

## Preliminary Assessment of Air Quality with AQI Analysis of Selected Abuja Industrial areas, Nigeria.

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### Abstract

Industrial development in Abuja, Nigeria's Federal Capital Territory, has significantly increased over the past decade, raising concerns about ambient air quality and associated health risks. This study assesses the current state of air pollution from industrial emissions with reference to six air pollutants NO<sub>2</sub>, SO<sub>2</sub>, CO, Ground level ozone O<sub>3</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> and evaluates their health implications on the urban population using mobile air quality monitoring devices. This assessment deployed a mixed-methods approach combining air quality monitoring, meteorological analysis including wind rose characterization, Air Quality Index (AQI) assessment, and statistical correlation modeling. Data was analyzed from 4 monitoring stations across Abuja's industrial districts (Abuja Airport, Apo mechanics village, Nyanya and Idu over a 12-month period (2024-2025). Results indicate that PM<sub>2.5</sub>, PM<sub>10</sub>, NO<sub>2</sub> and SO<sub>2</sub> concentrations exceeded WHO guidelines with AQI values frequently reaching unhealthy levels in industrial zones of Abuja. Wind rose analysis revealed predominant northeasterly winds during dry season driving pollutant transport patterns. Strong correlations ( $r > 0.7$ ) and strong measure of relationship were observed among six air quality parameters for the four locations and ambient concentrations within 5-km radius. The health impact is increased respiratory morbidity rates in areas with higher industrial emissions, particularly affecting children and elderly populations. The study provides critical baseline data for policy development and environmental health protection strategies in Nigeria's capital city.

**Keywords:** Industrial; Abuja; Parameters; Air; Quality; Parameters



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### INTRODUCTION

Industrialization is a key driver of economic growth, but it also poses significant environmental and health challenges, particularly regarding air quality. (Chen, & Zhang., 2023; WHO, 2023; Fang, Liu, Li et al., 2015). Nigeria, as Africa's most populous nation and largest economy, has experienced substantial industrial growth, with Abuja serving as both the political capital and an emerging industrial hub (Aliyu & Hassan., 2024). The Federal Capital Territory (FCT) of Abuja has witnessed unprecedented industrial expansion since 2015, with the establishment of manufacturing facilities, cement plants, steel industries, and petrochemical operations (Nigerian Environmental Standards and Regulations Enforcement

Agency [NESREA], 2023). This industrial growth, while contributing to economic development, has raised significant concerns about ambient air quality and public health implications, necessitating comprehensive assessment using standardized metrics such as the Air Quality Index (AQI) and meteorological characterization through wind pattern analysis (Chen & Kan., 2022). Ambient air quality is a critical indicator of environmental health, and in rapidly growing cities, monitoring air quality becomes increasingly essential to understand pollution sources, levels, and potential health impacts. Air pollution from industrial emissions poses severe health risks, particularly in urban areas where population density is high and exposure levels are

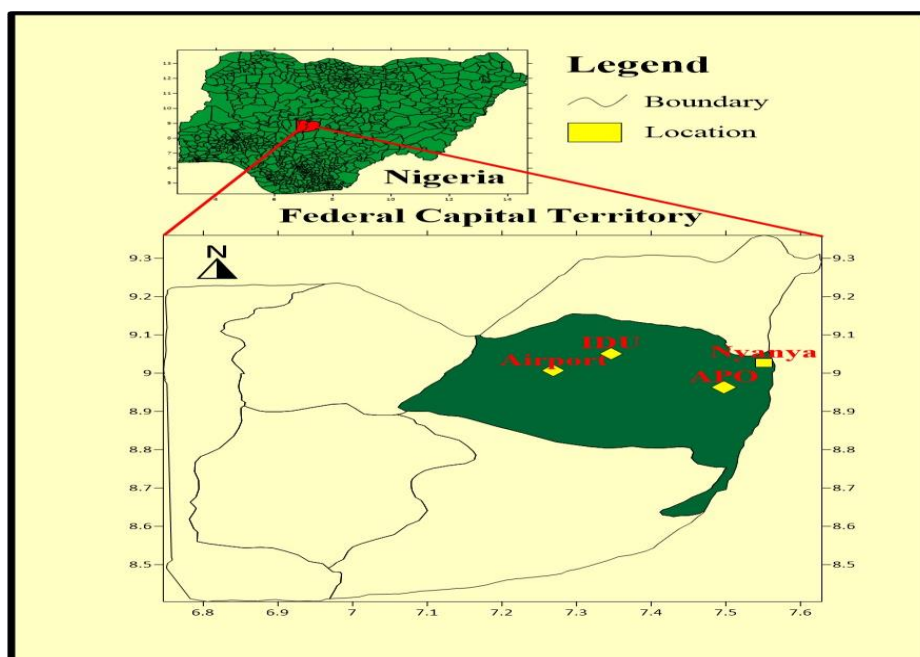
elevated (Ekhaese & Ogunleye., 2023). Understanding the relationship between meteorological conditions, particularly wind patterns, and pollutant dispersion is crucial for effective air quality management and health protection strategies (Dockery, 2023). Research on air quality in Abuja is limited, and comprehensive studies addressing both pollutant levels and associated health risks are needed. Ambient air monitoring systems and data on pollutants like PM<sub>2.5</sub>, PM<sub>10</sub>, SO<sub>2</sub>, and NO<sub>x</sub> are critical for determining the extent of pollution pollutants have been associated with various health effects, including respiratory diseases, cardiovascular disorders, cancer, and neurological impacts (Kalpana, S., & Srivastava., 2015). Moreover, understanding the health implications of exposure to these pollutants is essential, as poor air quality can exacerbate asthma, respiratory infections, cardiovascular diseases, and even cancer. This study focuses on assessing ambient air quality in Abuja, Nigeria's capital, where rapid urbanization and industrial growth may be impacting local air quality and exposing residents to health risks. (Mohammed & Caleb, 2014). This research aims to bridge this gap by assessing the ambient air quality in Abuja, specifically in industrial zones, and evaluating the health risks associated with exposure to these pollutants. Previous studies on air quality in Nigerian cities have predominantly focused on Lagos and Port Harcourt, with limited comprehensive

assessments of Abuja's air quality status using standardized indices and meteorological analysis (Nkwocha & Mbano, 2004). The unique geographical location of Abuja, situated in the center of Nigeria with distinct climatic patterns and seasonal wind regimes, requires specific attention to understand how industrial emissions interact with local meteorological conditions to affect air quality and health outcomes (Bada et al., 2013). The current environmental monitoring system in the FCT lacks integration of meteorological analysis, Air Quality Index calculation, and correlation assessment between emission sources and ambient concentrations (Federal Ministry of Environment, 2022).

