Assessment and Modelling of Particulate Matter ($PM_{2.5}$ and PM_{10}) Concentration around North Central Region of Nigeria

B.B. Kpeseh[1,2*], I. Umaru[2], A.A. Mundi[2]

[1]Department of Weights and Measures, Federal Ministry of Industry, Trade and Investment, Abuja, Nigeria

[2]Department of Physics, Nasarawa State University, Keffi, Nigeria

[*]Corresponding Author

DOI: https://doi.org/10.51244/IJRSI.2026.1306000507

Received: 04 July 2026; Accepted: 10 July 2026; Published: 21 July 2026

ABSTRACT

Air Pollution has become one of the most conspicuous pollutants around the globe today, for which Particulate Matter ($PM_{2.5}$ and PM_{10}) is inclusive, having the highest air pollutant index (API) value contrasted with the other criteria contaminations. Long-term exposure to these pollutants may lead to a marked reduction in life expectancy due to increase in cardiopulmonary and lung disease mortality. This study provides baseline data on Particulate Matter ($PM_{2.5}$ and PM_{10}) concentration in the region and models it to indirect data using the average direct satellite captured data sourced 24 Hours from NASA through NASRDA software. A number of anthropogenic activities increase the concentration of $PM_{2.5}$ and PM_{10} in the North Central Region of Nigeria, which are linked to health issues in the area. $PM_{2.5}$ and PM_{10} are fine atmospheric particles and coarse particles, respectively that contribute to the low life expectancy of less than 60 years in Nigeria. The absence of Particulate Matter monitoring stations and inadequate equipment in the Country for timely prediction of its status for information that permits the regulatory authority and local community to take prudent steps and lessen the effect of particulate contamination, calls for the use of forecast models that would readily ensure data availability. This study applies the Multiple Linear Regression (MLR) model to predict Particulate Matter ($PM_{2.5}$ and PM_{10}) concentration and Air Quality Index prediction in Six States and the Federal Capital Territory which has two main seasons (Dry and Wet) in 2020, 2021 and 2022. The meteorological variables (of temperature) for the average of 12 Months was used to model the concentration. The Air Quality Index was calculated with the indirect data and it showed a percentile difference of about 5% between direct and indirect Particulate Matter concentration. The highest AQI for PM_{10} concentration for the direct data across the locations were 103μg/m^3, 101 μg/m^3 and 103 μg/m^3 for 2020, 2021 and 2022 respectively while the lowest were 79 μg/m^3, 82 μg/m^3 and 83 μg/m^3 for the same 2020, 2021 and 2022 respectively. For $PM_{2.5}$ concentration, the AQI for the direct data across the locations were 51μg/m^3, 53 μg/m^3 and 53 μg/m^3 in 2020, 2021 and 2022 respectively while the lowest were 32 μg/m^3, 45 μg/m^3 and 27 μg/m^3 for 2020, 2021 and 2022 respectively. The highest AQI for PM_{10} concentration for the indirect data across the locations were 113μg/m^3, 111 μg/m^3 and 113 μg/m^3 in 2020, 2021 and 2022 respectively while the lowest were 89 μg/m^3, 92 μg/m^3 and 93 μg/m^3 in 2020, 2021 and 2022 respectively. The highest AQI for $PM_{2.5}$ concentration indirect data across the locations were 53μg/m^3, 53 μg/m^3 and 52 μg/m^3 in 2020, 2021 and 2022 respectively while the lowest were 45 μg/m^3, 41 μg/m^3 and 39 μg/m^3 in 2020, 2021 and 2022 respectively. The AQIs with highest concentration for all the years exceeded the WHO World Annual Standard of 24 Hours for both $PM_{2.5}$ and PM_{10} which is <50 μg/m^3 and <100 μg/m^3 respectively. This result is unhealthy for such locations and is a contributing factor to cases of cardiopulmonary and lung disease mortality around the region. The performance indicators used are Root Mean Square Error (RMSE) and the value of coefficient determination (R^2). The error in the model was evaluated based on RMSE and the accuracy was assessed using R^2. The increasing values of R^2 and decreasing RMSE indicated that the Particulate Matter ($PM_{2.5}$ and PM_{10}) is very well explained by the input variable in the model being developed. It's either RMSE was decreasing or increasing and R2 increasing

or decreasing for each location. The indicator showed that the calculated indirect AQI and concentration can be relied on across the locations in the absence of direct data from Polar Satellites.

Keywords: Air Quality Index (AQI), Particulate Matter ($PM_{2.5}$ and PM_{10}), Concentration.

INTRODUCTION

Atmospheric pollution is a major problem worldwide, especially in developing countries Particulate Matter (PM) is a complex mixture of contaminants that includes dust, smoke, and other kinds of liquid and solid items suspended in the air, as well as bio-particulates. A positive link exists between acute and chronic exposure to Particulate Matter in the air and the risk of health complications, such as airway inflammation and lung performance [63]. Particulate Matter is a major pollutant that has been associated with several health problems, the most common of which are respiratory and cardiovascular problems [34].

