if appropriate dust control measures are not taken. Objective of this research was to monitor particulate matter levels in the ambient air of the Bonpara region, analyze their variations across different locations, and assess the impact of meteorological factors on their dispersion.

Ecosystems are exposed to multiple air pollutants simultaneously, but it can be difficult to assess the overall impact of air pollution on organisms in a particular ecosystem [11]. But these pollutions have a big adverse impact on the ecosystems as well. Air pollution effects on the physiology, growth and reproduction [12].

2. Methodology

Study location was at Bonpara Bypass, Baraigram, Natore District, Rajshahi Division. The bus stop is in Majgaon, Baraigram Upazila-6430, Natore district, Rajshahi Division. Samples were collected from the Bonpara Bypass and around a 3km radius from the center of the Bypass. Collected data were in three directions from the center. They are North-East (N-E), South-East (S-E), and West direction. In each direction, PM measurement was conducted at an interval of 500m, 1km, and 3km respectively. The area of Bonpara is 6.92 sq. km and the position on the world map is 24° 17' 39.12" north latitude and 89° 4' 52.32" east longitude. Study location is shown in figure 1. During dry season, PM measurement was conducted from 3 February 2024 to 10 February 2024, and during wet season measurement was conducted from 5 September 2024 to 11 September 2024. The sample collection time was around 30 minutes in every stations.

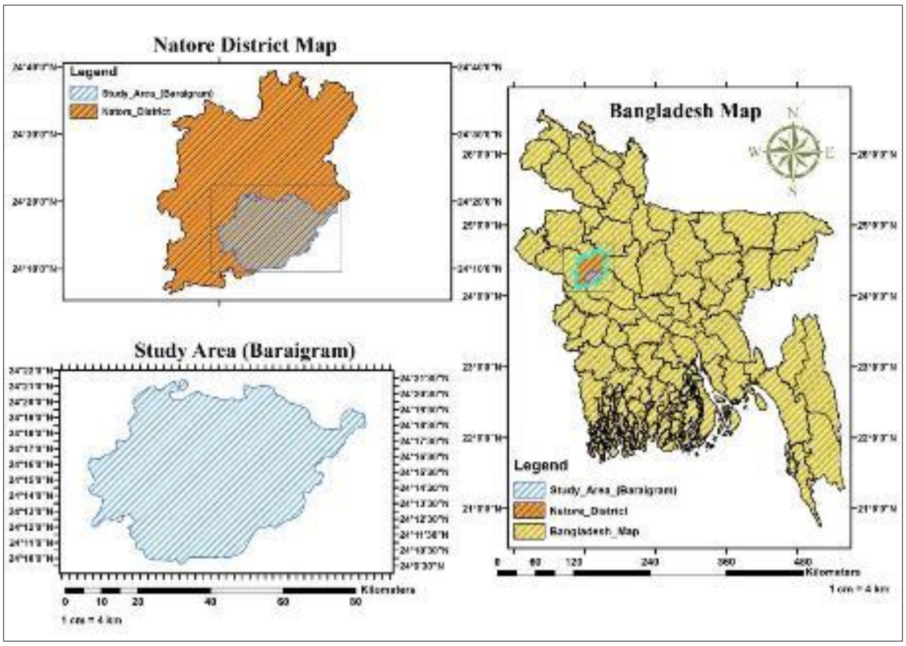

Figure 1 Location of Study Area (Baraigram, Natore)

PM measurements were taken from 10 selected stations in dry season and wet season as shown in figure 2. 1. PM measurement station 01 was in Bonpara Bypass (24° 17' 53.8296", 89° 4' 48.5652"), station 02 was 500m west of the

Bypass (24° 17' 54.3228", 89° 4' 31.0152"), station 03 was 1km west of the Bypass (24° 17' 55.0752", 89° 4' 12.486"), station 04 was 3km west of the Bypass (24° 17' 59.3196", 89° 2' 57.7392"), station 05 was 500m North-East of the Bypass (24° 1' 48.65808", 89° 4' 58.908"), station 06 was 1km North-East of the Bypass (24° 18' 20.3292", 89° 5' 11.4612"), station 07 was 3km North-East of the Bypass (24° 19' 12.0648", 89° 5' 46.3092"), station 08 was 500m South-East of the Bypass (24° 17' 44.6604", 89° 5' 3.2496"), station 09 is 1km South-East of the Bypass (24° 17' 37.1652", 89° 5' 21.0228"), and station 10 was 3km South-East of the Bypass (24° 17' 22.2108", 89° 6' 30.3984"). Total 140 samples were taken from selected 10 stations.