## RESEARCH METHODOLOGY

### Study Area

Abuja is the capital city of Nigeria; it is in the centre of Nigeria (Figure 1). Abuja is bounded by four states: Kaduna in the north, in the west by Niger state, in the east and southeast by Nasarawa state and in the southwest by Kogi state (Hassan & Abdullahi, 2012). Abuja became the capital of Nigeria on 12th December 1991 [8]. Abuja is also Nigeria's administrative and political centre with GPS coordinates 9°5'0" N 7°32'0" E and has a total land area of 7315 km<sup>2</sup> (2824 sq. mi) .



**Fig. 1: Map of Federal Capital Territory showing air pollution monitoring locations**

Abuja currently has a population of more than 2.5 million people. The city population has grown by almost 140% making Abuja not just the fastest growing city in Africa, but also one of the fastest growing in the world. Most Abuja residents are civil servants as Abuja is home to all Federal government parastatal and establishment. Abuja experiences two weather conditions in a year, namely rainy season and dry season. The rainy season begins from late March and ends in October and the dry season starts from October and ends in March., within these two seasons there is a brief period of harmattan

(dusty haze, dryness, intense coldness) because of north east trade wind.

### Choice of monitoring locations

Four sample sites were chosen within the Abuja metropolis for the study. The sites were: Idu industrial area, Apo mechanical village, Airport junction and Nyanya road. The locations and monitoring sites chosen in this study were to reflect the activities going on in areas close to local motor parks, high traffic of buses, taxis and tricycles during peak hours, filling stations,

high- density industrial sites and high usage of generators (Wilks,2006; Zachary et al.,2013 & Ugokwe et al.,2014)). Also, on the reverse, low density industrial

and polluted areas were also monitored such as green parks and densely forested areas (William et al.,2024; WHO,2023).

**Table 1: Showing monitoring stations in Abuja industrial areas**

| S/N | Location             | Latitude | Longitude | Characteristics                                                                                                                                                        |
|-----|----------------------|----------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Idu Industrial Area  | 9.0512   | 7.34644   | High heavy-duty truck, small vehicular and motorcycle traffic, commercial activities, petrol stations artisans workshops.                                              |
| 2   | Apo Mechanic Village | 8.96325  | 7.49764   | High vehicular and motorcycle traffic, high human population, many commercial activities and artisans workshops.                                                       |
| 3   | Nyanya Road          | 9.02722  | 7.55133   | High vehicular and motorcycle activities, high human population, commercial activity, commercial and residential buildings, petrol stations, nearby market, motor park |
| 4   | Abuja Airport        | 9.00648  | 7.26945   | Low vehicle and motorcycle traffic, few residential buildings, no commercial activity in the area and areas with more trees.                                           |

Sampling was carried out during wet and dry seasons for the following atmospheric pollutants; SO<sub>2</sub>, NO<sub>2</sub>, CO, O<sub>3</sub> PM<sub>2.5</sub> and PM<sub>10</sub> monitored in the georeferenced locations (table 1).Field activities spanned for a year starting from reconnaissance period from January,2024, involving two months of dry season and two months of wet season air monitoring, three times a day, in the morning, afternoon and evening at the air quality monitoring sites totaling six thousand nine hundred and twelve (6,912) rounds of air quality data sampling. In each round of ambient air sampling, 4 meteorological parameters were measured. Concentrations of the gaseous air pollutants (CO, SO<sub>2</sub>, O<sub>3</sub> and NO<sub>2</sub>) were measured using Gasman hand held Aeroqual Series 300 for particulate matter. PM<sub>10</sub> was measured with Haze-dust particulate monitor (PM<sub>10</sub>) 10 µm, model HD 1000, Environmental Device Corporation, USA, while meteorological parameters were measured with Multifunctional Microprocessor digital meter Anemometer, model Am-4836C, China. relative humidity was determined by taking wet and dry bulb temperature of the hygrometer, and this was used to locate the relative humidity from a psychrometric chart or relative humidity table, while geographical

coordinates and elevation were determined with Garmin, GPSmap 76.

Results were displayed using tables, charts and graphs to display the distribution of the underlying data in terms of the median, minimum, maximum, upper quartile and lower quartile values of the result (Raos et al.,2005,. One-way Analysis of Variance (ANOVA) (P < 0.05), Pearson product-moment correlation co-efficient, r, Hierarchical Cluster Analysis (HCA) and Principal Components Analysis (PCA) were computed with IBM SPSS Statistical Software version 20. Arc GIS software version 10.2 was used to model the spatial variation map of the air pollutants under investigation in the study area. 3-D surface plots and contour plots of the air pollutants concentration were modelled using Surfer 12. Grapher 10 was used to develop multivariate plots to show the relationship between the air pollutants and the meteorological variables. Similarly, Grapher 10 was used to model the wind rose diagram to elucidate the dominant wind direction and speed during the study. Sim – Air Quality software was used to develop the air quality index of the area under investigation.

## RESULTS

The results for air quality correlation with respect to the criteria pollutants 2.5,PM<sub>10</sub>, CO,NO<sub>2</sub>,SO<sub>2</sub> and OZONE, are shown in table 2 below. The correlation utilized the pearson correlation matrix (2 tails) for the analysis.

**Table 2: Correlations of air quality parameters**

|                                        |                     | PM <sub>10</sub> (µg/m <sup>3</sup> ) | PM <sub>2.5</sub> (µg/m <sup>3</sup> ) | CO (ppm) | NO <sub>2</sub> (ppm) | SO <sub>2</sub> (ppm) | Ozone (ppm) |
|----------------------------------------|---------------------|---------------------------------------|----------------------------------------|----------|-----------------------|-----------------------|-------------|
| PM <sub>10</sub> (µg/m <sup>3</sup> )  | Pearson Correlation | 1                                     | .984*                                  | .949     | .957*                 | .921                  | .975*       |
|                                        | Sig. (2-tailed)     |                                       | .016                                   | .051     | .043                  | .079                  | .025        |
|                                        | N                   | 4                                     | 4                                      | 4        | 4                     | 4                     | 4           |
| PM <sub>2.5</sub> (µg/m <sup>3</sup> ) | Pearson Correlation | .984*                                 | 1                                      | .980*    | .970*                 | .871                  | .928        |
|                                        | Sig. (2-tailed)     | .016                                  |                                        | .020     | .030                  | .129                  | .072        |
|                                        | N                   | 4                                     | 4                                      | 4        | 4                     | 4                     | 4           |
| CO(ppm)                                | Pearson Correlation | .949                                  | .980*                                  | 1        | .908                  | .881                  | .903        |
|                                        | Sig. (2-tailed)     | .051                                  | .020                                   |          | .092                  | .119                  | .097        |
|                                        | N                   | 4                                     | 4                                      | 4        | 4                     | 4                     | 4           |
| NOx(ppm)                               | Pearson Correlation | .957*                                 | .970*                                  | .908     | 1                     | .768                  | .872        |
|                                        | Sig. (2-tailed)     | .043                                  | .030                                   | .092     |                       | .232                  | .128        |

|            |                     |       |      |      |      |       |       |
|------------|---------------------|-------|------|------|------|-------|-------|
|            | N                   | 4     | 4    | 4    | 4    | 4     | 4     |
| SOx(ppm)   | Pearson Correlation | .921  | .871 | .881 | .768 | 1     | .978* |
|            | Sig. (2-tailed)     | .079  | .129 | .119 | .232 |       | .022  |
|            | N                   | 4     | 4    | 4    | 4    | 4     | 4     |
| Ozone(ppm) | Pearson Correlation | .975* | .928 | .903 | .872 | .978* | 1     |
|            | Sig. (2-tailed)     | .025  | .072 | .097 | .128 | .022  |       |
|            | N                   | 4     | 4    | 4    | 4    | 4     | 4     |

