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Research Paper

Quantifying Particulate Pollution from Road Constructions in Port Harcourt Nigeria: Implications for Urban Air Quality Management.

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ABSTRACTS
In metropolitan areas, particulate matter pollution is a serious health hazard, especially in developing nations. The concentrations of PM brought on by road development at the study locations, are examined. Measurements were taken over several days during periods of high activity using Extech Model VPC300. The time series findings revealed the day and time with the highest PM level with the highest PM_{10} values at 300µg/m³ and $PM_{2.5}$ been 170µg/m³. A common trend between both concentrations is an increase in pollutant levels in the morning, peaking around mid-morning, and then declining. The correlation matrix helps in detecting day with the strongest link between the PM and the local meteorological parameters. Furthermore, the PM demonstrated rising AQI values with increasing concentrations highlighting a concerning trend. The research developed epidemiological models to quantify the association between pollutant exposure and health consequences. The research suggested eco-friendly practices for controlling PM emissions in road construction. By building of green barriers encircle around the construction domain. This strategy demonstrates a dedication to using greener building techniques aligning with more general sustainability objectives and creating a pollution-free environment for communities in and around construction sites.

Keywords: *PM, Road constructions, Frequency distribution, AQI, Eco-friendly*

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I. Introduction

Particulate matter (PM) is the fourth most common cause of death, based on the most recent statistics from the Global Burden of Disease (GBD) research [1]. Due to its detrimental impacts on human health and the issues with air quality, the high levels of air pollution in major cities across the world, particularly in developing nations that are experiencing rapid economic growth, are a major concern [2]. Humans take in about 15 m³ of air each day, some of which is made up of microscopic particles. As demonstrated by numerous scientific investigations (3] [4] [5], there is evidence linking this pollutant to several serious health problems, such as allergies, respiratory irritation, lung inflammation, cardiovascular disease, asthma, pneumonia, bronchitis, allergies, neurological disorders, reproductive troubles, cancer, and mortality. PM is a major contributor to global morbidity and mortality, particularly in urban regions experiencing rapid economic growth [6] [7] [8]. Road constructions in Port Harcourt the business hub of the Niger Delta is investigated in this research as the important sources of PM emissions.

The major center for Nigerian oil refining is Port-Harcourt, which is situated in the Niger-Delta coastal zone. The city, which serves as the hub of Nigeria's oil economy, has recently experienced significant large-scale modernization and urbanization especially vast roads constructions. Although these advancements boost connectedness and economic progress, they also present serious health hazards to the general people. Due to the large number of exposed people and the variety of emission sources with intricate chemical patterns, exposure to PM calls for concern in these metropolitan settings.

The recent dust incident in Port Harcourt and the surrounding areas has raised awareness of air pollution in the media in academic circles. The World Health Organization [9] found that throughout River's state, including Port-Harcourt, where criterion air pollutants were much higher than the WHO specification, air pollution was linked to connected morbidities and deaths due to decades of oil exploration.

Additionally, [10] study to determine the disease prevalence linked to industrial-related air pollution in specific Niger Delta communities showed a strong correlation between air pollutants that include particulate matter and morbidities like traumatic skin growth, child deformities, and respiratory diseases. An essential part of urban growth is building roads. Port Harcourt, the hub of Nigeria's oil economy, faces significant air pollution challenges exacerbated by road construction activities. Recent media and academic attention on dust incidents highlight the urgency of addressing PM pollution in this region. To comprehend their temporal fluctuations, possible health hazards, and relationships with meteorological factors, this study assesses $PM_{2.5}$ and PM_{10} concentrations from road-building activities in Port Harcourt.

II. Materials and Method.

2.1. The Research Areas

The research areas are situated in Rivers State, Nigeria, and it is within the Greenwich Meridian (GM) at latitudes 4°05'29"N and 4°56'15'N and longitudes 6°52'28'E and 7°07'00"E. The boundaries of the Igbo-Etche, Okirika, Obio-Akpor, Eleme, and Oyibo LGAs are all included in the city and surroundings of Port Harcourt City. The region is situated in the sedimentary formation that makes up the coastal zone of the Niger Delta. Due to its proximity to the Atlantic Ocean, the coastal city is subject to the influence of the equatorial monsoon climate on its atmospheric properties. The city's temperature and precipitation patterns are governed by continental and maritime air masses [11].

2.2 Data acquisition phase

The environmental data, which included temperature, relative humidity, wind speed, $PM_{2.5}$, and PM_{10}, was collected using a video particle counter, the Extech Model VPC300 which was calibrated according to manufacturer specifications to ensure data accuracy. Data were collected on Mondays, Wednesdays, and Fridays during the dry season from 8:00–11:00 AM and 11:00 AM–4:00 PM to capture peak activity periods.

2.3 Air Quality Index

The Air Quality Index (AQI) is a daily report that offers vital information about the quality of the air that people can breathe in, including how harmful it is and how serious health issues are [12] [13] [14]. In addition, AQI provides details on the harmful consequences of breathing in polluted air as well as the potential side effects that could appear hours or days later. Based on possible health hazards, the AQI is divided into five categories: good, moderate, poor, extremely poor, and hazardous (Table 1). Additionally, Equation (1) was utilized to compute the air quality index (AQI) based on the mean values.

$$AQI = I_{high} - I_{low} / C_{high} - C_{low} (C_p - C_{low}) + L_{low} \quad (1)$$

C_{low} denotes the lower limit of the pollutant in the Cp domain, C_{high} denotes the higher limit, I_{low} denotes the lower limit of the AQI corresponding to C_{low}, and I_{high} denotes the higher limit of the AQI corresponding to C_{high}. Also, Cp represents the amount of PM ($PM_{2.5}$ and PM_{10}).

Table 1 PM range and matching AQI category

$PM_{2.5}$	PM_{10}	AQI	Ranking
0-15	0-15	0-50	Good
15-26	16-35	51-100	Moderate
26-40	36-40	101- 150	Poor
40-125	51-150	151-200	Very poor
>125.5	>150	>200	Hazardous

2.4. Epidemiological data

Epidemiological data was collected and analyzed to understand the prevalence, distribution, and factors affecting health and illness in the study areas related to PM. This data is essential for researchers, public health practitioners, and policymakers in identifying health hazards, monitoring disease outbreaks, assessing public health interventions, and informing health policies. Mortality and morbidity data were sourced from the Rivers State General Hospitals (Table 2).