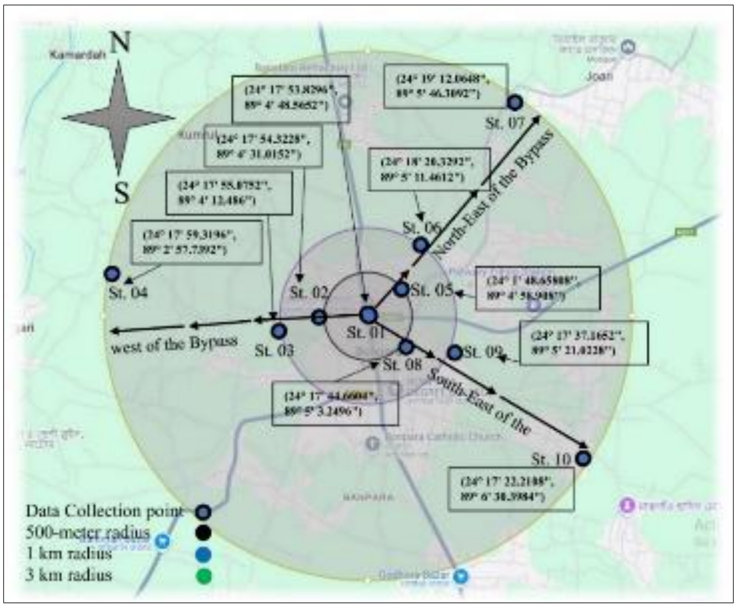

Figure 2 Sampling Locations

Dust particle meter SR-516 was used for PM measurement during study period, which could detect 1.0um, 2.5um, and 10um particle size dust quantity concentration, temperature, humidity and AQI level. With 3.2-inch TFT full-color display, automatic and manual measurement, real-time date and time, rechargeable lithium battery or separate external USB power supply, sensor life was about 8000 hours. Sampler is shown in figure 3.

Figure 3 Dust Particle Meter SR-516

All the data was collected from the indicated Station were processed and analyzed using Microsoft Office Excel 2021. Arch GIS software was used as well for attaching the study areas.

3. Result and Discussion

The Bonpara Bypass, particularly at Sampling Station 1, experiences a consistently high volume of traffic. This route serves as a crucial passage for vehicles traveling from greater Rajshahi and Pabna district towards the capital, Dhaka, making it a key focal point for this study. Additionally, ongoing construction activities were observed at Stations 07 and 08 during the study period. Figures 4 to 10 illustrate the PM concentration in the air during the dry season throughout the study period, while Figures 11 to 17 depict the PM concentration in the air during the wet season.

Figure 4 illustrates that on Day 01 of the dry season, the wind direction was from west to east. The average $PM_{2.5}$ and PM_{10} concentrations in the center and upwind direction were 64 μg/m^3 and 76 μg/m^3, respectively. In the downwind direction, the average $PM_{2.5}$ and PM_{10} concentrations increased to 102 μg/m^3 and 112 μg/m^3. A significant rise in PM concentration was observed along the wind direction. The average humidity recorded was 49%.

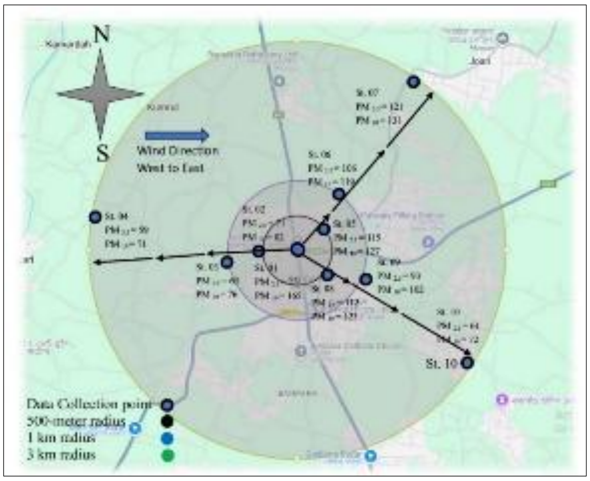

Figure 4 Day 1 (Dry Season)

Figure 5 illustrates that on Day 02 of the dry season, the wind direction remained west to east. The average $PM_{2.5}$ and PM_{10} concentrations in the center and upwind direction were 83 μg/m^3 and 91 μg/m^3, respectively. In the downwind direction, these values measured 96 μg/m^3 and 109 μg/m^3. The recorded average humidity for the day was 55%.

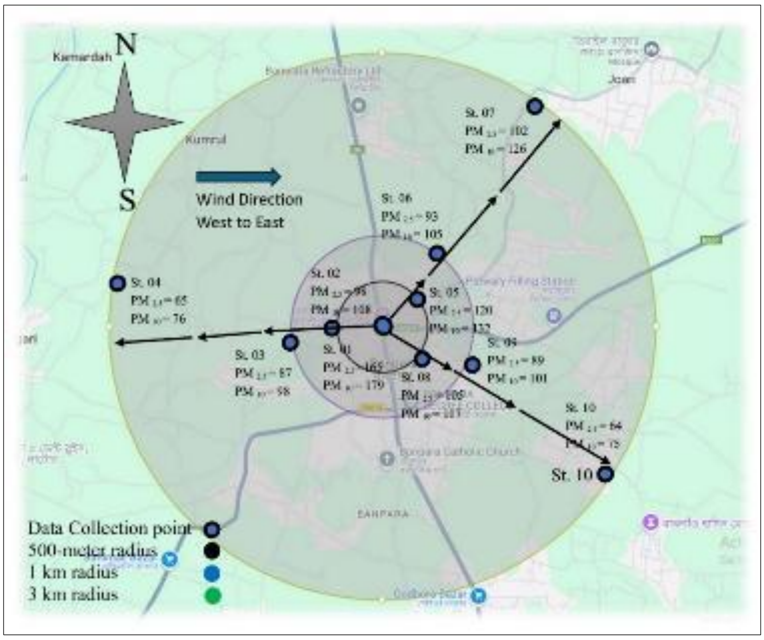

Figure 5 Day 2 (Dry Season)

Figure 6 illustrates that on Day 03 of the dry season, the wind direction shifted from northwest to southeast. The average $PM_{2.5}$ and PM_{10} concentrations in the center and upwind direction were 82 µg/m^3 and 95 µg/m^3, respectively, while in the downwind direction, they measured 91 µg/m^3 and 102 µg/m^3. The recorded average humidity for the day was 53%.