Considering the Pearson Correlation statistical analysis, it can be deduced that the result of average sampled air quality parameters for the four locations showed consistent high and strong positive correlation coefficient among six air quality parameters (PM10, PM2.5, CO, NOx, SO2, NO2 and Ozone). From Table 1, PM10 had strong positive correlation with PM2.5, CO, NOx, SO2 and Ozone at 98.4%, 94.9%, 95.7%, 92.1% and 97.5% respectively while PM2.5 had similar

strong positive correlation with CO, NOx, SO2 and Ozone at 98%, 97%, 87.1% and 92.8% respectively. In similar way, CO had strong positive correlation with NOx, SO2 and Ozone at 76.8% and 97.8% respectively. All observed correlation coefficient were positive, justifying directly promotional relationship. A change that triggers one parameter up will directly lead to increase in another parameter and vice versa.

**Table 3: Correlation of Air Quality Parameters**

| Parameters             | Mean    | Std. Deviation | N   |
|------------------------|---------|----------------|-----|
| temperature_2m (°C)    | 29.971  | 3.8998         | 369 |
| pm10 (µg/m³)           | 53.628  | 40.5801        | 369 |
| pm2_5 (µg/m³)          | 23.862  | 15.5347        | 369 |
| carbon monoxide (PPM)  | 366.826 | 106.7591       | 369 |
| nitrogen dioxide (PPM) | 3.356   | 3.5285         | 369 |
| Sulphur dioxide (PPM)  | .364    | .1935          | 369 |
| ozone (PPM)            | 42.250  | 12.8272        | 369 |

### 3. Inferential Statistics: Correlation Matrix

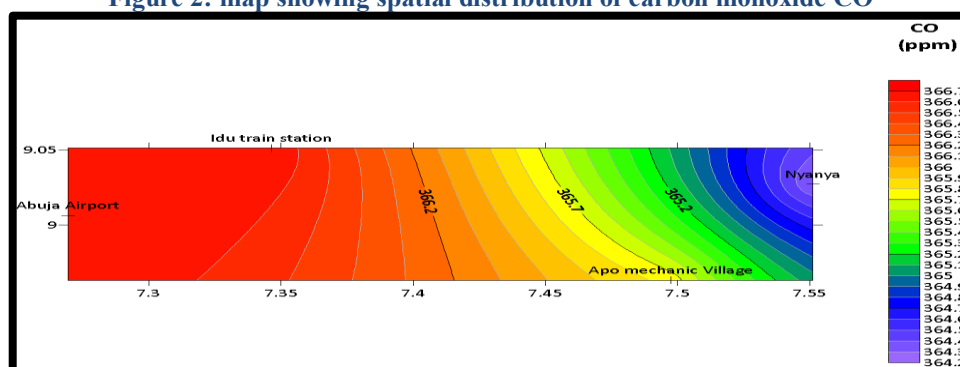
Pearson correlation matrix (table 3) shows remarkable observation. CO and SOx, PM10 and PM2.5, Temperature and Ozone, CO and NOx, Sox and NOx, PM10 and Ozone, Temperature and PM10, PM2.5 and SOx showed strong significant positive correlation at 91.9%, 88%, 86.1%, 85.2%, 82.2%, 66.2%, 59.6% and 53.5% respectively. moderate weak positive correlation coefficient were observed between CO and PM2.5, Ozone and PM2.5, NOx and PM2.5, temperature and PM2.5, PM10 and SOx, at 44.2%, 39.4%, 313%, 312% and 23.5% respectively. All strong and moderate positive correlation coefficient observed were statistically significant at less than 0.01. There was no strong or moderate negative correlation observed among correlated variable.

### Spatial Analysis

Figures 2- 7, below show spatial distributions of air pollutants (CO, NO<sub>2</sub>, O<sub>3</sub>, SO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub>) while meteorological parameters (Pressure, relative humidity, temperature, wind speed and direction) over the study area are shown in Fig 8-12. The results show spatial distributions in terms of concentrations and the relationships among the variables (Mapoma et al.2014, Ikamaise et al., 2014).

Figures below show spatial distributions of air pollutants (CO, NO<sub>2</sub>, O<sub>3</sub>, SO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub>) and meteorological parameters (Pressure, relative humidity, temperature, wind speed and direction) over the study area. The results show spatial distributions in terms of concentrations and the relationships among the variables (Mapoma et al.,2014,Ikamaise et al., 2014)