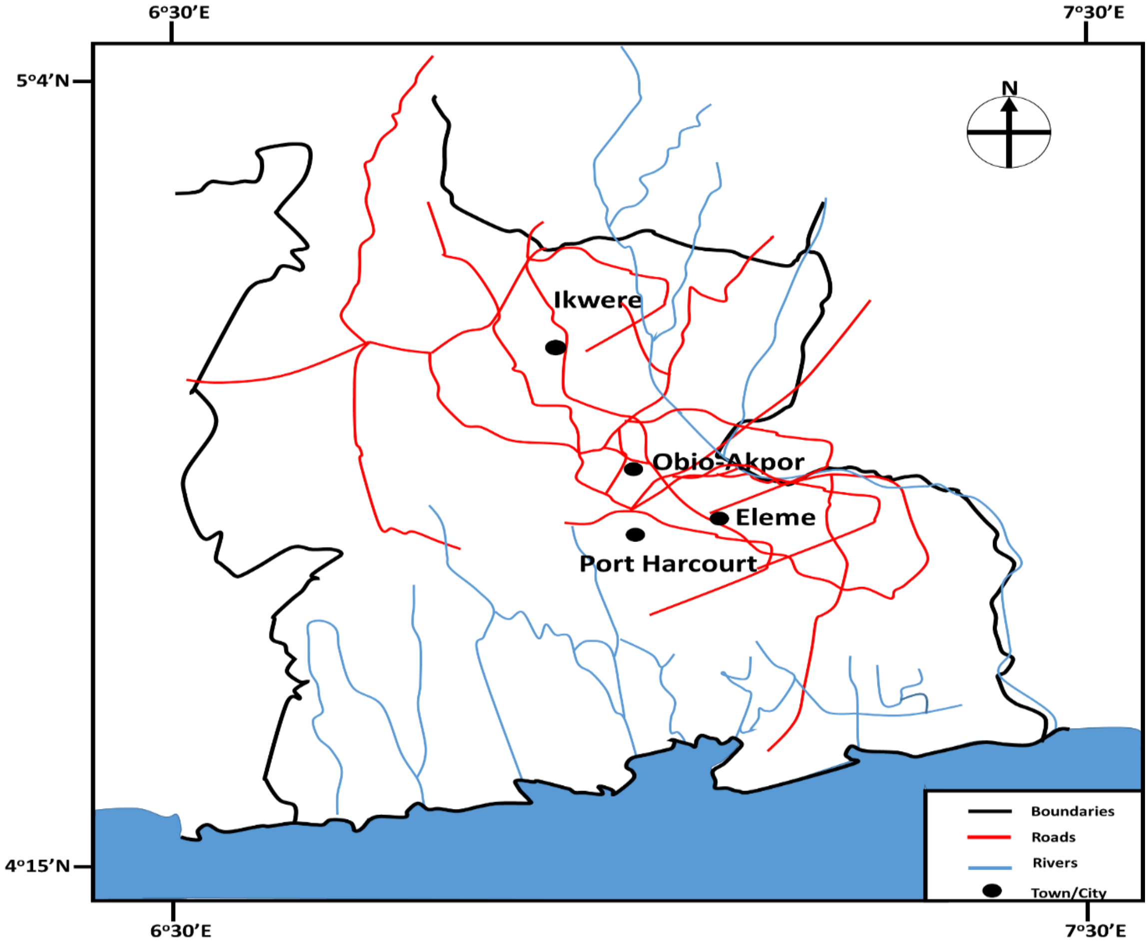


Figure 1: Research areas

Table 2 A compilation of epidemiological data from the study regions

Mortality data	Morbidity data	Exposure data	Demographic/Socioeconomic data	Geographic data
Total no. of death-48	Incidence rate-29 respiratory cases per 100 persons per year	Average $PM_{2.5}$ and PM_{10} concentration- 129µg/m³, 221µg/m³	Population size- 4000	Research locations- Port-Harcourt, Obio Akpor, Ikwere, and Eleme
No. of death attributed to respiratory diseases-14	Prevalence rate-397	Exposure assessment- 365 for infants 365 for children, 4380 adults 18980	Population distribution- 500 infants, 1000 children,2500 adults. 1850 Male, 2150 female	Wind pattern- 0.0426 miles/hour and wind direction is South-East.
Mortality rate for different age group- 2 Infant, 4 children, 8 adults	Hospitalization rate-45		Socioeconomic factor- mostly civil servants and artesian	Land use pattern- residential and industrial.
Gender specific mortality rate. 21 male, 8 female.	Disability adjustment life years (DALYs)- 3.5 million years of healthy life lost due to particulate matter.			

III. Results and Discussion

The plot (Fig. 2) shows the concentration variation across the research locations. The highest $PM_{2.5}$ concentration is 131.6µg/m³ at Ikwere, while the lowest is 127.46µg/m³ between Obio-Akpor and Port-Harcourt. Similarly, PM_{10} maximum concentration is 265µg/m³ at Port-Harcourt (Fig. 3). Generally, analyzing these amounts against the revised WHO 2021 Air Quality Index standards, which are 15 µg/m³ for $PM_{2.5}$ and 45 µg/m³ for PM_{10}, show that these locations are polluted [15]