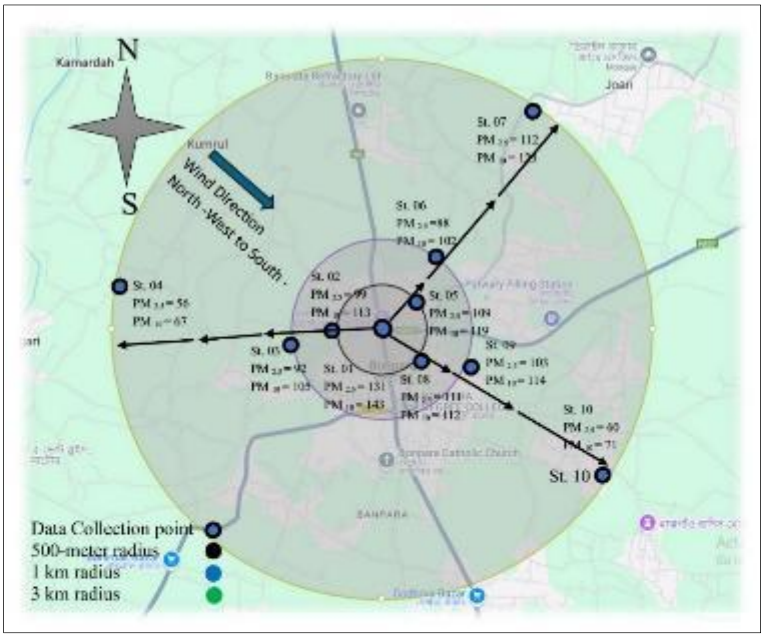

Figure 6 Day 3 (Dry Season)

Figure 7 illustrates that on day 04 of the dry season, the wind blew from the South-West towards the North-East. The mean concentrations of $PM_{2.5}$ and PM_{10} measured from the center to the upwind direction were 88 µg/m^3 and 101 µg/m^3, respectively. In contrast, the average $PM_{2.5}$ and PM_{10} levels in the downwind direction were higher, at 122 µg/m^3 and 133 µg/m^3. The day's average humidity was recorded at 46%.

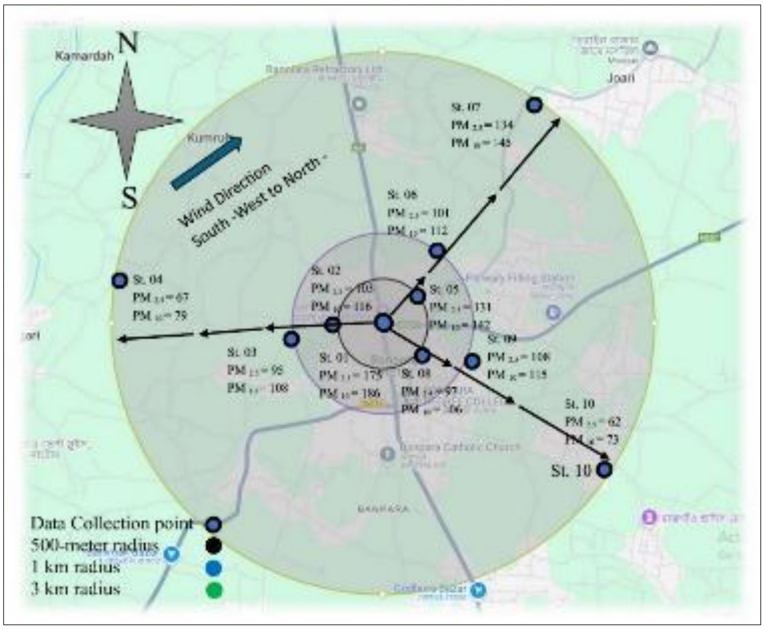

Figure 7 day 4 (Dry Season)

Figure 8 demonstrates that on day 05 of the dry season, the wind originated from the North-West and moved towards the South-East. The average $PM_{2.5}$ and PM_{10} concentrations from the center to the upwind direction were 66 µg/m^3 and

74 µg/m^3, respectively. In the downwind direction, the average concentrations increased, reaching 86 µg/m^3 for $PM_{2.5}$ and 98 µg/m^3 for PM_{10}. The overall humidity for the day was recorded at 51%.