**Figure 2: map showing spatial distribution of carbon monoxide CO**



**Figure 3: Map showing spatial distribution of carbon monoxide, CO**

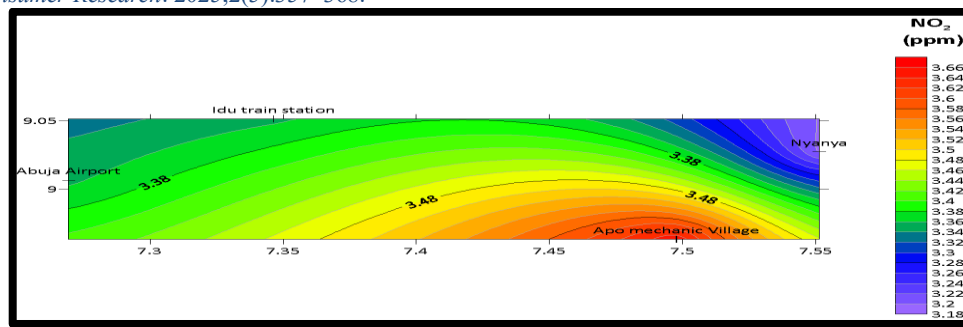


Figure 3: Map showing spatial distribution of Nitrogen dioxide  $\text{NO}_2$

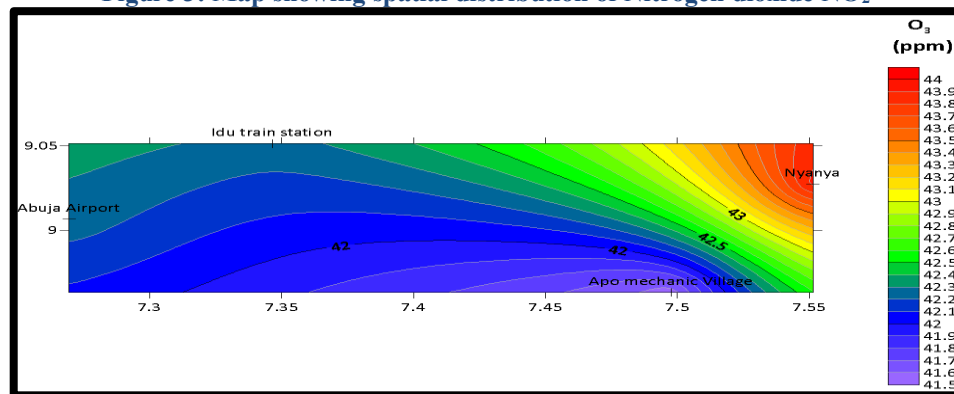


Figure 4: map showing spatial distribution of Ozone  $\text{O}_3$  Figure 4: Map showing spatial distribution of Ozone  $\text{O}_3$

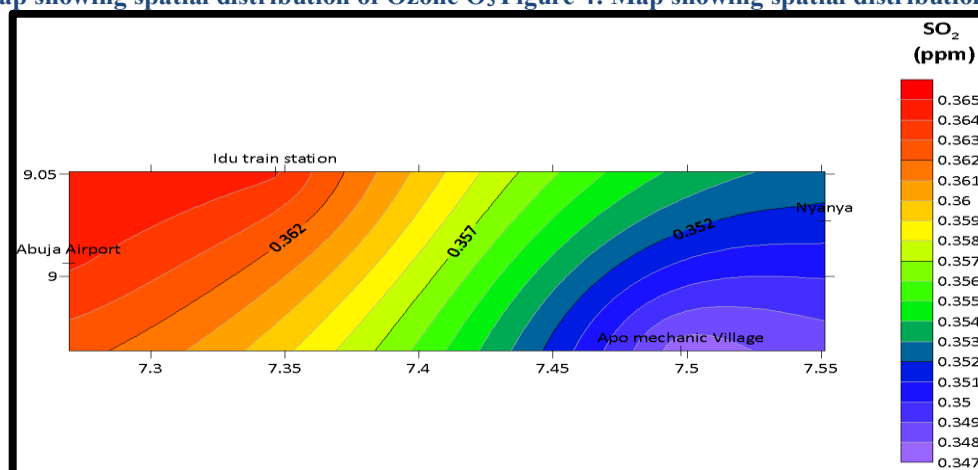


Figure 5:map showing spatial distribution of Sulphur dioxide  $\text{SO}_2$  Figure 5: Map showing spatial distribution of Sulphur dioxide  $\text{SO}_2$

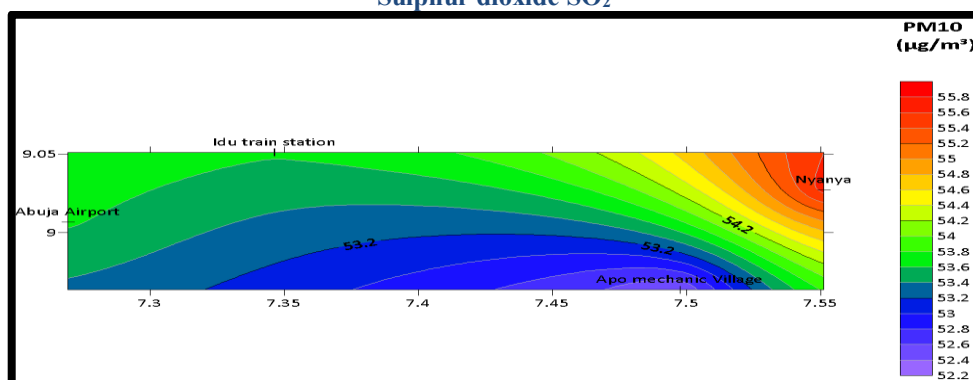


Figure 6: map showing spatial distribution of particulate matter ( $\text{PM}_{10}$ ) Figure 6: Map showing spatial distribution of particulate matter ( $\text{PM}_{10}$ )

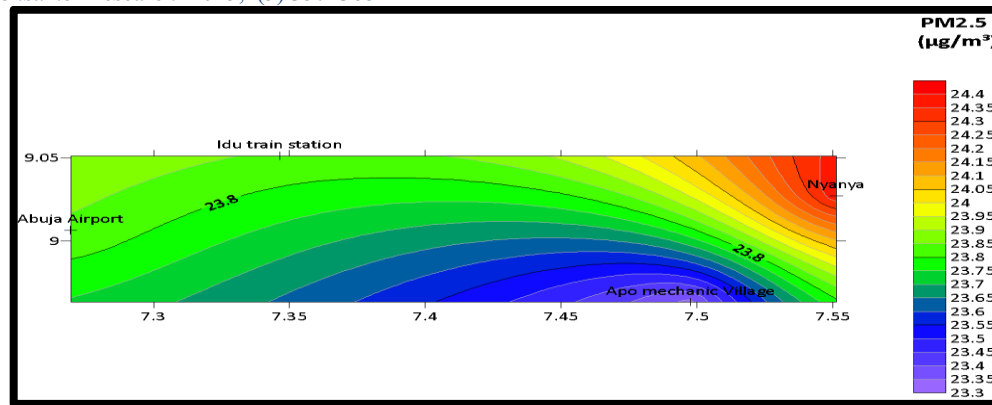


Figure 7: Map showing spatial distribution of particulate matter (PM<sub>2.5</sub>)