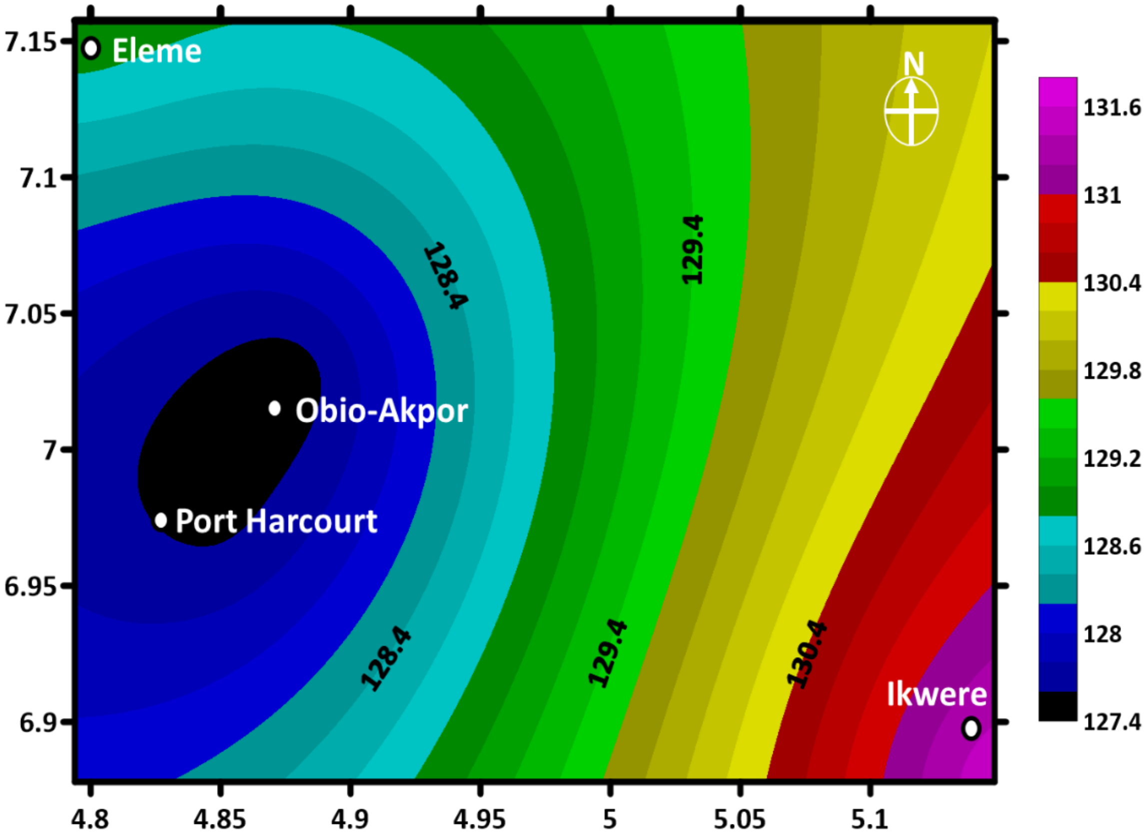


Fig. 2. Contour map for $PM_{2.5}$

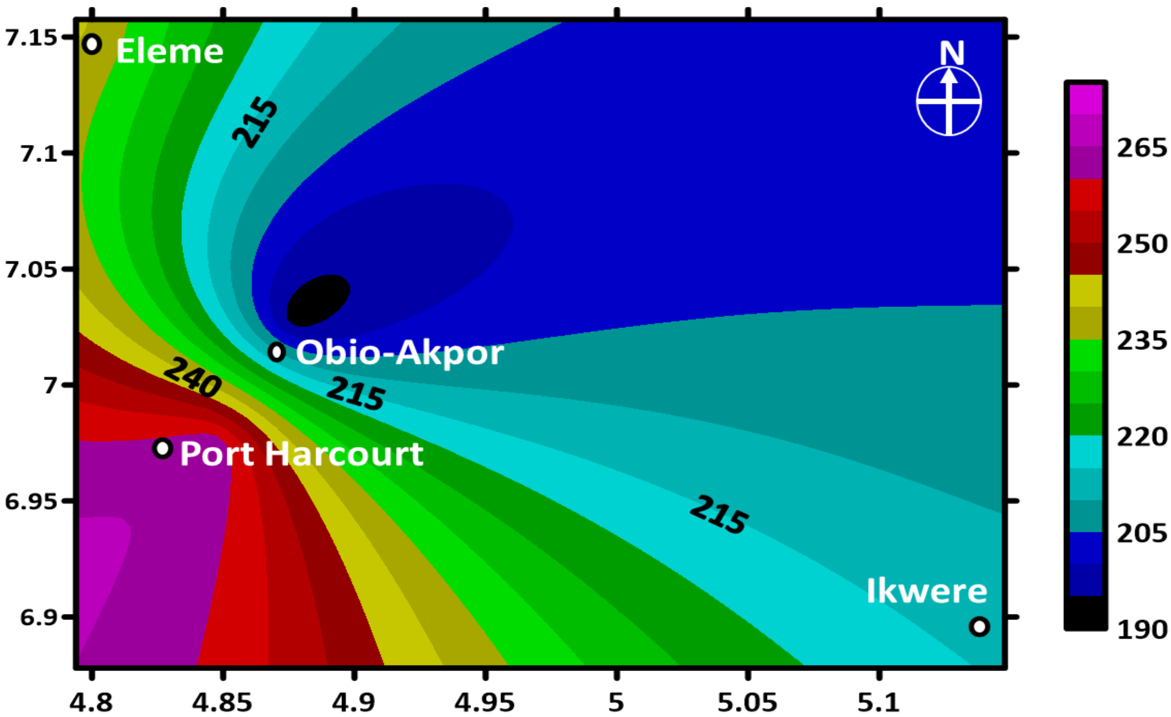
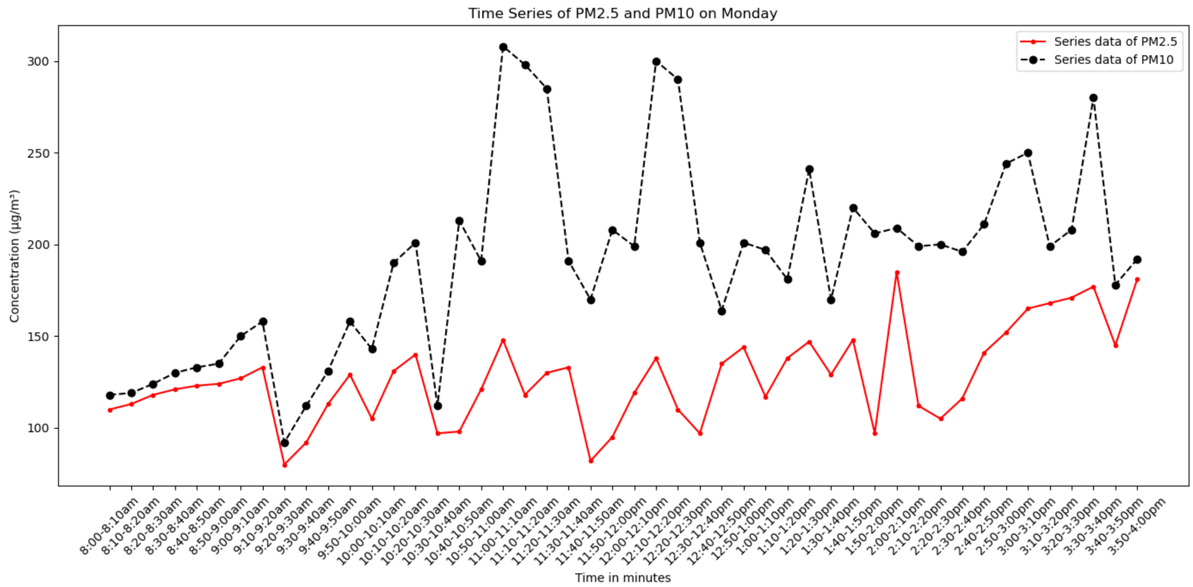
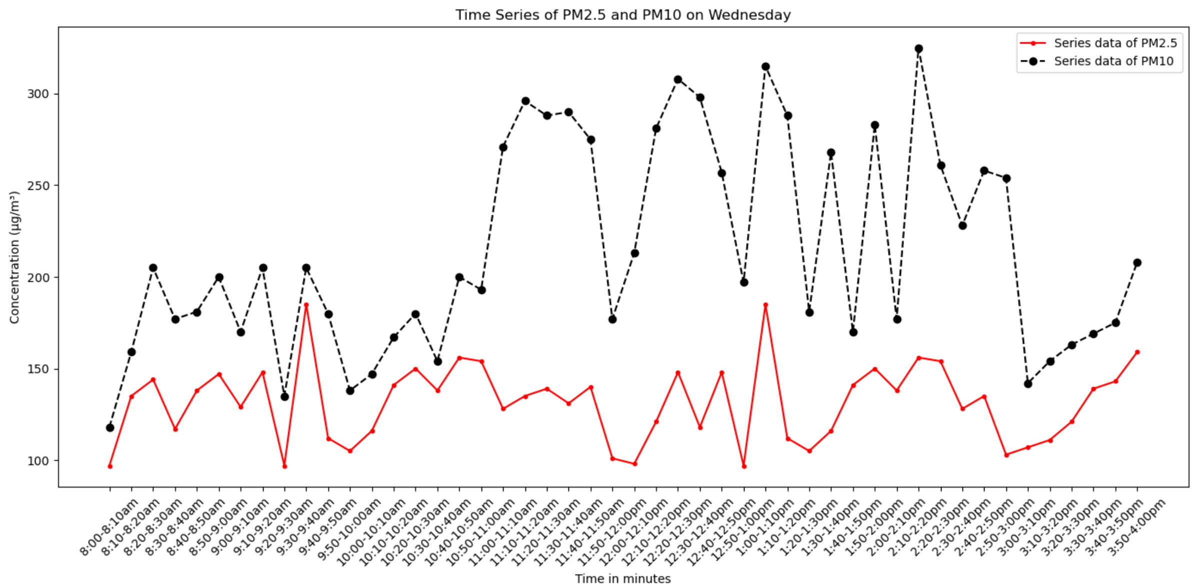


Fig. 3. Contour map for PM_{10}

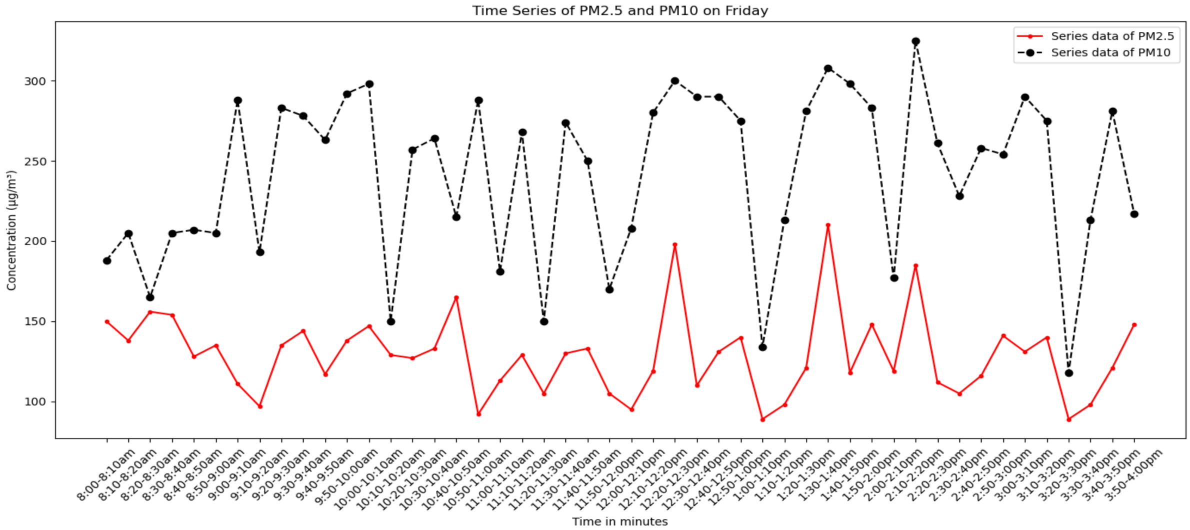
The time series plots provide the concentration of $PM_{2.5}$ and PM_{10} pollutants in minutes on Monday, Wednesday, and Friday (Figs. 4 a, b, c). The Concentration of PM_{10} generally exceeds $PM_{2.5}$ levels with the highest PM_{10} values been 300µg/m³, while that of $PM_{2.5}$ is 170µg/m³, (Fig. 4a). This indicates a higher prevalence of coarser particles in the air compared to the finer particles. The plot also shows that both pollutants exhibit fluctuating patterns throughout the day suggesting that various factors, such as traffic, industrial activity, and weather conditions, influence their concentration. A common trend between both concentrations is an increase in pollutant levels in the morning, peaking around mid-morning, and then declining. This pattern is likely linked to increased human activity during these hours. The graphic displays the Wednesday $PM_{2.5}$ and PM_{10} concentrations throughout time (Fig. 4b). The concentration of $PM_{2.5}$ varies during the day. Higher concentration occurs between 8:30 and 11:00 AM, after which there is a slack and then another slowdown at 1:00 PM. From 8:00 AM to 4:00 PM, the $PM_{2.5}$ concentration appears to have increased overall. On Friday (Fig. 4c), both $PM_{2.5}$ and PM_{10} showed moderate to high levels throughout the day with slight peaks in the morning and afternoon for $PM_{2.5}$.