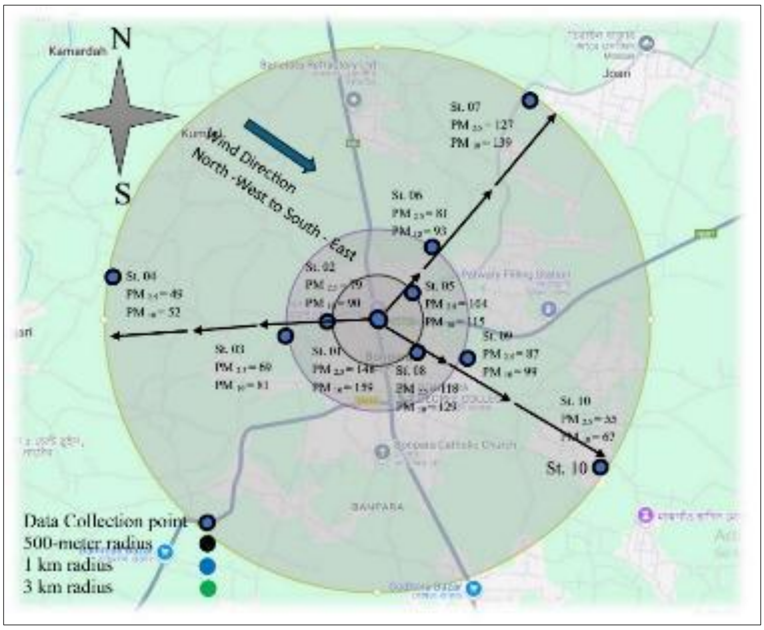

Figure 8 Day 5 (Dry Season)

Figure 9 depicts that on day 06 of the dry season, the wind was blowing from the West to the East. The average concentrations of $PM_{2.5}$ and PM_{10} measured from the center to the upwind direction were 76 µg/m^3 and 88 µg/m^3, respectively. In the downwind direction, the average levels increased, with $PM_{2.5}$ at 96 µg/m^3 and PM_{10} at 107 µg/m^3. The day's overall humidity was noted to be 45%.

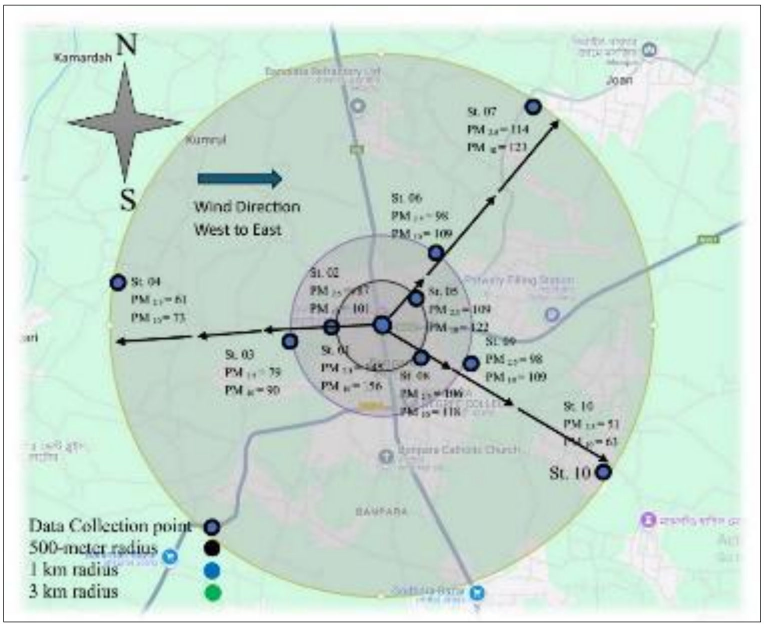

Figure 9 Day 6 (Dry Season)

Figure 10 illustrates that on day 07 of the dry season, the wind direction was from West to East. The average concentrations of $PM_{2.5}$ and PM_{10} in the upwind direction from the center were 78 µg/m^3 and 89 µg/m^3, respectively. In the downwind direction, the average $PM_{2.5}$ and PM_{10} levels rose to 94 µg/m^3 and 106 µg/m^3. The overall humidity for the day was recorded at 54%.

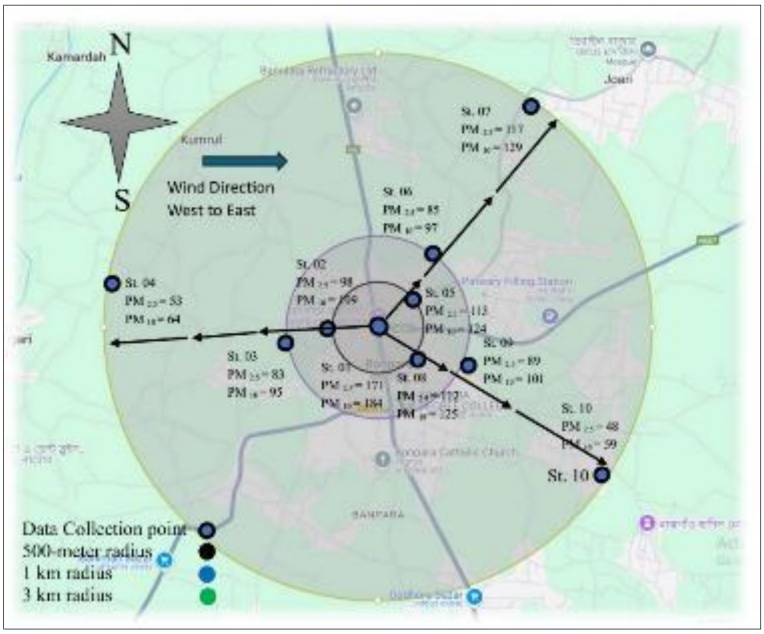

Figure 10 Day 7 (Dry Season)