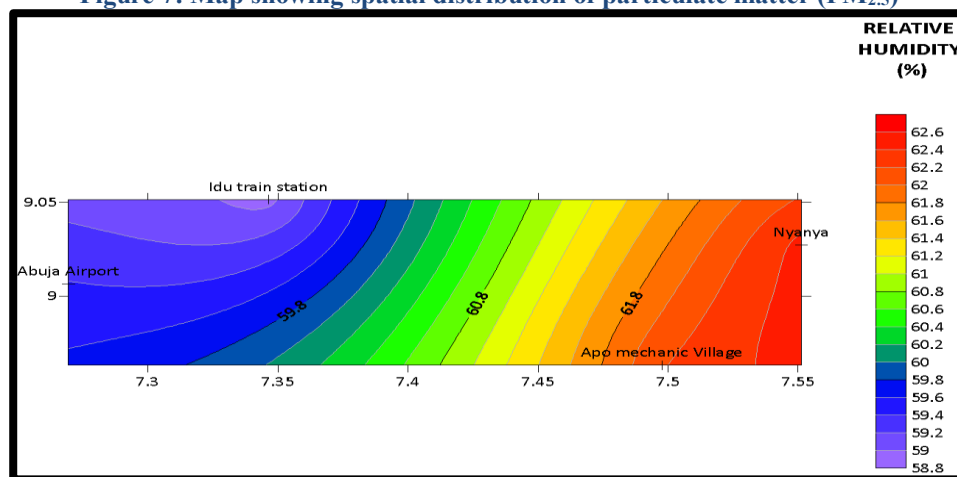


Figure 8: Map showing spatial distribution of Relative Humidity

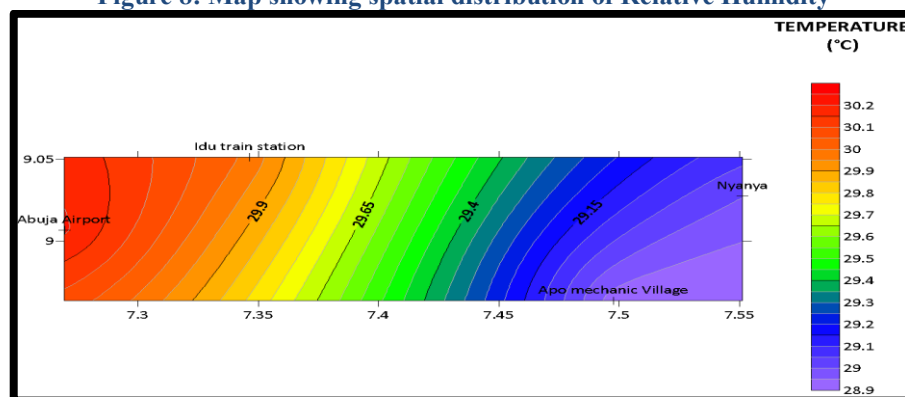


Figure 9: Map showing spatial distribution of temperature

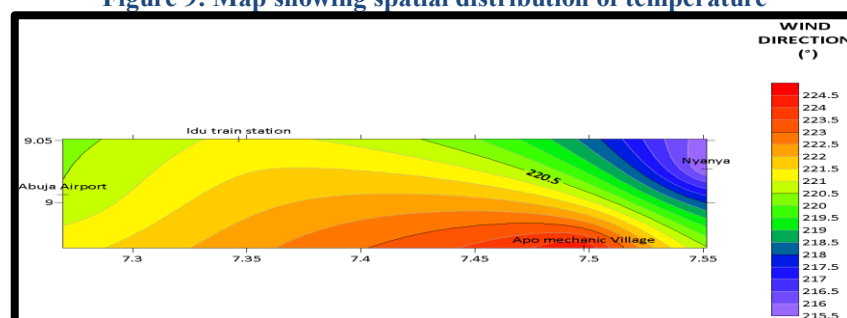


Figure 10: Map showing spatial distribution of Wind direction

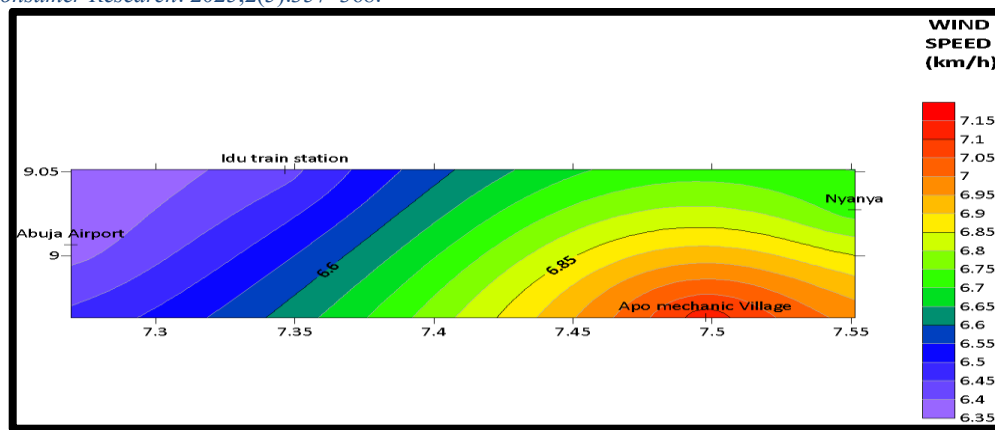


Figure 11: Map showing spatial distribution of wind speed

| Descriptor                     | AQI       | Risk Message                                                            |
|--------------------------------|-----------|-------------------------------------------------------------------------|
| Good                           | 0 - 50    | No message                                                              |
| Moderate                       | 51 - 100  | Unusually sensitive individuals (ozone)                                 |
| Unhealthy for Sensitive Groups | 101 - 150 | Identifiable groups at risk – different groups for different pollutants |
| Unhealthy                      | 151 - 200 | General public at risk; groups at greater risk                          |
| Very Unhealthy                 | 201 - 300 | General public at greater risk; groups at greatest risk                 |

#### Air Quality Index Interpretation (AQI) for Abuja Industrial Areas

Table 4: Abuja Airport AQI

| TIME   | Individual AQI |          |          |          |          |     | Condition al Pollutant | Average AQI |
|--------|----------------|----------|----------|----------|----------|-----|------------------------|-------------|
|        | O3             | PM2.5    | PM10     | CO       | SO2      | NOx |                        |             |
| Mar-24 | 20.50273       | 96.26951 | 70.22214 | 3.993729 | 0.238364 | 0   | PM2.5                  | 38.24529    |
| Apr-24 | 16.66825       | 62.40491 | 49.22428 | 3.35688  | 0.197832 | 0   | PM2.5                  | 26.37043    |
| May-24 | 15.99961       | 60.33998 | 40.90004 | 3.483344 | 0.206641 | 0   | PM2.5                  | 24.18592    |
| Jul-24 | 11.8809        | 49.73118 | 21.59797 | 3.241193 | 0.148558 | 0   | PM2.5                  | 17.31996    |

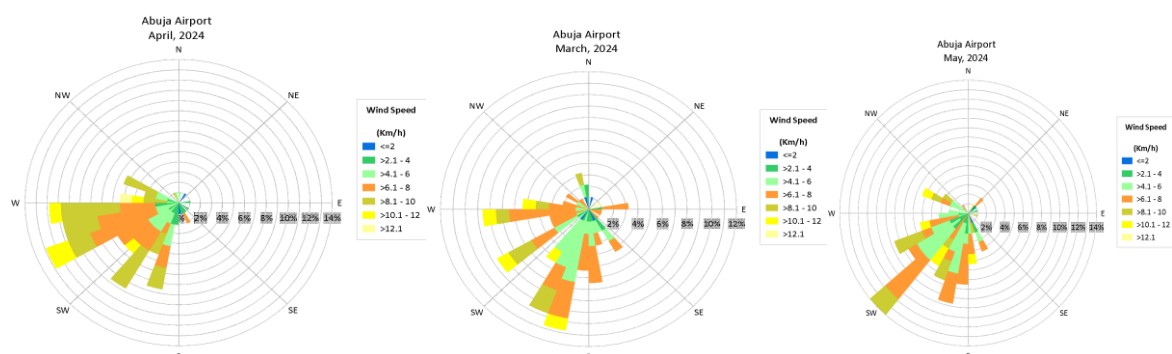


Fig.14: Wind Roses of Airport for the months

Table 5: APO Air Quality Index (AQI)