(a)



(b)



(c)

Figures 4 a, b, c: Time evolution in minutes for $PM_{2.5}$ and PM_{10} concentration for Monday, Wednesday and Friday

Figs. 5a-f illustrates the frequency distribution of $PM_{2.5}$ levels recorded on Monday, Wednesday, and Friday during two-time intervals: 8 am to 11 am and 11 am to 4 pm (Figs. 5a-f). On Mondays, the most common $PM_{2.5}$ levels range from 108 to 122 µg/m³, with mean values of 116 µg/m³ for the first time interval and 127 µg/m³ for the second. In the afternoon, between 11 am and 4 pm, the levels are concentrated between 128 and 152 µg/m³, with a frequency of 139.7 (Figs. 5a-b). This indicates that $PM_{2.5}$ measurements are predominantly found in the higher concentration ranges, which raises concerns about air quality, as these values exceed many international air quality standards for $PM_{2.5}$ [16][17]. For Wednesdays, the highest frequency of $PM_{2.5}$ levels is observed in the range of 132 to 153 µg/m³ at 142.6 during the 8 am to 11 am interval. Similarly, from 11 am to 4 pm, the maximum frequency is again found in the 132 to 153 µg/m³ range at 141.5 (Fig. 5c-d). On Fridays (Figs. 5e-f), the most common $PM_{2.5}$ concentration during the 8 am to 11 am period falls within the range of 124 to 141 µg/m³, with a frequency of 132.9. In the afternoon from 11 am to 4 pm, the highest frequency is found in the 107 to 124 µg/m³ range, at a frequency of 116.6.

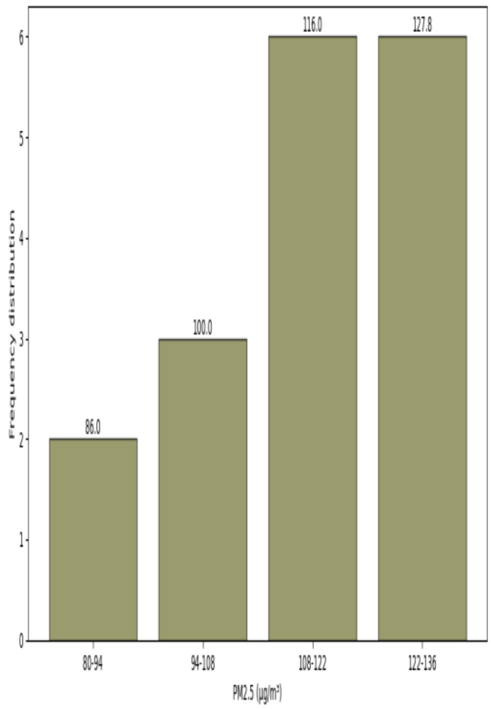
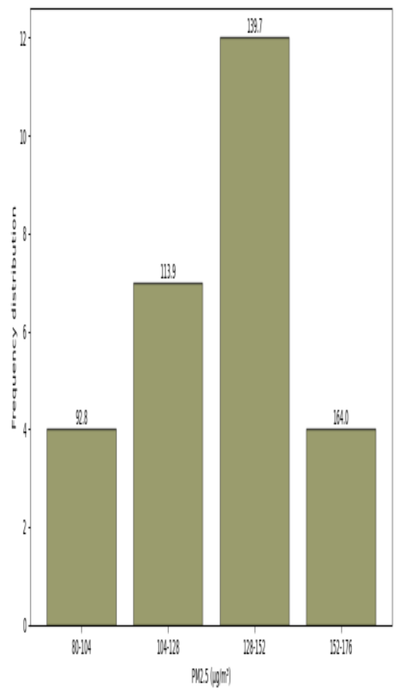


Fig. 5a Monday 8 to 11am



5b Monday 11am to 4pm

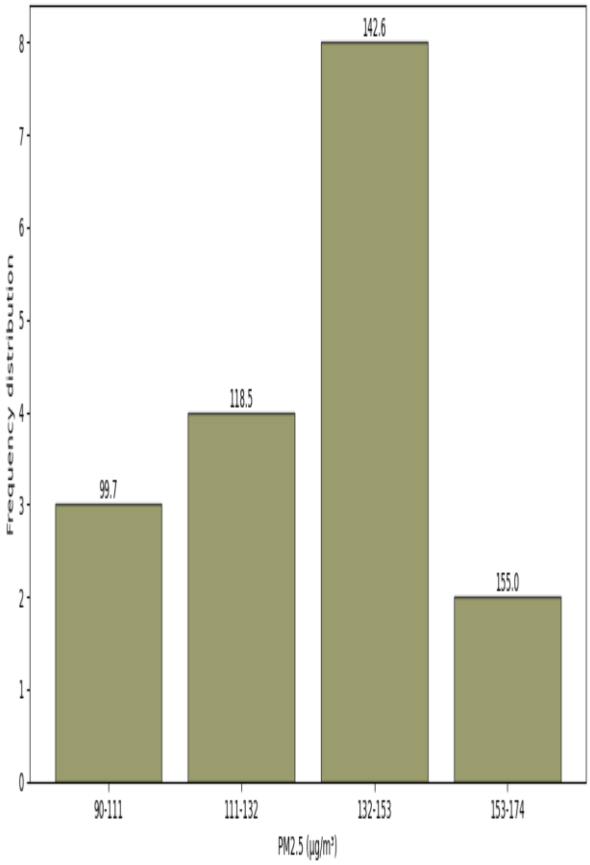
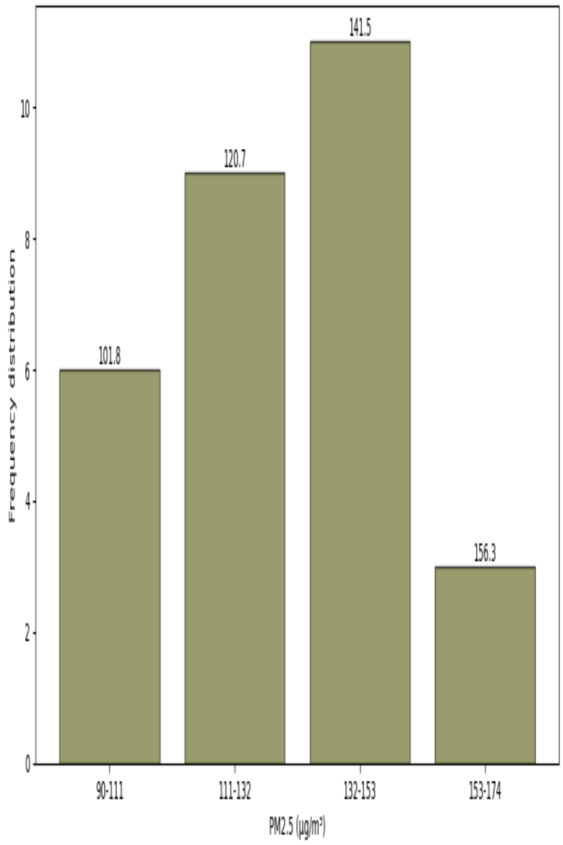