Figure 11 shows that on day 01 of the Wet season, the wind was blowing from the South-West to the North-East. The average concentrations of $PM_{2.5}$ and PM_{10} measured from the center to the upwind direction were 30 µg/m^3 and 37 µg/m^3, respectively. In the downwind direction, the average concentrations increased to 36 µg/m^3 for $PM_{2.5}$ and 43 µg/m^3 for PM_{10}. A noticeable increase in particulate matter levels was observed along the wind's path. The recorded average humidity was 81%, and it was a rainy day during the sampling period.

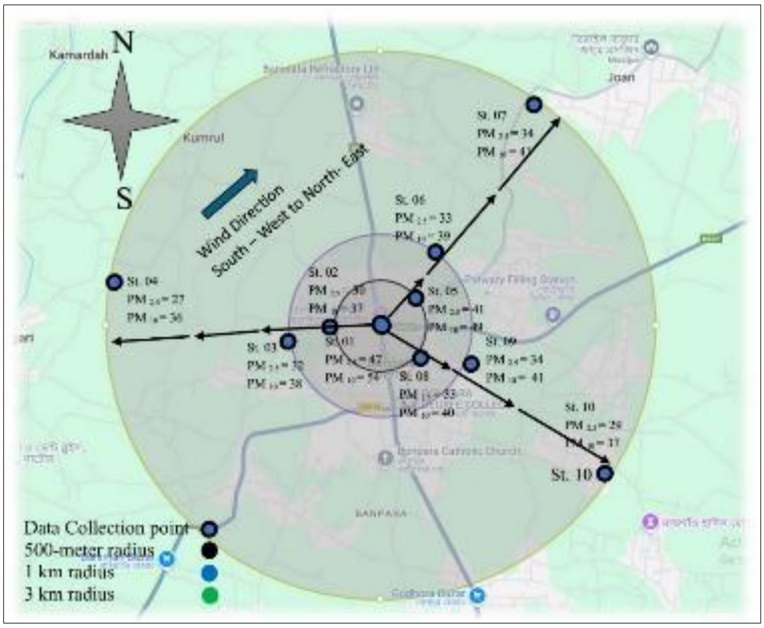

Figure 11 Day 1 (Wet Season)

Figure 12 illustrates that on day 02 of the Wet season, the wind direction was from the North-West to the South-East. The average concentrations of $PM_{2.5}$ and PM_{10} measured from the center to the upwind direction were 32 µg/m^3 and 39 µg/m^3, respectively. In the downwind direction, the concentrations increased to 43 µg/m^3 for $PM_{2.5}$ and 51 µg/m^3 for PM_{10}. The average humidity recorded for the day was 87%, and it was another rainy day during the sampling.

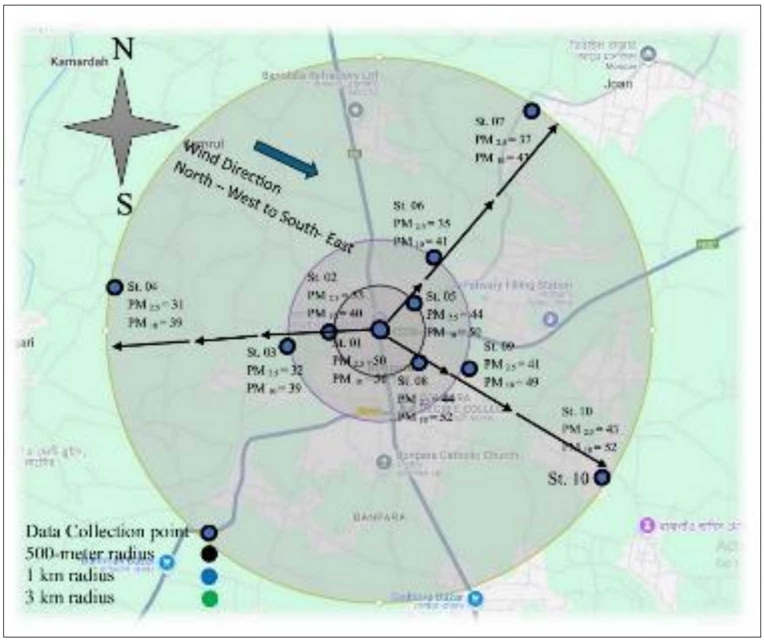

Figure 12 Day 2 (Wet Season)

Figure 13 demonstrates that on day 03 of the Wet season, the wind was blowing from the South-West to the North-East. The average concentrations of $PM_{2.5}$ and PM_{10} measured from the center to the upwind direction were 38 μg/m^3 and 43 μg/m^3, respectively. In the downwind direction, the concentrations slightly increased to 42 μg/m^3 for $PM_{2.5}$ and 49 μg/m^3 for PM_{10}. The recorded average humidity for the day was 79%.