Particulate Matter is a major pollutant in the environment that can penetrate the respiratory system and create health concerns and problems due to its size (aerodynamic diameter) [54]. Depending on the climatological parameters, Particulate Matter with a diameter of less than 10 µm is classified as repairable-suspended-particulate-matter. It can change its physicochemical properties and can float in the air for a short to longer period. As a result, it has the potential to alter the environment's radioactive balance on a local to regional scale, potentially harming the ecosystem and climate [65]. These Particulate Matter sizes absorb hazardous substances, which are then breathed into the human body and deposited in the lungs, resulting in a variety of cardiovascular and respiratory problems, leading to morbidity and mortality [35]. According to previous research in Sao Paulo, environmental particles have a significant impact on human and animal health [5].

Suspended particles in the air with a larger mass and size fall to the ground through a dry or wet deposition process. On the contrary, the fine and ultra-fine particles stay in the atmosphere for longer periods, sometimes up to weeks, and can be carried to different regions by air circulations, thereby affecting the environment of distant and far-off locations [40]. Moreover, particles in the atmosphere have an impact on cloud formation and dissipation, which govern heat transport in the atmosphere and cause climate change [50].

Particulate Matter comes in different sizes. Particulate Matter (PM) is a mixture of complex particles both in solid and liquid forms that varies their mineralogical physical and chemical features depending on categories design in accordance to their different aerodynamics diameter, either Ultrafine PM 0.1 (Particulate aerodynamics diameter less than 100nm), Fine $PM_{2.5}$ (less than 2.5µm), Coarse $PM_{10-2.5}$ (greater than 2.5 and less than 10µm) or PM_{10} (less than 10 down to 2.5µm). Particulate Matter has some chemical constituents which includes the elemental carbon, sea salt, organic carbon, crustal material, secondary inorganic aerosols. Particles can either be directly emitted by all kinds of natural sources or by virtually any form of anthropogenic activities. Large number of research have revealed the relationship of adverse health effect due to exposure to Particulate Matter over shorter days and longer periods, ranging from temporal changes (through increased symptoms risk that requires hospital admission) and death risk increase rate due to cardiovascular, respiratory diseases and lung cancer [65]; [63]; & [45].

MATERIALS AND METHODS

Study Area

The Study Area is North Central region of Nigeria which comprises of Six States and the Federal Capital Territory namely Benue, Nasarawa, Niger, Kogi. Kwara and Plateau States. The major anthropogenic activities in this region are Agriculture, Construction, Bush Burning, Transportation, Cattle Rearing, Mining, Manufacturing, Trade, Urbanization, etc. It is a stretch across the middle belt region of Nigeria's map that is across the whole width of the country, from the border with Cameroun to that of Benin Republic. The region's population accounts for about 11% of the total population of over 200million of the country. The most populous States are FCT, Kwara and Plateau and they represents sixth, seventh and eighth most populous States in the country. It's among the Six Geopolitical Zones of the country which has a total population of over 20million people as at 2006 census. See Fig. 1, the shaded region on the map of Nigeria;

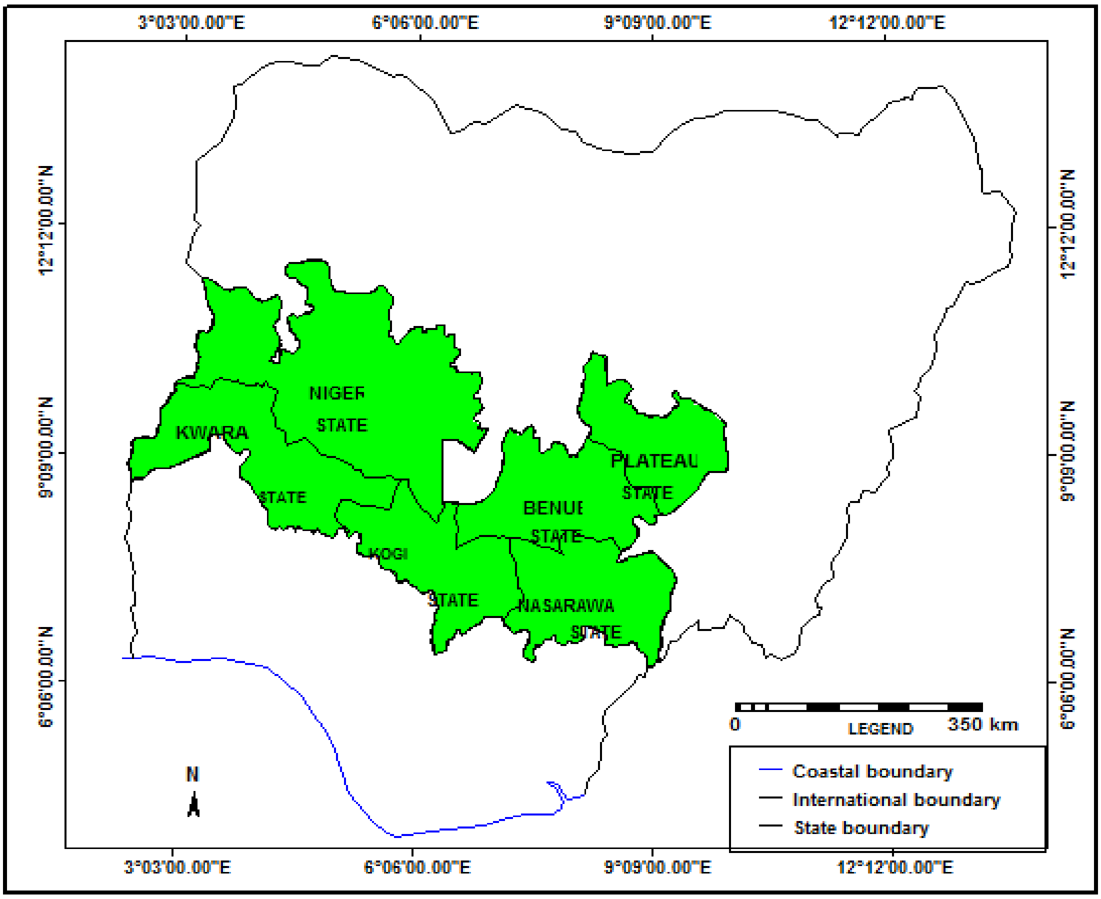

Fig. 1: The map of Nigeria showing the North Central Region of Nigeria with Six States and the Federal Capital Territory around the Study Area.