Fig. 5c. Wednesday 8am to 11am



5d. Wednesday 11am to 4pm

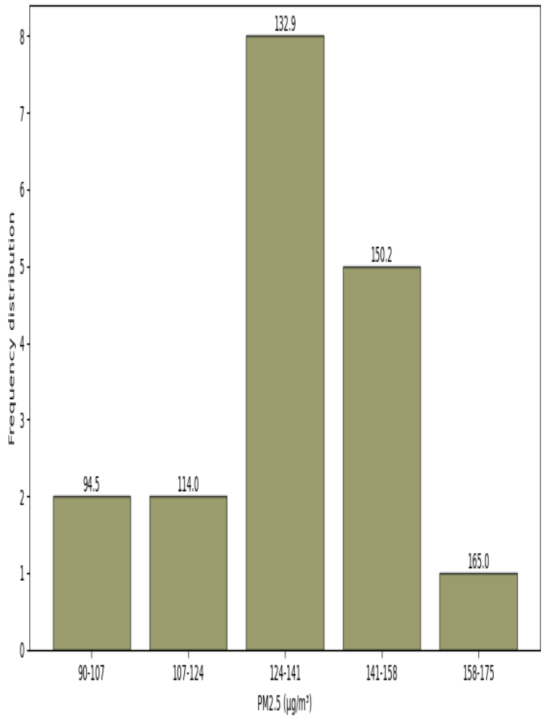
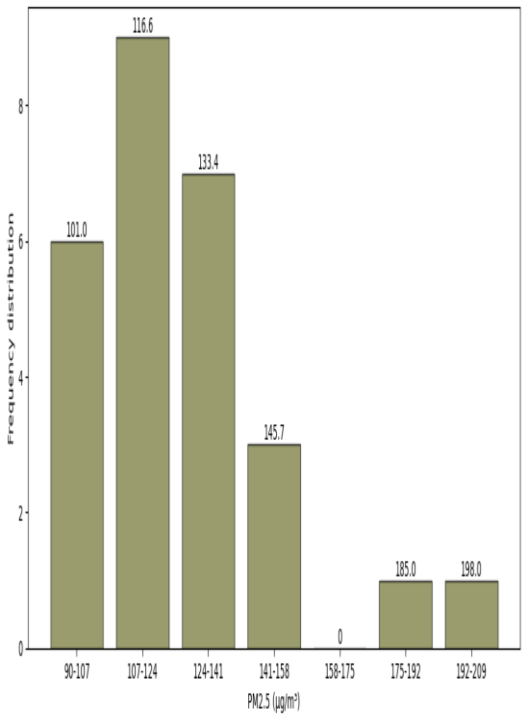


Fig. 5e. Friday (8am to 11am)



5f. Friday (11am to 4pm)

Figures 5: Frequency of distribution of $PM_{2.5}$ for days in weeks: Monday (a) 8am to 11 am (b) 11 am to 4 pm Wednesday (c) 8 to 11 am (d) 11 am to 4 pm Friday (e) 8 to 11 am (f) 11 am to 4 pm

The frequency distribution of PM_{10} concentrations is illustrated in Figs. 6a-f. On Monday, between 8 and 11 a.m., the most common PM_{10} range is 112.4 µg/m³, occurring between 112 and 134 µg/m³. In the afternoon, the highest concentration, ranging from 186 to 212 µg/m³, is observed between 11 a.m. and 4 p.m. (Figs. 6a-b). For Wednesday (Figs. 6c-d), the highest pollutant concentration in the morning falls between 172 and 203 µg/m³, with a frequency of 187.3. The maximum concentration at noon is recorded between 272 and 305 µg/m³. On Friday morning, the most frequent PM10 readings range from 204 to 231 µg/m³, averaging 207.4 µg/m³. Similarly, in the afternoon, from 11 a.m. to 4 p.m., the maximum value ranges from 275 to 308 µg/m³, with an average of 285.7 µg/m³ (Figs. 6e-f). Again, the PM_{10} values are above the WHO recommendation threshold45 µg/m³ [18].

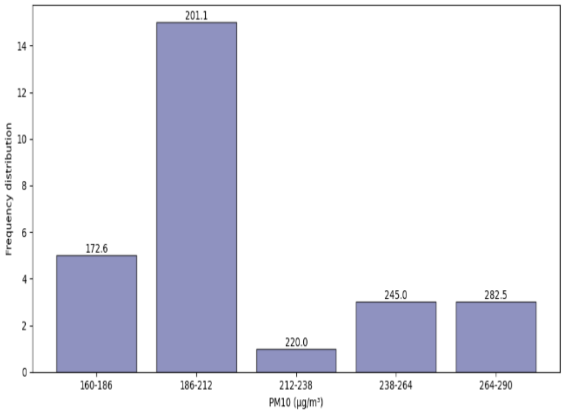
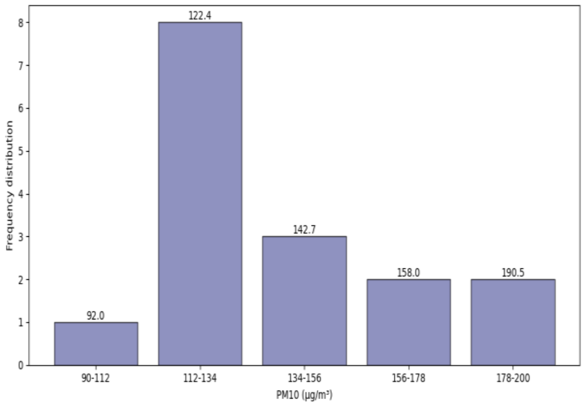
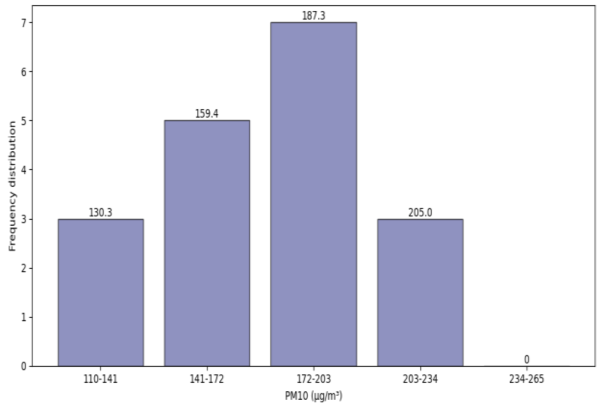


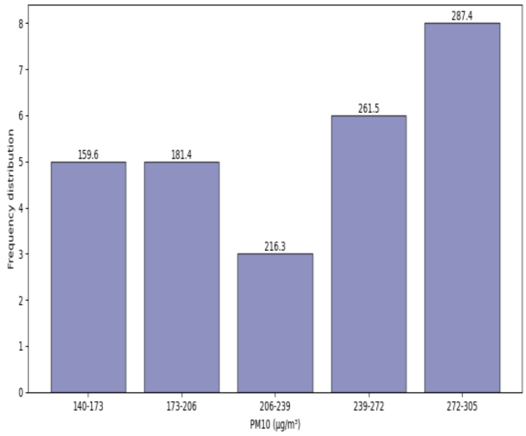
Fig 6a Monday 8am to 11am



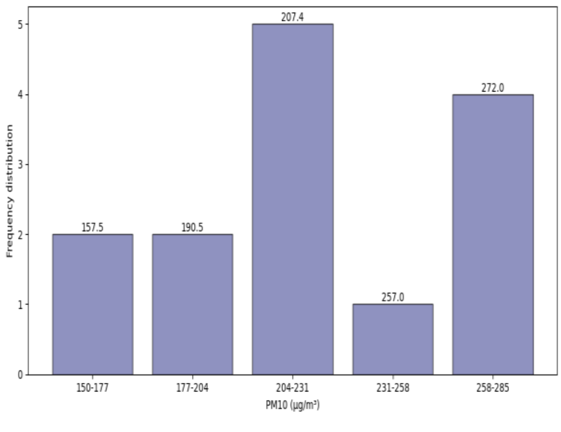
6b Monday 11am to 4pm



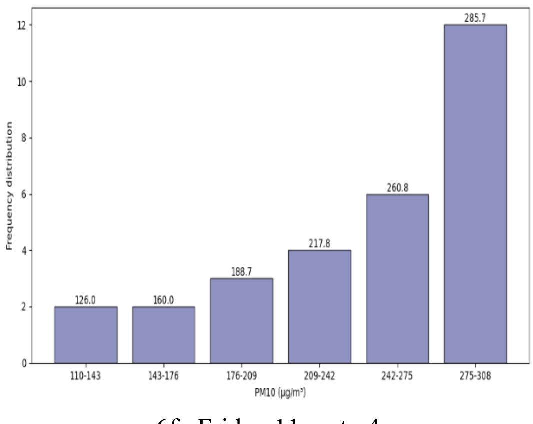
6c. Wednesday 8am to 11am



6d. Wednesday 11am to 4pm



6e Friday 8am to 11am



6f. Friday 11am to 4pm

Figure 6: Frequency of distribution of PM_{10} for days in weeks: Monday (a) 8 to 11 am (b)11 am to 4 pm Wednesday (c) 8 to 11 am, (d)11 am to 4 pm. Friday ((e): 8 to 11 am, (f): 11 am to 4 pm