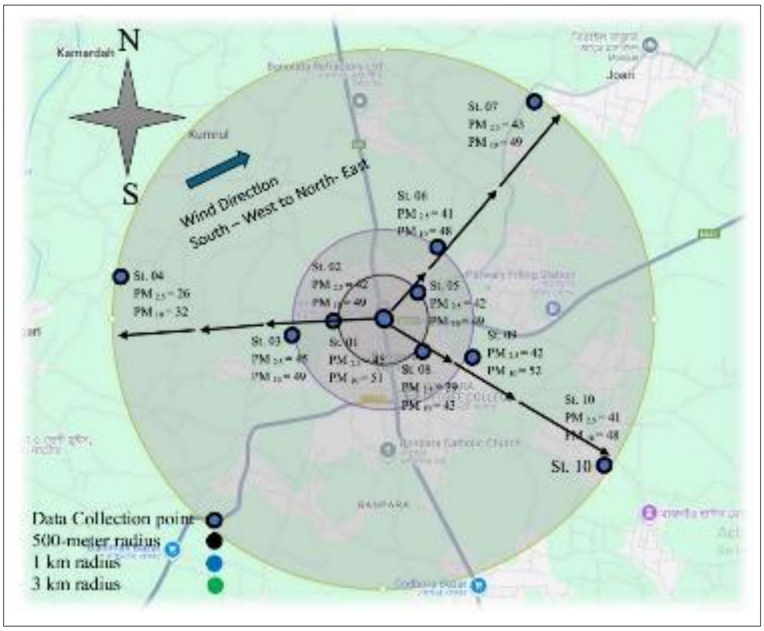

Figure 13 Day 3 (Wet Season)

Figure 14 illustrates that on day 04 of the Wet season, the wind was blowing from the North-West to the South-East. The average concentrations of $PM_{2.5}$ and PM_{10} measured from the center to the upwind direction were 35 μg/m^3 and 41 μg/m^3, respectively. In the downwind direction, the average concentrations for $PM_{2.5}$ and PM_{10} were 35 μg/m^3 and 42 μg/m^3. While the average $PM_{2.5}$ levels remained the same in both the upwind and downwind directions, the average PM_{10} levels were higher in the direction of the wind. The recorded average humidity for the day was 81%.

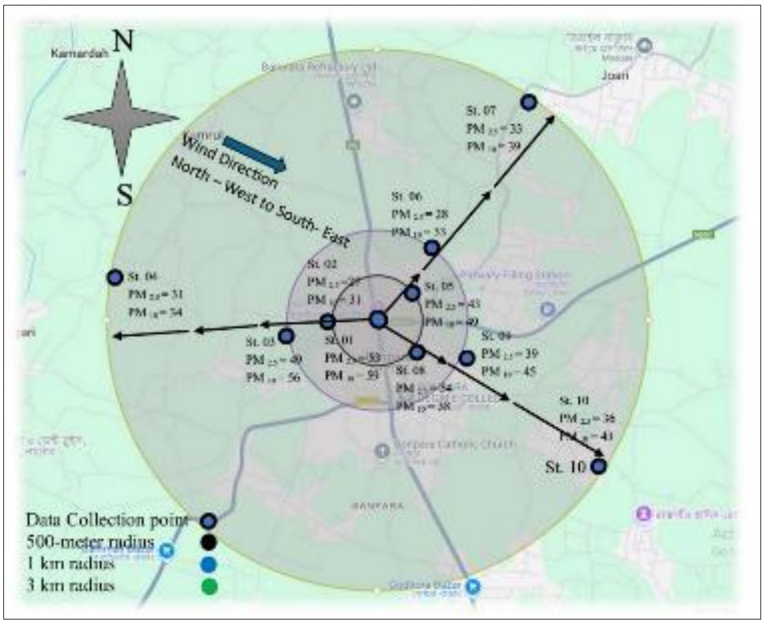

Figure 14 Day 4 (Wet Season)

Figure 15 shows that on day 05 of the Wet season, the wind was blowing from the South-West to the North-East. The average concentrations of $PM_{2.5}$ and PM_{10} measured from the center to the upwind direction were 33 µg/m^3 and 39 µg/m^3, respectively. In the downwind direction, the concentrations increased slightly, with $PM_{2.5}$ at 35 µg/m^3 and PM_{10} at 43 µg/m^3. The recorded average humidity for the day was 88%, and it was another rainy day during the sampling period.

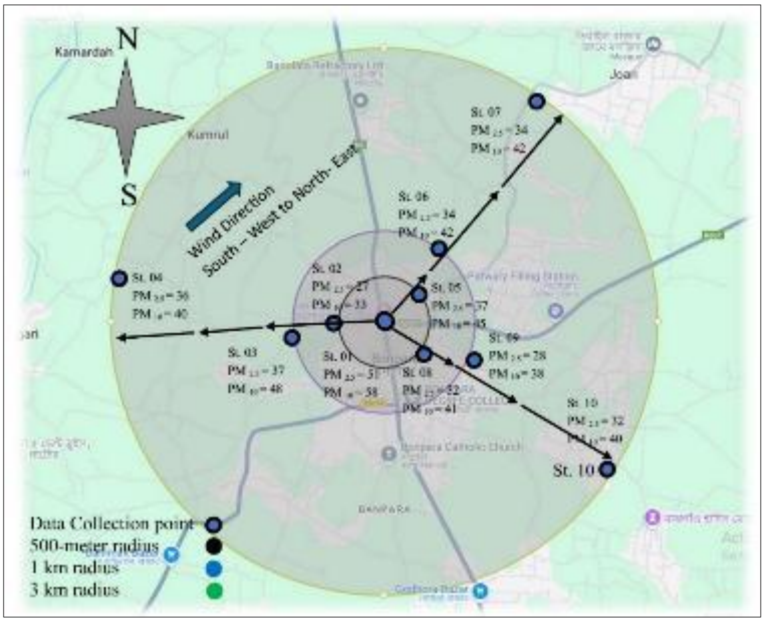

Figure 15 Day 5 (Wet Season)