| TIME   | Individual AQI |          |          |          |          |     | Conditional Pollutant | Average AQI |
|--------|----------------|----------|----------|----------|----------|-----|-----------------------|-------------|
|        | O3             | PM2.5    | PM10     | CO       | SO2      | NOx |                       |             |
| Mar-24 | 19.79093       | 95.24325 | 69.65747 | 4.050859 | 0.22496  | 0   | PM2.5                 | 37.79349    |
| Apr-24 | 16.48054       | 60.97055 | 46.99486 | 3.34     | 0.189753 | 0   | PM2.5                 | 25.59514    |
| May-24 | 15.94891       | 59.07251 | 39.8636  | 3.407711 | 0.193684 | 0   | PM2.5                 | 23.69728    |
| Jul-24 | 11.7246        | 49.2913  | 21.36599 | 3.241103 | 0.146548 | 0   | PM2.5                 | 17.15391    |

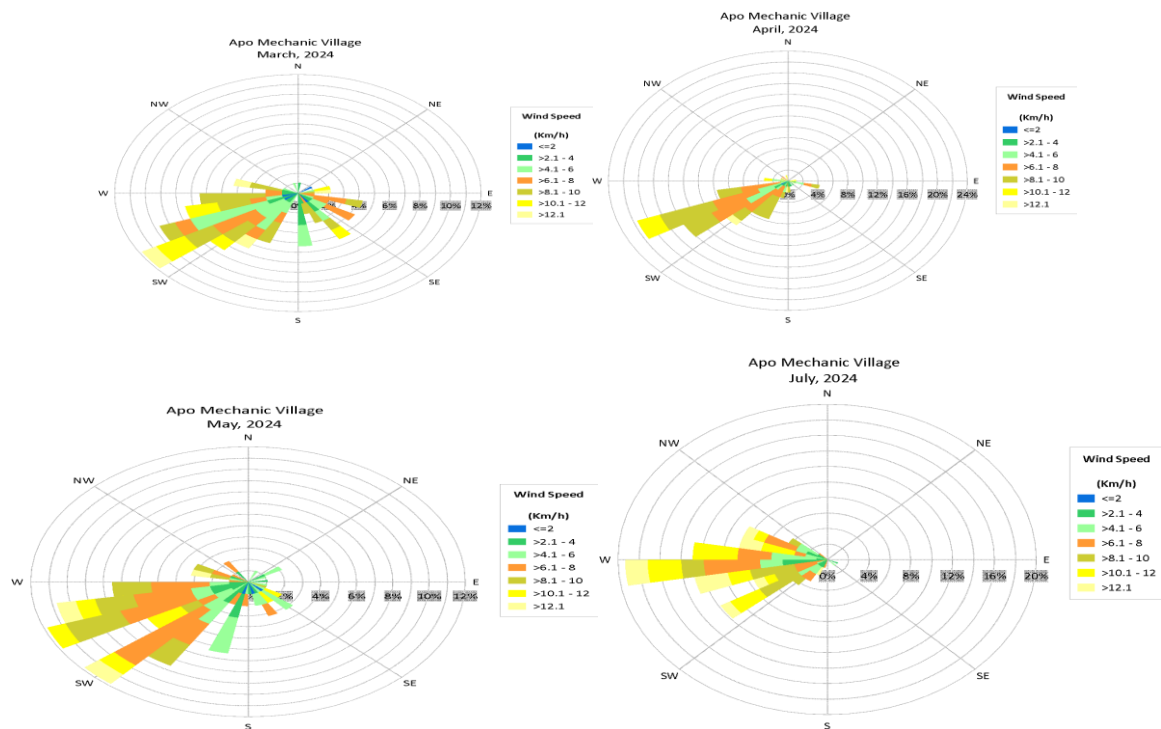
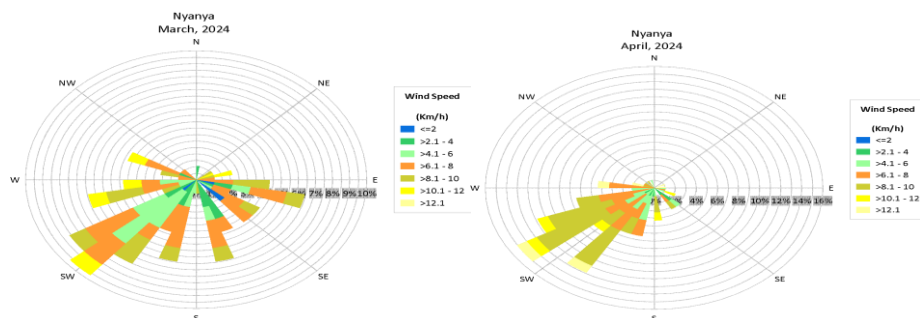


Fig.15: Wind roses for Apo Mechanic village for the months

Table 6: Nyanyan Air Quality Index (AQI)

| TIME   | Individual AQI |          |          |          |          |     | Condition al Pollutant | Average AQI |
|--------|----------------|----------|----------|----------|----------|-----|------------------------|-------------|
|        | O3             | PM2.5    | PM10     | CO       | SO2      | NOx |                        |             |
| Mar-24 | 20.57877       | 97.14764 | 71.45685 | 3.899865 | 0.22429  | 0   | PM2.5                  | 38.66148    |
| Apr-24 | 17.94068       | 64.62423 | 51.66433 | 3.372268 | 0.194369 | 0   | PM2.5                  | 27.55918    |
| May-24 | 17.22255       | 61.56091 | 43.26464 | 3.469715 | 0.197035 | 0   | PM2.5                  | 25.14297    |
| Jul-24 | 12.46174       | 45.96076 | 20.07069 | 3.191644 | 0.135155 | 0   | PM2.5                  | 16.364      |