Materials

The materials used for this research are principally secondary data obtained from NASA, USA through the NARSDA, Nigeria. The Specialized Arc Map Software Version 10.4.1 was used in converting and exporting DBF Format to readable Microsoft Excel Software. The Microsoft Excel Window Version 2013 App was used for data analysis and calculation. Airnow AQI Calculator Version 2024 was used for calculating the Air Quality Index (AQI). It converts the Particulate Matter ($PM_{2.5}$ and PM_{10}) concentration into AQI and vice versa. The secondary data was modelled using the Multivariate Linear Regression (MLR) Model. The meteorological factor of temperature whose values were downloaded alongside the secondary data aided in modelling.

Method of Data Collection

The Secondary Data used was collected by National Space Research and Development Agency (NASRDA), Abuja Nigeria, through the National Aeronautics and Space Administration (NASA), USA site which was extracted from the study regions for about three different time intervals: 00:00:00 to 23:59:00 using coordinates of the Study Area for 24 hours daily throughout the year 2020, 2021 and 2022.

The coordinates (Longitudes and Latitudes) of the locations in the North Central Region of Nigeria were used to define the region of interest. Bounding Points gave analyzable region to indicate the spatial limits of the subset granules that went into making visualization. Each of the States of Benue, Nasarawa, Niger, Kogi, Kwara, Plateau and FCT in the Region were selected with the Coordinates and Bounding Points as; (6.4600E, 8.4457N, 7.6465N, 9.2368N and 6.625E, 8.625N, 7.625E, 9.125N), (3.1641E, 7.9184N, 6.1963E, 9.4565N and 3.375E, 8.125N, 6.125N, 9.375N), (7.5146E, 8.3578N, 8.7012E, 9.5004N and 7.625E, 8.375N, 8.625N, 9.375N), (7.6025E, 7.2153N, 10.459E, 8.4457N and 7.625E, 7.375N, 10.375N, 8.375N), (6.2842E, 7.2592N, 7.4268E, 8.6215 and 6.375N, 7.375N, 7.375E, 8.375N), (3.8232E, 8.6655N, 6.5479E, 10.8627N and 3.875E, 8.875N, 6.375E, 10.625N), (7.8223E, 9.2807N, 9.7119E, 10.2475N and 7.875E, 9.375N, 9.625E, 10.125N) respectively.

The Atmospheric Satellites information came in NETCDF format, which was extracted by a specialized software called the Arc Map 10.4.1, the processes followed thus; NETCDF layer was made together with the Copy Raster tools in the Multi-dimensional toolbox of Arc Map 10.4.1. After extraction, the coordinates in the North Central Region of Nigeria file was clipped and imported into the software according to the States in the Region and then converted from features to points, from the tool in the data management toolbox and the coordinates of the points assigned using the "ADD XY CORDINATES" found in the coverage toolbox. The points and coordinates were used to extract values from the processed data using the "Extract multi-values to points" tool in the spatial analysis toolbox. The extracted values for the different States were exported in DBF format which was read by Microsoft Excel. Finally the extracted values were imported into Excel Window, the data cleaned and graphs were plotted to show trends and relationships. The process was repeated for each of the locations.

Technique of Data Analysis

From the secondary data downloaded which is the direct value of Particulate Matter ($PM_{2.5}$ and PM_{10}) in the Study Area, the factors influencing the concentration which are meteorological factors (Wind Speed, Humidity, Temperature, Wind Direction, etc) were also considered. The values for temperature were rightly available and used from the list of factors. The direct Air Quality Index (AQI) was thereafter calculated for each of the years from 2020 to 2022 using the annual average concentration of Particulate Matter with the aid of Airnow AQI Calculator which is available online through the its link (http://www.airnow.gov/aqi/aqi-calculator-concentration). The calculator was programmed to convert the concentration to Air Quality Index mode and the values obtained were recorded according to the years. Using the Multivariate Linear Regression Model, another set of indirect values were obtained from the data collected.

The Multivariate Linear Regression (MLR) is used to model the Particulate Matter concentration to obtain predicted values that are close to the actual standard values [3]. The formula for MLR was applied as in Equation 1.

$$PM = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta n X n + \varepsilon \qquad (1)$$

After the data was collected on PM concentration (dependent variable) and potential influencing factors (independent variables, which is temperature as a relevant factor affecting Particulate Matter level) for the Study Area. A Regression Analysis was performed using statistical tool on the Originlab Software to estimate the intercept (β_0) and coefficients (β_1 to βn) for the model. The predicted Particulate Matter was calculated using the coefficients which was plugged into the values of the independent variables (X_1 to Xn) of the formula to predict Particulate Matter concentration for new data points. The Root Mean Square Error (RMSE) or Mean Absolute Error (MAE) was evaluated using the Microsoft Equation3.0 software for computation, which represents the error (ε) term on the formula. All the terms were then substituted to obtain indirect values of PM concentration in the Study Area, after which the Air Quality Index is calculated using the same calculator. It is then represented according to the years under study.