Figure 16 depicts that on day 06 of the Wet season, the wind was blowing from the South-West to the North-East. The average concentrations of $PM_{2.5}$ and PM_{10} measured from the center to the upwind direction were 32 µg/m^3 and 40 µg/m^3, respectively. In the downwind direction, the concentrations increased to 37 µg/m^3 for $PM_{2.5}$ and 44 µg/m^3 for PM_{10}. The recorded average humidity for the day was 78%.

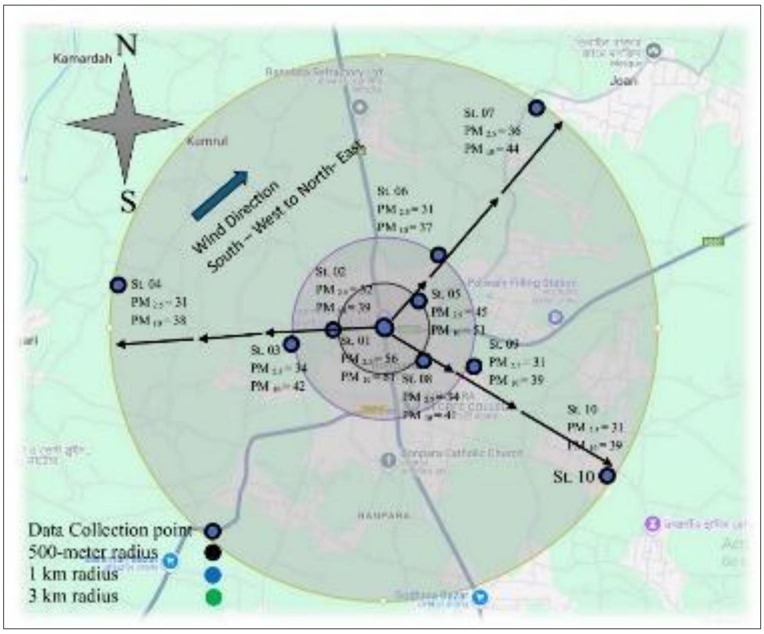

Figure 16 Day 6 (Wet Season)

Figure 17 shows that on day 07 of the Wet season, the wind was blowing from the South-West to the North-East. The average concentrations of $PM_{2.5}$ and PM_{10} measured from the center to the upwind direction were 32 µg/m^3 and 39 µg/m^3, respectively. In the downwind direction, the concentrations increased to 36 µg/m^3 for $PM_{2.5}$ and 43 µg/m^3 for PM_{10}. Particulate matter levels were higher in the direction of the wind. The recorded average humidity for the day was 88%, and it was yet another rainy day during the sampling period.

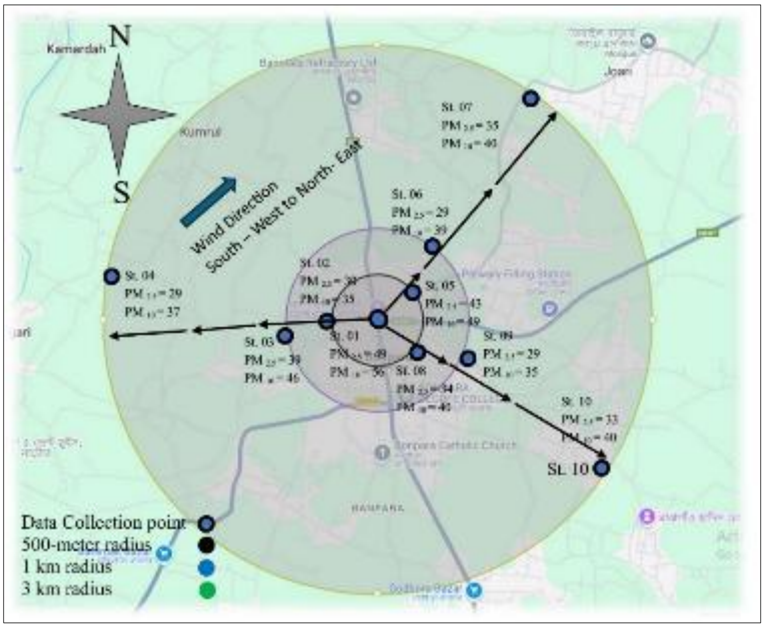

Figure 17 Day 7 (Wet Season)

Construction of a building took place during the dry season at stations 07 and 08. These construction sites exhibited significantly higher levels of $PM_{2.5}$ and PM_{10} compared to other locations, except station 01. The $PM_{2.5}$ levels exceeded the standard value of 65 µg/m^3, as specified by the Bangladesh Air Pollution Control Rules 2022. Construction activities are varied in their sources of air pollution, often releasing particulate matter, gases, and other pollutants into the atmosphere. Some of the common ways in which construction work contributes to air pollution [2]. Activities like excavation, demolition, and material handling generate significant dust emissions, which are major contributors to both coarse particulate matter (PM_{10}) and fine particulate matter ($PM_{2.5}$) [13]. In India, the primary sources of ambient particulate matter pollution include biomass burning for household and commercial use, industrial emissions, and construction activities [14].