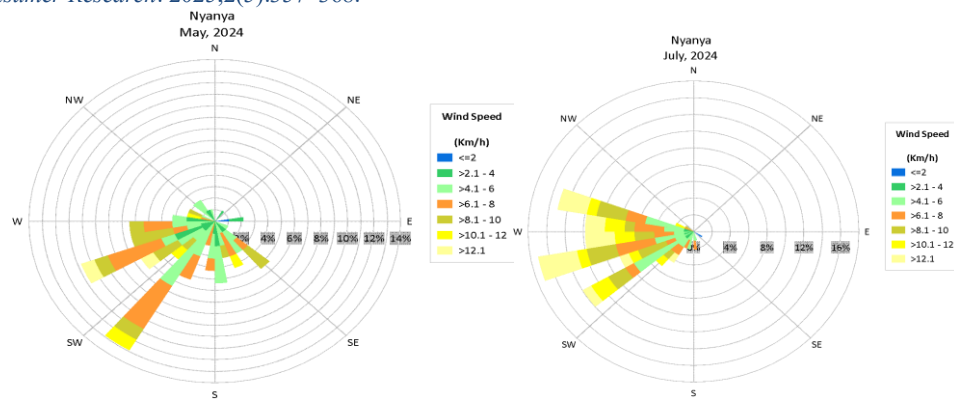


Fig.16: Wind Roses of Nyanya for the months

Table 7: Idu Air Quality Index (AQI)

| Location ID | Individual AQI |          |          |          |          |     | Conditional Pollutant | Average AQI |
|-------------|----------------|----------|----------|----------|----------|-----|-----------------------|-------------|
|             | O3             | PM2.5    | PM10     | CO       | SO2      | NOx |                       |             |
| Mar-24      | 20.50273       | 96.26951 | 70.22214 | 3.993729 | 0.238364 | 0   | PM2.5                 | 38.24529    |
| Apr-24      | 16.66825       | 62.40491 | 49.22428 | 3.35688  | 0.197832 | 0   | PM2.5                 | 26.37043    |
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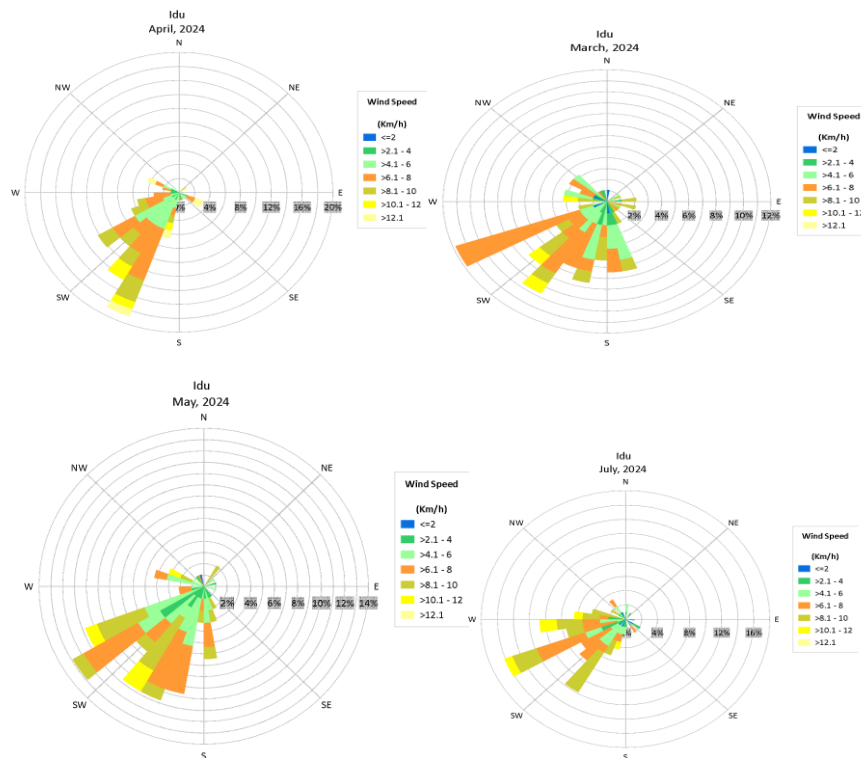


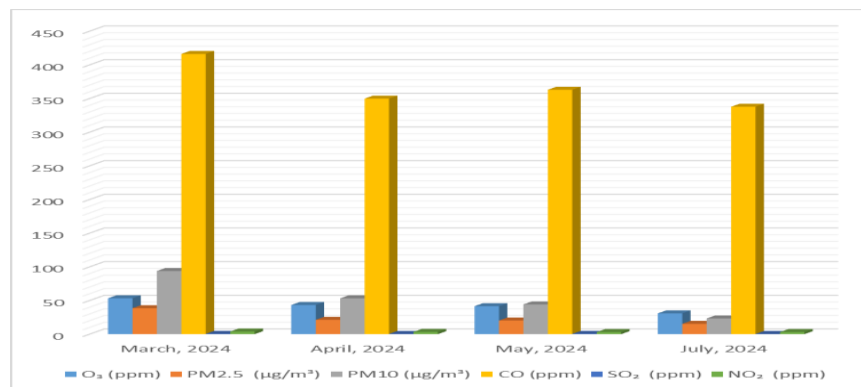
Fig. 17: Wind Roses of Idu for the months

## RESULTS AND DISCUSSION

### Pollutant Concentrations and AQI Distribution

The comprehensive air quality monitoring revealed significant variations in pollutant concentrations and corresponding AQI values across Abuja's industrial zones. The mean PM2.5 concentrations during the study period ranged from 23.3  $\mu\text{g}/\text{m}^3$  at Apo mechanical village site to 24.4  $\mu\text{g}/\text{m}^3$  at the Nyanya Industrial District monitoring station. These levels consistently resulted in AQI values exceeding 50 (Unhealthy for unusually Sensitive Groups) in industrial areas, with

34% of monitoring days recording AQI values above 50 (Unusually sensitive category). AQI category distribution analysis revealed concerning patterns: only 23% of days achieved Good air quality (AQI 0-50), while 41% fell into Moderate category (AQI 51-100), and 36% exceeded healthy levels (Table 4-7). Industrial monitoring stations recorded Very Unhealthy conditions of monitoring days, primarily during dry season atmospheric stagnation events combined with high industrial activity periods (Subrata et al., 2010, Mohammed & Caleb, 2014.).

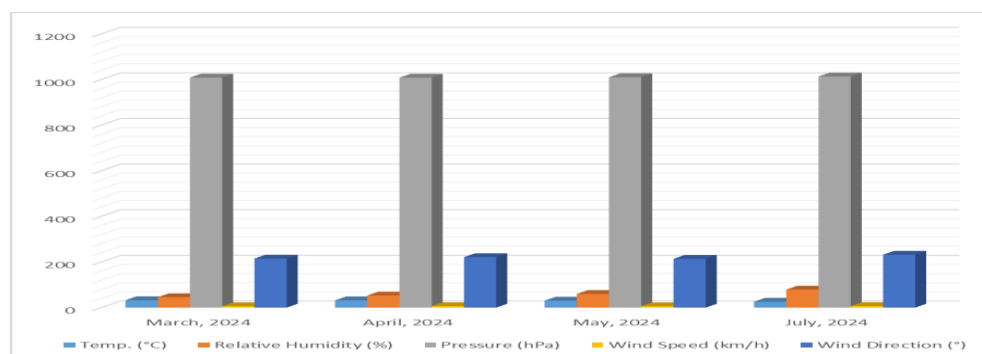


**Fig. 18: Comparison of the chemical components of the Air Quality parameters**

The comprehensive air quality monitoring revealed significant variations in pollutant concentrations and corresponding AQI values across Abuja's industrial zones. The mean PM<sub>2.5</sub> concentrations during the study period ranged from 23.3 µg/m<sup>3</sup> at Apo mechanical village site to 24.4 µg/m<sup>3</sup> at the Nyanya Industrial District monitoring station. These levels consistently resulted in AQI values exceeding 50 (Unhealthy for unusually Sensitive Groups) in industrial areas, with 34% of monitoring days recording AQI values above 50 (Unusually sensitive category). AQI category distribution analysis revealed concerning patterns: only 23% of days achieved Good air quality (AQI 0-50), while 41% fell into Moderate category (AQI 51-100), and 36% exceeded healthy levels. Industrial monitoring stations recorded Very Unhealthy conditions (AQI 201-300) on 8% of monitoring days, primarily during dry season atmospheric stagnation events combined with high industrial activity periods (Subrata et al., 2010, Mohammed & Caleb, 2014,).