RESULTS AND DISCUSSION

From the secondary data collected, graphs were plotted to show trends of the direct data. The graphs explained the impact of seasonal variation in both Dry and Wet Seasons. The graphs were plotted for all the locations for both Particulate Matter ($PM_{2.5}$ and PM_{10}) concentrations in 2020, 2021 and 2022. The average of 12 months in each of the location was considered for the plotting. Fig. 2-7, represents graphs of direct data for Particulate Matter ($PM_{2.5}$ and PM_{10}) concentrations in 2020, 2021 and 2022 as downloaded through NASRDA. From the graphs in Fig. 2-7 there was higher concentration of Particulate Matter in the Dry Seasons more than the Wet Seasons. The Seasonal variations in the region determined temperature impact. From late October to April, which is Dry Season, the temperature is usually high and lower from March to September. Table 1 and 2, represents the average value or mean value of the Particulate Matter ($PM_{2.5}$ and PM_{10}) concentrations in 2020, 2021 and 2022 across the Study Area. Since the downloaded data came with 12 months, the average was considered and tabulated. The Air Quality Index (AQI) of the concentration was calculated and inputted in the same table. Table 3 and 4, represents the modelled concentration or the indirect concentration. Since temperature was downloaded alongside with the data, it was used in the modelling as a meteorological factor.

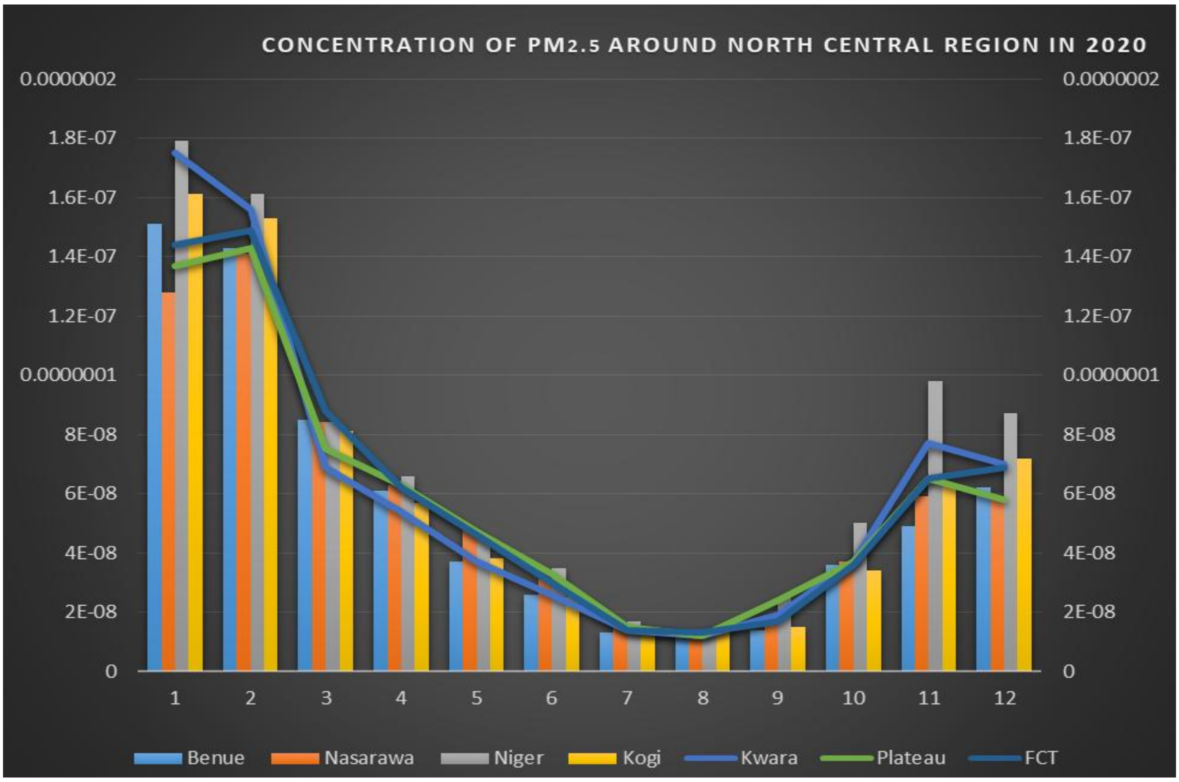

Fig. 2. Graphical representation of the concentration of $PM_{2.5}$ around Study Area in 2020