The research revealed that the particulate matter levels were higher at the center of the Bonpara Bypass during both the dry and wet seasons. Data collected indicated that the average $PM_{2.5}$ and PM_{10} concentrations at the center of the Bonpara Bypass were 156 μg/m^3 and 169 μg/m^3, respectively, during the dry season. In contrast, at all other stations, the average $PM_{2.5}$ and PM_{10} values were approximately 95 μg/m^3 and 104 μg/m^3. During the wet season, the average $PM_{2.5}$ and PM_{10} values at the center of the Bonpara Bypass decreased to 50 μg/m^3 and 56 μg/m^3, respectively. Outside of the Bypass, the average concentrations of $PM_{2.5}$ and PM_{10} across all stations were around 35 μg/m^3 and 42 μg/m^3. The Bonpara Bypass experienced heavy traffic activity, while other locations had little to no traffic activity. Traffic activities are the cause of the elevated level of Particulate matter [15]. The road transportation system has direct relationship to air pollution such as Vehicle speed, mileage, age of vehicles and the average speed during peak hours [16].

The study found that $PM_{2.5}$ and PM_{10} concentrations in Bonpara were much higher in areas downwind of the Bonpara Bypass, highlighting the significant influence of wind direction on the dispersion of particulate matter. When the wind originated from the bypass, elevated levels of both $PM_{2.5}$ and PM_{10} were detected in its path. Particulate matter concentration can either increase or decrease based on the direction and speed of the wind. Higher wind speeds create stronger turbulence, which enhances the dispersion of pollutants, allowing them to spread more effectively [7]. Wind direction, in addition to wind speed, plays a crucial role in determining PM concentrations, as it affects the spatial distribution of pollution sources and the movement of air pollutants [17].

The study observed that during the dry season, when humidity levels are lower, $PM_{2.5}$ and PM_{10} concentrations tend to be higher. However, in the wet season, when rainfall is frequent and humidity is higher, the levels of $PM_{2.5}$ and PM_{10} are generally lower [15]. Precipitation has been identified as one of the main natural mechanisms in the majority of places for lowering PM levels [18].

In recent years, several studies have highlighted the link between fine particulate matter and various health issues, emphasizing the harmful effects of its toxic components. Health issues, including respiratory symptoms and reduced lung function, can result from exposure to fine particulate matter [19, 20, 21, 22, 23]. Amidst the environmental challenges in Bangladesh and the swift, unplanned urbanization, many studies have been carried out on air pollution. One notable study examined air pollution levels in Dhaka during the winter of 1995-1996 [24]. From 1996 to 2003, air quality evaluations in Chittagong, Bangladesh, indicated moderate pollution levels, marked by elevated concentrations of suspended particulate matter. The results also pointed to the likelihood of more severe pollution in the years to come [25]. In 2022, Bangladesh implemented its most recent legislation addressing air pollution [26]. The regulations governing air pollution in Bangladesh are outlined in the Air Pollution Control Rules, Bangladesh. According to the country's air quality standards (S.R.O. 255-law/2022), the annual average concentration of $PM_{2.5}$ in ambient air must not exceed 35 μg/m^3, while the daily average should remain below 65 μg/m^3. Similarly, for PM_{10}, the annual average should stay under 50 μg/m^3, with the daily average not exceeding 150 μg/m^3.

4. Conclusion

The Bonpara Bypass has been witnessing escalating levels of particulate matter. The study indicated that $PM_{2.5}$ and PM_{10} concentrations at the bypass were significantly higher compared to locations 500 meters, 1 kilometer, and 3 kilometers away in the west, northeast, and southeast directions. This rise in particulate matter near the bypass is primarily attributed to transportation, with vehicle emissions contributing substantially to the elevated PM levels. However, areas located 500 meters, 1 kilometer, and 3 kilometers from the bypass in the mentioned directions showed lower PM concentrations, due to less traffic and the presence of more agricultural land. Particulate matter concentrations are notably higher in the direction of the wind, as dust, pollutants, and other particles are carried by the wind. Consequently, PM levels were higher downwind of the bypass, while areas upwind exhibited lower levels. Wind direction plays a critical role in the dispersion and distribution of particulate matter.

In addition, construction sites near Bonpara also had elevated levels of $PM_{2.5}$ and PM_{10}, surpassing other locations, with activities such as excavation and material handling contributing to increased particulate matter. During the dry season, when humidity levels are lower, PM concentrations tend to rise. Conversely, in the wet season, frequent rainfall and higher humidity help reduce PM levels. To improve air quality in the Bonpara Bypass area, enhanced traffic control, cleaner vehicles, and better traffic management strategies are necessary to curb PM pollution

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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