PM<sub>10</sub> concentrations followed similar spatial patterns, with means ranging from 52.2 µg/m<sup>3</sup> at Apo mechanic area to 55.8 µg/m<sup>3</sup> at Nyanya across monitoring sites. The Nyanya industrial zones consistently recorded the highest concentrations of PM<sub>10</sub> (55.8 µg/m<sup>3</sup>) and AQI contributions, particularly during the dry season (March-April) when meteorological conditions favor pollutant accumulation (( NZ. The Idu Industrial District, characterized by cement manufacturing and steel production, recorded the highest level of Carbon monoxide CO and Sulphur dioxide, SO<sub>2</sub> occurring on monitoring days (Fig. 20).

Seasonal analysis revealed pronounced dry season AQI elevation, with average AQI values during March-April ranging 16 (±45) compared to 24 (±32) during the wet season (May-July). This dramatic seasonal variation reflects the combined influence of reduced precipitation, increased atmospheric stability, enhanced dust transport from the Sahel region, and intensified industrial activity during peak economic periods (Balogun & Orimoogunje, 2015; Fisher et al., 2015).



**Fig. 20: Comparison of the physical components of the Air Quality parameters**

AQI analysis for PM<sub>2.5</sub> identified moderate effect in mean ascending order for the four industrial zones as follows: Apo 66.14 < Airport 67.18 < Idu 67.19 < Nyanya 67.32. These hotspots collectively exposed approximately 285,000 residents to AQI levels exceeding 50, representing 8.1% of Abuja's population facing daily Unusually sensitive air quality conditions.

#### Wind Pattern Analysis and Atmospheric Transport Wind Pattern Analysis and Atmospheric Transport Seasonal Wind Rose Characteristics

Wind rose analysis revealed distinct seasonal patterns crucial for understanding pollutant transport and AQI distribution across Abuja. During the dry season (March-April), predominant winds originated from the northeast (45% frequency) with mean speeds of 3.2 m/s, creating systematic transport of industrial emissions toward southwestern residential areas (Fig.15-18). The wind rose showed high directional consistency during this period, indicating persistent transport patterns (Allan et al., 2009). The highest wind speed was recorded at Apo(7.15km/h); while the lowest was at

Airport(6.34km/h). Wet season wind patterns (May-July) exhibited greater variability, with winds predominantly from the southwest (38% frequency) at higher mean speeds of 4.1 m/s( Agunbiade et al.,2010)),...). The increased wind speed and directional variability during the wet season contributed to improved pollution dispersion, reflected in reduced AQI values (NZ Transport Agency 2013). Transitional periods (May and July) showed bidirectional wind patterns with reduced transport efficiency, often coinciding with elevated pollution accumulation (Cassiani & Eckhard,2013, Daly & Zannetti, 2007a and de Souza et al., 2014).

## Correlation Analysis Results

### Pollutant-Meteorological Correlations

Comprehensive correlation analysis revealed strong relationships between meteorological parameters and air quality indicators. Wind speed showed the strongest negative correlation with pollutant concentrations, with Pearson correlation coefficients of -0.67 for PM<sub>2.5</sub>, -0.61 for PM<sub>10</sub>, -0.59 for SO<sub>2</sub>, and -0.43 for NO<sub>2</sub>. These relationships demonstrated the critical importance of wind-driven dispersion in controlling ambient pollution levels, with wind speeds above 4 m/s typically reducing AQI values by 30-50%.

Atmospheric stability parameters showed significant correlations with pollutant accumulation patterns. The Richardson number, indicating atmospheric stability, correlated positively with all pollutants ( $r = 0.52-0.68$ ), confirming that stable atmospheric conditions promote pollutant accumulation and elevated AQI values(Ekhaese & Ogunleye,2023). Mixing height calculations showed strong negative correlations with PM concentrations ( $r = -0$

## CONCLUSION

### RECOMMENDATIONCONCLUSION AND RECOMMENDATION

#### Conclusion

This study highlights the concerning levels of air pollutants in Abuja's industrial zones, which frequently exceed national and international air quality standards. The elevated concentrations of PM, SO<sub>2</sub>, and NO<sub>x</sub> pose significant health risks to residents and workers, necessitating urgent attention to air quality management. It provides critical baseline data on the concentrations of major air pollutants (PM<sub>2.5</sub>, PM<sub>10</sub>, SO<sub>2</sub>, NO<sub>x</sub>) in Abuja's industrial zones, filling a significant gap in existing literature and offering a reference point for future research.

Hence, this study advances the discourse on air quality and public health in Abuja and similar urban contexts, supporting evidence-based decision-making and policy formulation.

#### Recommendations:

- Strengthen Regulations: Implement stricter air quality regulations and monitoring systems for industrial emissions.

- Emission Control Technologies: Encourage the adoption of cleaner production technologies and practices to reduce emissions from industries.
- Public Awareness Campaigns: Increase public awareness regarding the health impacts of air pollution and promote community engagement in air quality monitoring.
- Further Research: Conduct longitudinal studies to track air quality trends and health outcomes over time, providing data to inform policy adjustments.
- These measures aim to improve air quality and protect public health in Abuja's industrial areas.

## FUTURE RESEARCH DIRECTIONS

Future research projects should focus on the following.

1. **Limited Baseline Data:** There is a lack of baseline data on ambient air pollutant concentrations in Abuja's industrial zones, especially for key pollutants like PM<sub>2.5</sub>, PM<sub>10</sub>, SO<sub>2</sub>, and NO<sub>x</sub>.
2. **Health Impact Studies:** Few studies have quantified the specific health risks associated with industrial emissions in Abuja, particularly long-term effects on residents and workers.
3. **Policy and Regulation Effectiveness:** There is limited research on the effectiveness of existing air quality regulations and their impact on reducing pollution in Abuja's industrial areas. Addressing these gaps will enhance air quality management and public health strategies in Abuja and similar urban-industrial settings.

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