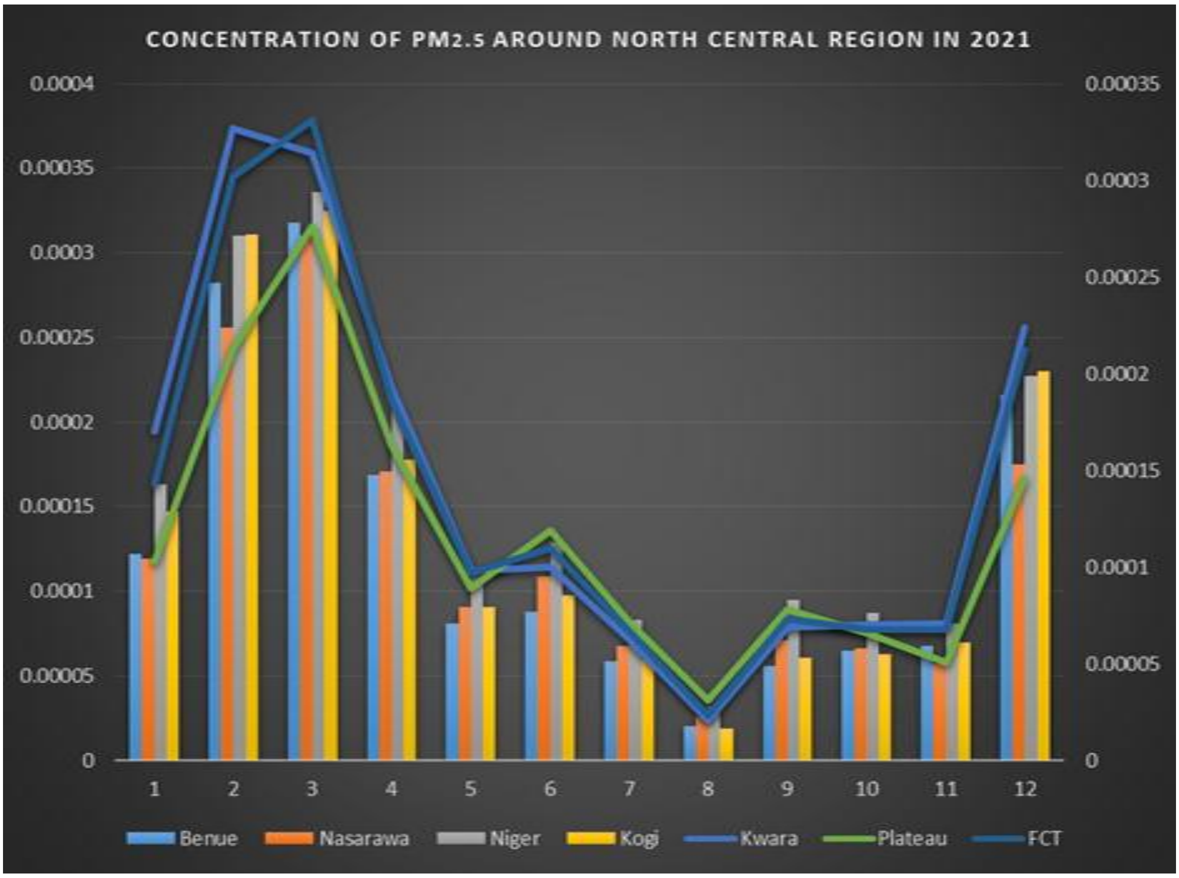

Fig. 3. Graphical representation of the concentration of $PM_{2.5}$ around Study Area in 2021