Figs. 7a-b illustrates the air quality index (AQI) over three days—Monday, Wednesday, and Friday—for $PM_{2.5}$ and PM_{10}. Using in situ information on PM concentrations, the calculation for the AQI at the study locations is based on equation (1). For the three days, the AQI results are above the safety level (Table 2). Furthermore, both types of particles demonstrate rising AQI values with increasing concentrations highlighting a concerning trend, particularly for larger particles [19] [20] [21].

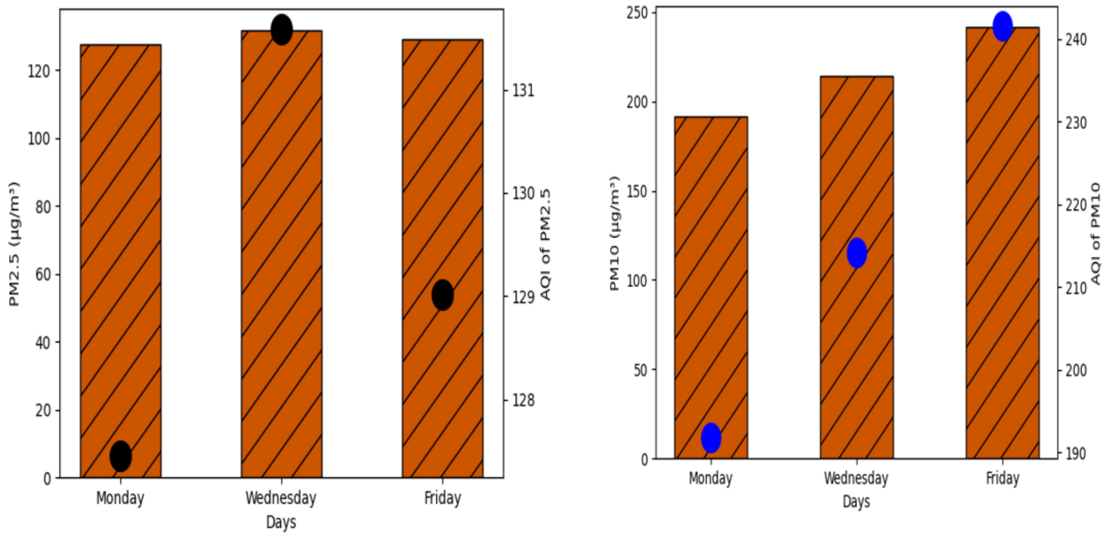
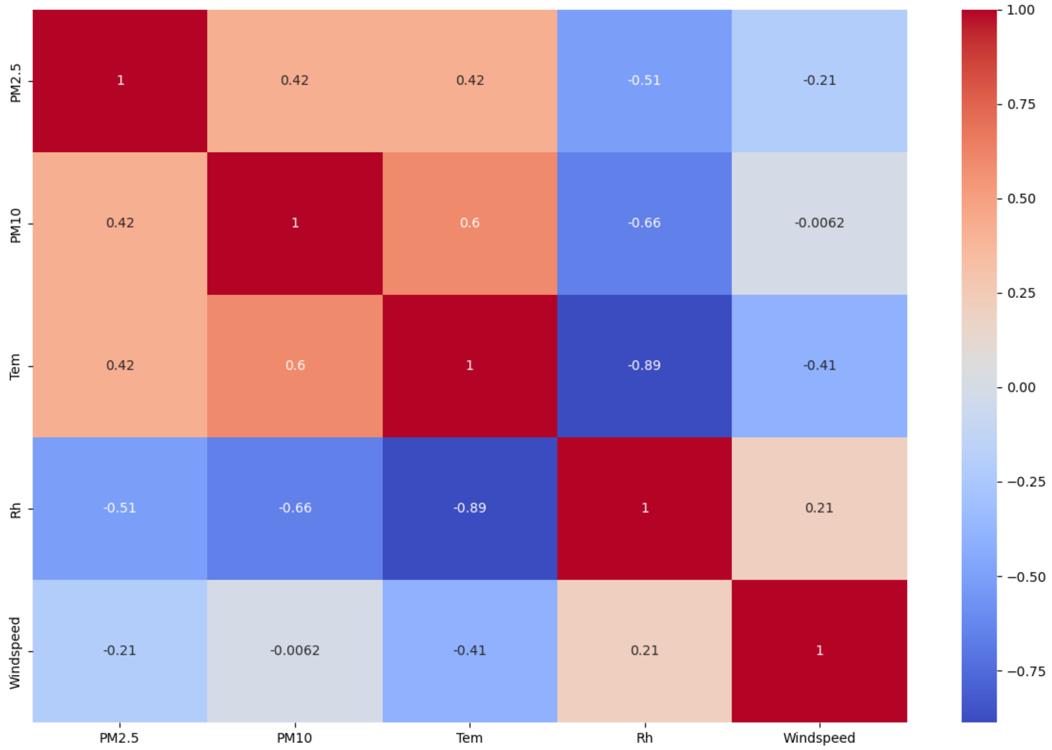


Fig.7 Daily average concentration and AQI for the study locations (a) $PM_{2.5}$ (b) PM_{10}

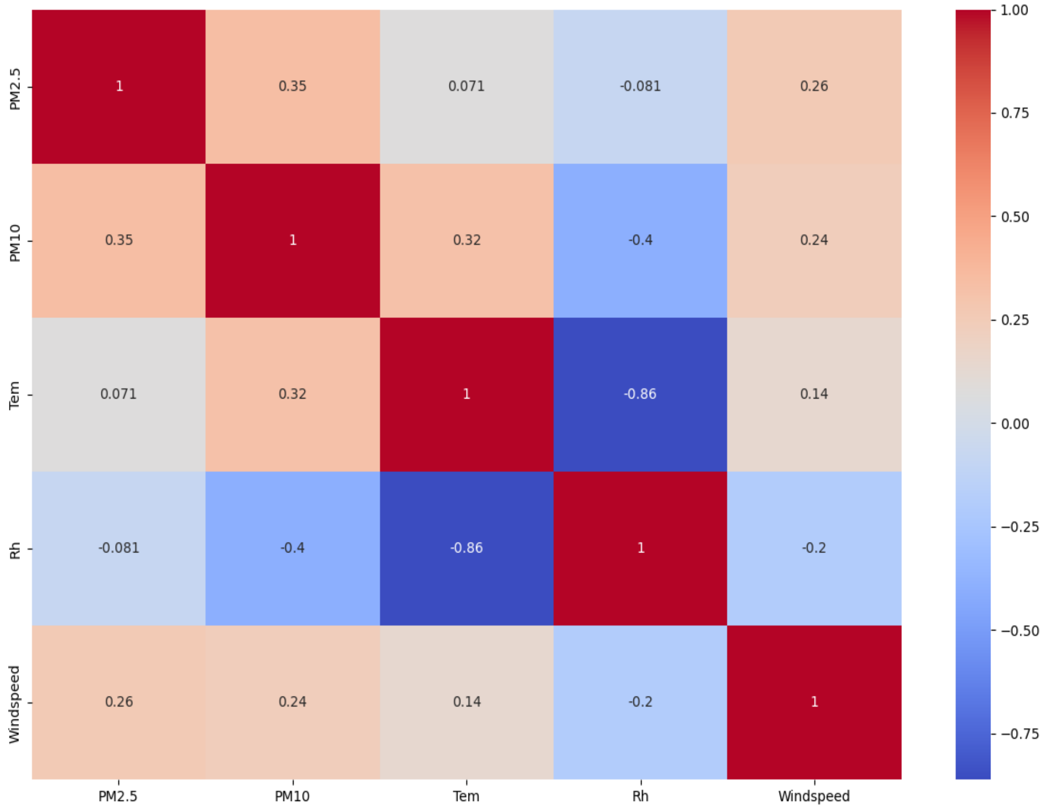
Table 2 Air Quality Index (AQI) for the study locations.