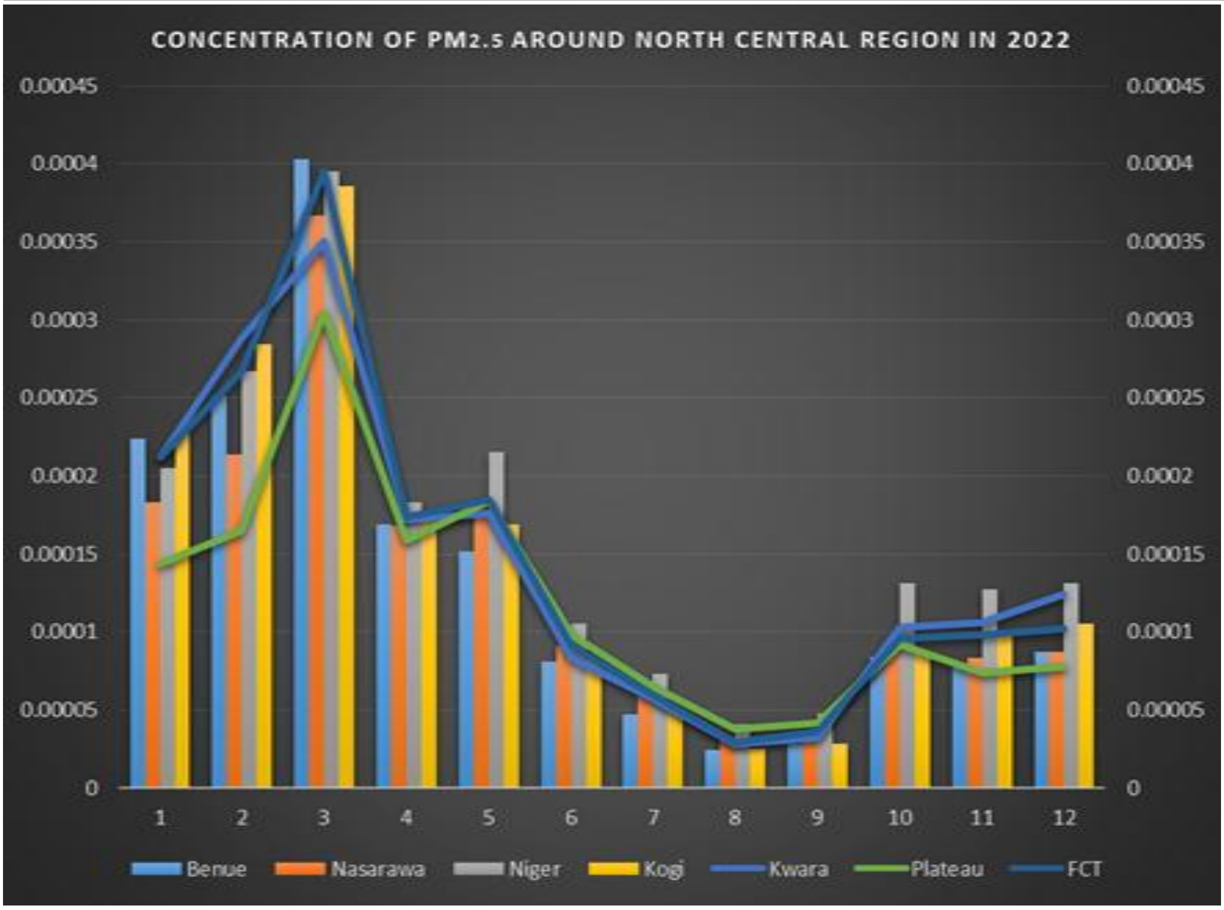

Fig. 4. Graphical representation of the concentration of $PM_{2.5}$ around Study Area in 2022

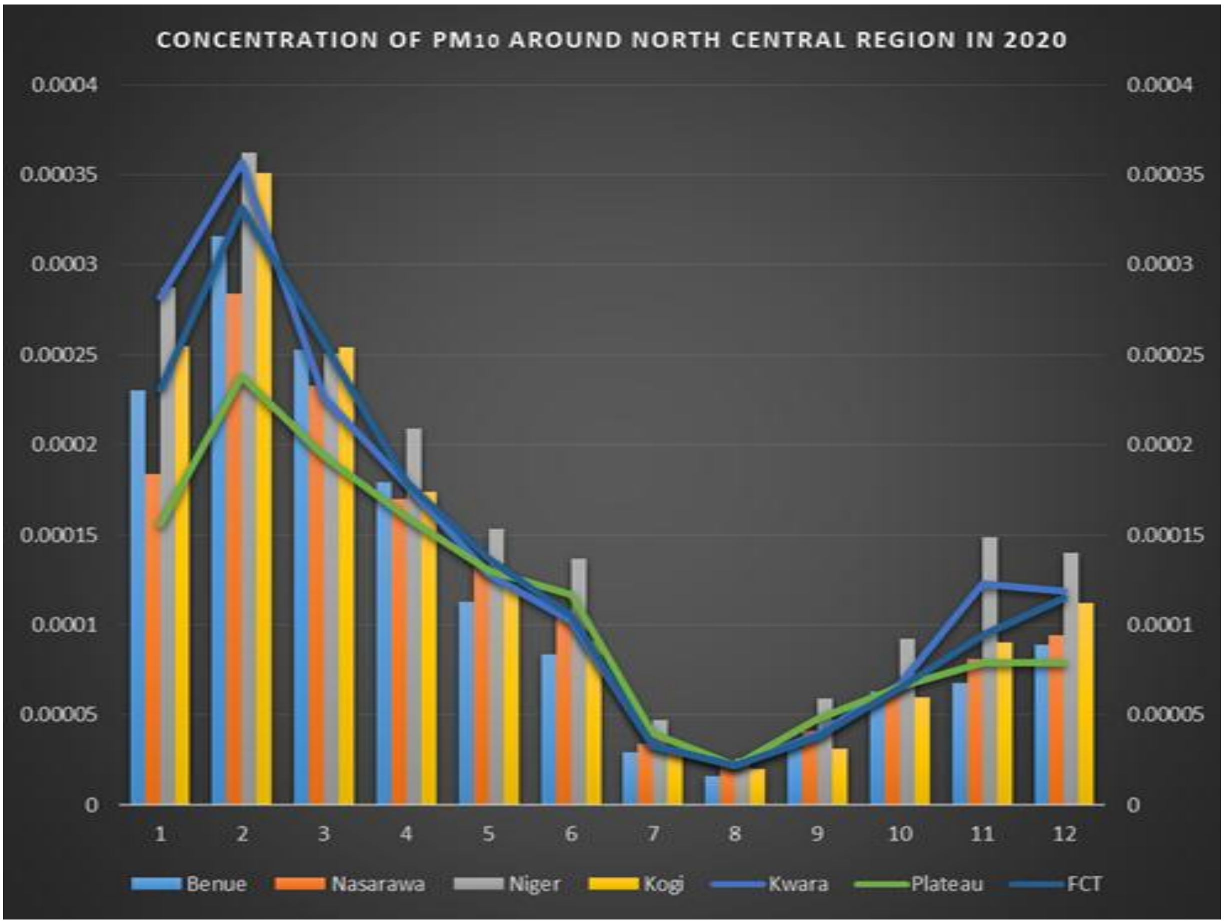

Fig. 5. Graphical representation of the concentration of PM_{10} around Study Area in 2020

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

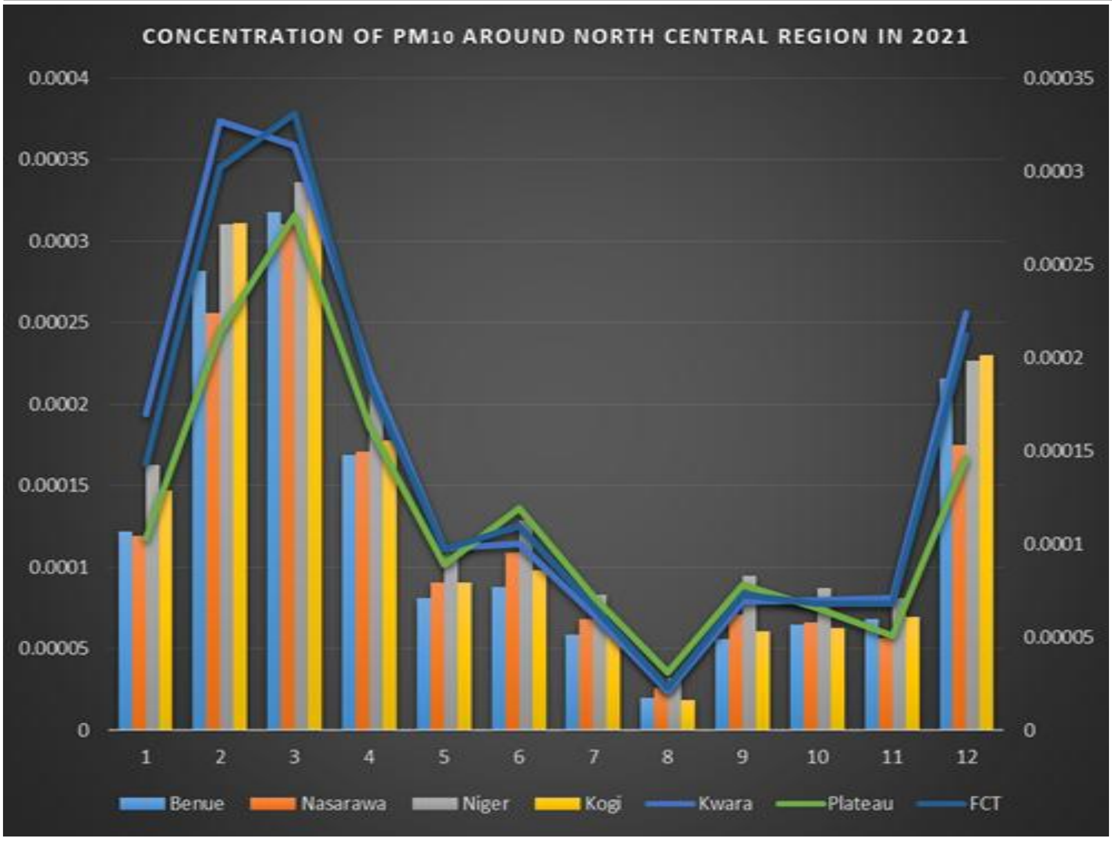

Fig. 6. Graphical representation of the concentration of PM_{10} around Study Area in 2021