Day	PM size	AQI	Category
Monday	$PM_{2.5}$	103	Poor
	PM_{10}	192	Very poor
Wed.	$PM_{2.5}$	139	Poor
	PM_{10}	215	Hazardous
Friday	$PM_{2.5}$	129	Poor
	PM_{10}	240	Hazardous

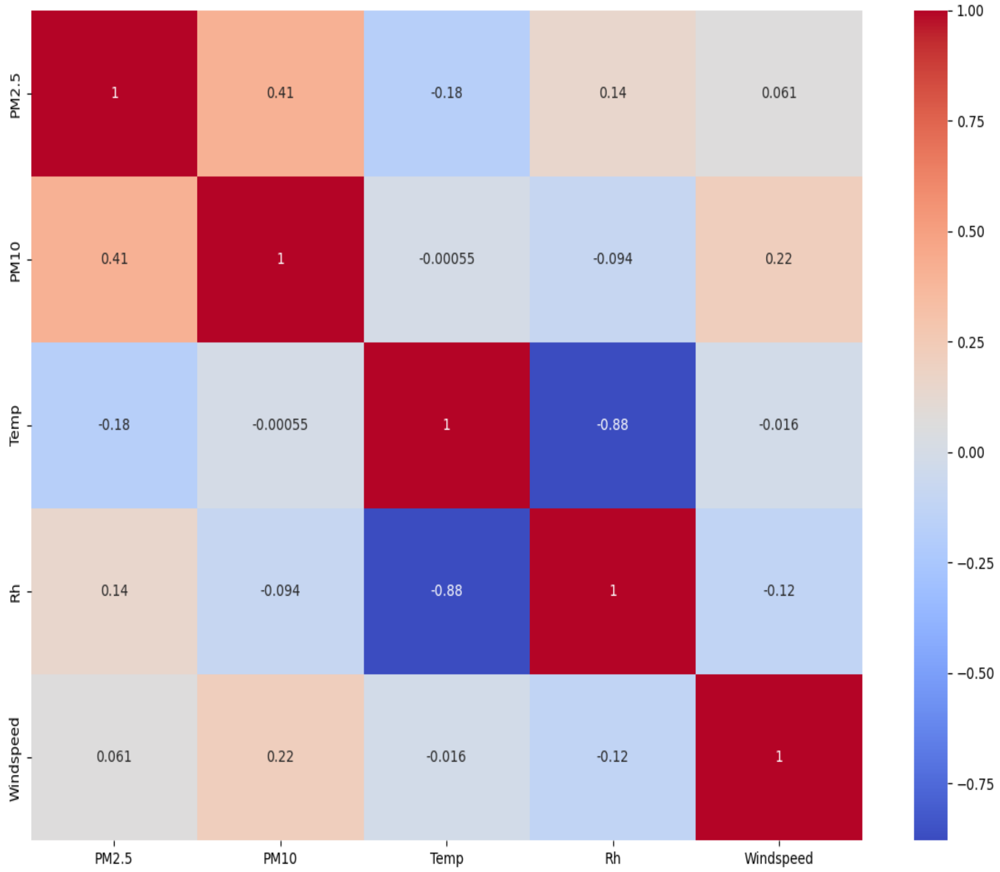
Various environmental variables measured on Monday, Wednesday, and Friday are shown in correlation matrices (Figs. 8a-c). The correlation between $PM_{2.5}$ and PM_{10} for the three days is as follows: Monday at 0.42, Wednesday at 0.35, and Friday at 0.41, with Wednesday showing a noticeably weaker correlation. On Monday, the relationship between PM_{10} and temperature indicates a positive correlation, with both values at 0.42. In contrast, on Monday, the correlation between relative humidity and wind speed was negative (Fig. 6a). On Wednesday, a weak positive correlation was observed between PM_{10} and both temperature (0.32) and wind speed (0.26), while the temperature showed only a marginal correlation of 0.071 (Fig. 6b). Lastly, on Friday, a positive correlation was noted between PM_{10}, relative humidity, and wind speed, with values of 0.41, 0.14, and 0.061, respectively (Fig. 6c). These variations in the plots may stem from the differences in study locations, timeframes, and environmental conditions. The differing relationships among the variables across the plots underscore the complexity of environmental interactions and highlight the importance of context-specific analyses in environmental studies.



(a) Monday



(b) Wednesday



(c) Friday

Figures 8: Correlation Plot for days in week (a) Monday (b) Wednesday (c) Friday

In the summary statistics for Monday (Table 3a), the mean represents the average value of each variable, with $PM_{2.5}$ having an average concentration of 127.46 and PM_{10} having a higher average concentration of 191.79. The mean temperature is 32.06°C, indicating a warm climate, while relative humidity is around 60.28%. Wind speed is the most consistent across measurements. The standard deviation measures the variability or dispersion of values around the mean, with PM10 showing more variability. Skewness reflects the symmetry of the data distribution, with $PM_{2.5}$ and PM_{10} having slight positive skewness, while temperature and Rh have negative skewness. Kurtosis measures the "tailedness" or the presence of outliers in the data, with all variables having negative kurtosis, indicating a somewhat flat distribution. The standard error provides an estimate of how far the sample mean is likely to be from the true population mean, with PM_{10} having the largest standard error of 7.65, indicating higher uncertainty in the estimation of its mean.

The average values of several variables are displayed in Tuesday's summary statistics (Table 3b). The mean values are slightly higher than in Table 3b, with PM_{10} showing a larger increase. The mean temperature was 32.49°C, reflecting a warm environment. The mean relative humidity was 60.91%, while the average wind speed was 1.32. The standard deviation represents the spread of values around the mean, with PM_{10} having higher variability than $PM_{2.5}$. The skewness describes the asymmetry of the data distribution, with $PM_{2.5}$ having a slightly positive skewness, PM_{10} showing a mild positive skewness, temperature having a negative skewness, Rh having some higher humidity values, and wind speed having a more noticeable positive skewness. All variables have negative kurtosis, indicating distributions with fewer outliers and flatter tails compared to a normal distribution. The standard error reflects the precision of the mean estimates, with PM_{10} having the largest standard error and $PM_{2.5}$ having more precision. Wind speed has the smallest standard error, suggesting the mean wind speed estimate is highly reliable.

The PM_{10} values in the Friday summary statistics show a greater average concentration than the two-days prior (Table 3c). The standard deviation demonstrates the variability of values around the mean, with PM10 also exhibiting a higher standard deviation than the other parameters. Skewness reveals the asymmetry in the data distribution: PM2.5 has a higher positive skewness, PM10 shows a negative skewness and relative humidity (Rh) has a mild positive skewness. Wind speed has a strong positive skewness, suggesting there are noticeably higher wind speed values relative to the mean. Regarding kurtosis, $PM_{2.5}$ shows a positive value, PM_{10} has a negative value, and Rh displays a small positive value. The standard error provides an estimate of the precision of the mean, with PM_{10} reflecting a higher standard error than the other variables.

Table 3 Summary statistics

	$PM_{2.5}$	PM_{10}	Temp.	Rh	Windspeed
Mean	127.45	191.79	32.05	60.27	1.36
Standard Deviation	24.94	53.02	3.03	13.17	0.16
Skewness	0.38	0.38	-0.58	0.43	0.02
Kurtosis	-0.26	-0.30	-1.08	-0.87	-1.52
Standard Error	3.59	7.65	0.43	1.90	0.02

(a)

	$PM_{2.5}$	PM_{10}	Temp	Rh	Windspeed
Mean	131.58	214.25	32.48792	60.9075	1.319791667
Standard Deviation	21.40	56.30035	2.924932	13.04706	0.154144002
Skewness	0.23	0.35853	-0.49522	0.559218	0.436401668
Kurtosis	-0.24	-1.16396	-1.37794	-1.04751	-1.110917169
Standard Error	3.09	8.13	0.42	1.89	0.02

(b)

	$PM_{2.5}$	PM_{10}	Temp	Rh	Windspeed
Mean	129.02	241.54	32.12	60.97396	1.26375
Standard Deviation	25.77	51.55416	2.74	13.38856	0.134777981
Skewness	0.94	-0.59327	-0.36	0.334807	1.095306117
Kurtosis	1.32	-0.71605	-1.34	-0.84169	0.260812799
Standard Error	3.72	7.44	0.40	1.93	0.019

(c)

Table 1: Summary Statistics for days in week (a) Monday; (b) Wednesday; (c)Friday

3.4 Epidemiological appraisal

A standardized questionnaire was distributed to 5,000 residents around the research locations to determine the effects of high PM on their health. A total of 4,000 completed questionnaires were successfully collected, indicating a significant level of community participation. Based on these responses, the distribution of the population is as follows: there are 4,000 individuals in total, including 1250 infants (31.25%), 1500 children aged 1 to 14 years (37.5%), and 1250 adults aged 15 years and above (Fig. 10). This suggests that children constitute a modest majority of the population, with the age categories fairly evenly represented.

Using data from the closest state general hospital to the study locations, Fig 11 displays the prevalence, incidence, and hospitalization rates for respiratory disorders. The prevalence is the highest, indicating that many people are affected by any form of respiratory disease. The incidence is lower, meaning fewer new cases are occurring. The hospitalization rate is moderate, suggesting that a significant number of people with respiratory diseases require hospital treatment.

To create a mathematical model that links exposure to $PM_{2.5}$ and PM_{10} from road construction to the related health burdens based on the epidemiological data (Table 2). Utilizing a Concentration-Response Function (CRF) method for simulating the connection between exposure to air contaminants and health impacts. With each unit change in exposure, this function measures the change in health risk. The association between exposure to PM2.5 and PM10 and the risk of respiratory illness can be estimated using a straightforward linear model:

$$Risk = \beta_0 + \beta_1 \times PM_{2.5} + \beta_2 \times PM_{10}$$

Where:

Risk=The probability of developing a respiratory illness.

β_0=The baseline risk, or the risk when exposure is zero.

β_1=The coefficient for $PM_{2.5}$, representing the change in risk associated with a unit increase in $PM_{2.5}$.

β_2= The coefficient for PM_{10}, representing the change in risk associated with a unit increase in PM_{10}.
$PM_{2.5}$ and PM_{10}: The concentrations of $PM_{2.5}$ and PM_{10}, respectively.

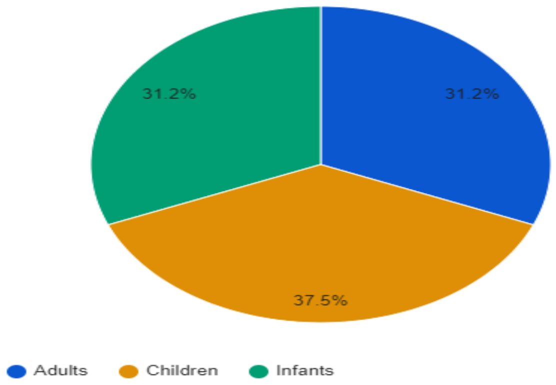


Figure 10: Population distribution of the quarry residents

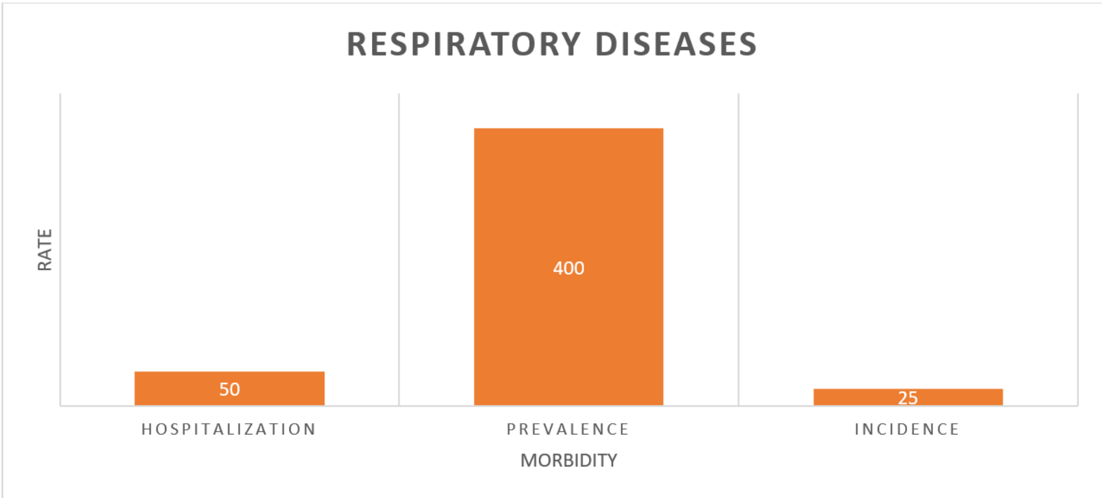


Figure 11: Respiratory disorder at the study locations

This virtual depiction included several well-known and cutting-edge strategies to provide a thorough framework for improving air quality and protecting public health in the impacted area (Fig. 12). Pivot to the diagram is the portrayal of water spraying as a key dust suppression strategy. To efficiently reduce dust generation from construction activities, water trucks are shown misting exposed soil and unpaved roads with a thin mist. This technique works especially well to lessen particulate re-suspension in regions where heavy machinery and active earthworks are present. Green barriers made of trees and plants that encircle the construction site are essential for keeping the PM contained. Along with vegetation, artificial screens, and temporary fencing are added as supplemental measures to provide targeted containment of PM and prevent its spread to nearby residential areas and commercial zones. These natural barriers not only serve as physical barriers to PM dispersion but also enhance the area's aesthetic and ecological value.

Additionally, the diagram highlights how important it is to use environmentally friendly building materials. Prioritizing materials that produce the fewest PM emissions during handling and use can help building projects drastically lessen their environmental impact. This strategy demonstrates a dedication to using greener building techniques and aligns with more general sustainability objectives. The figure also highlights worker safety, which emphasizes the dual responsibility of minimizing environmental impact and protecting the health of those directly involved in construction activities. Construction workers are seen wearing protective masks and safety gear to shield themselves from inhaling harmful PM. The diagram's backdrop depicts a clean and bustling urban setting, signifying the ultimate goal of these interventions: creating a pollution-free environment for communities in and around construction sites. This visual contrast highlights how important it is to incorporate pollution control measures into every stage of road construction. What sets this representation apart is its comprehensive approach; although individual tactics such as water spraying, green barriers, and protective gear are well-established, the diagram skillfully integrates these components into a single, coherent framework, highlighting the synergistic potential of these actions when taken together, providing a solid model for PM pollution reduction.

Figure12: Eco-friendly practices for controlling PM emissions in road construction

V. Conclusion

The findings show that the PM has increased in Port Harcourt due to road construction. PM_{10} indicates a higher prevalence of coarser particles in the air than $PM_{2.5}$. The time series analysis indicated that both pollutants exhibit fluctuating patterns throughout the day. The frequency distributions show the day and time with the highest frequency for $PM_{2.5}$ and PM_{10}. The correlation matrix indicated the strongest association between the PM, meteorological parameters, and the day with the strongest link. Furthermore, the AQI interpretation revealed a generally poor AQI. The research developed epidemiological models to quantify the association between pollutant exposure and health consequences. The study proposed an innovative eco-friendly technique to lessen particulate emissions. The method uses green barriers made of trees and plants encircling the construction site. Along with vegetation, artificial screens, and temporary fencing are added as supplemental measures to provide targeted containment of PM and prevent its spread to nearby residential areas and commercial zones.

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