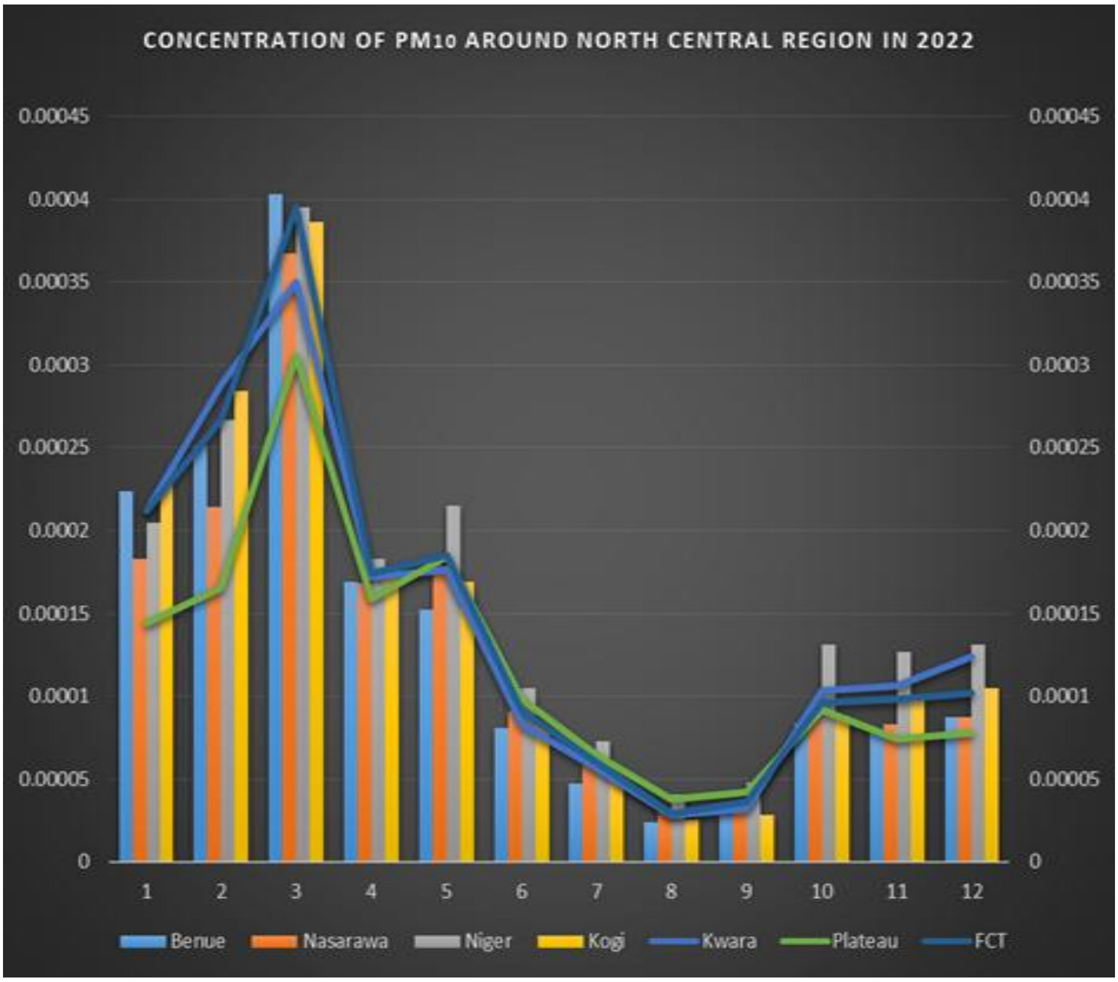

Fig. 7. Graphical representation of the concentration of PM_{10} around Study Area in 2022

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

Table 1: Mean Concentration and AQI of Direct $PM_{2.5}$ Concentration for all locations (2020 – 2022)

Year	**Location**	**$PM_{2.5}$ Concentration (μg/m³)**		**Level of Health Concern/ WHO Standard**
		Mean Conc.	**AQI**	
2020	Benue	5.70	32	Good
	Nasarawa	5.70	32	Good
	Niger	9.10	51	Moderate
	Kogi	5.90	33	Good
	Kwara	6.10	34	Good
	Plateau	5.90	33	Good
	FCT	8.80	49	Good
2021	Benue	4.80	27	Good
	Nasarawa	5.70	32	Good
	Niger	10.1	53	Moderate
	Kogi	5.00	28	Good
	Kwara	5.00	28	Good
	Plateau	4.80	27	Good
	FCT	8.20	46	Good
2022	Benue	6.30	35	Good
2022	Nasarawa	6.10	34	Good
	Niger	11.7	56	Moderate
	Kogi	6.30	35	Good
	Kwara	6.10	34	Good
	Plateau	6.40	36	Good
	FCT	7.70	43	Good

Table 2: Mean Concentration and AQI of Direct PM_{10} Concentration for all locations (2020 – 2022)

Year	**Location**	**PM_{10} Concentration (μg/m³)**		**Level of Health Concern/ WHO Standard**
		Mean Conc.	**AQI**	
2020	Benue	123	85	Moderate
	Nasarawa	119	83	Moderate
	Niger	159	103	Unhealthy
	Kogi	131	89	Moderate
	Kwara	139	93	Moderate
	Plateau	111	79	Moderate
	FCT	133	90	Moderate
2021	Benue	129	88	Moderate
	Nasarawa	127	87	Moderate
	Niger	155	101	Unhealthy
	Kogi	135	95	Moderate
	Kwara	143	95	Moderate
	Plateau	117	82	Moderate
	FCT	139	93	Moderate
2022	Benue	135	91	Moderate
	Nasarawa	133	90	Moderate
	Niger	159	103	Unhealthy
	Kogi	143	90	Moderate
	Kwara	143	95	Moderate
	Plateau	119	83	Moderate
	FCT	145	96	Moderate

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

Table 3: Modelled or Indirect Mean Concentration of $PM_{2.5}$ and AQI for all locations (2020 – 2022)

Year	**Location**	**Modelled $PM_{2.5}$ Concentration (μg/m³)**		**Level of Health Concern/ WHO Standard**
		Modelled Conc. ($PM = \beta_0 + \beta_1 X_1 + \varepsilon$)	AQI	
2020	Benue	8.60	48	Good
	Nasarawa	8.10	45	Good
	Niger	10.10	53	Moderate
	Kogi	9.60	52	Moderate
	Kwara	9.00	50	Moderate
	Plateau	8.80	49	Good
	FCT	9.10	51	Moderate
2021	Benue	7.70	43	Good
	Nasarawa	8.60	48	Good
	Niger	15.00	62	Moderate
	Kogi	7.90	44	Good
	Kwara	7.50	42	Good
	Plateau	7.30	41	Good
	FCT	8.10	45	Good
2022	Benue	8.20	46	Good
2022	Nasarawa	8.60	48	Good
	Niger	9.60	52	Moderate
	Kogi	7.90	44	Good
	Kwara	7.00	39	Good
	Plateau	7.20	40	Good
	FCT	8.80	49	Good

Table 4: Modelled or Indirect Mean Concentration of PM_{10} and AQI for all locations (2020 – 2022)

Year	**Location**	**Modelled PM_{10} Concentration (μg/m³)**		**Level of Health Concern/ WHO Standard**
		Modelled Conc. ($PM = \beta_0 + \beta_1 X_1 + \varepsilon$)	AQI	
2020	Benue	143	95	Moderate
	Nasarawa	139	93	Moderate
	Niger	179	113	Unhealthy
	Kogi	151	99	Moderate
	Kwara	154	100	Moderate
	Plateau	131	89	Moderate
	FCT	167	107	Unhealthy
2021	Benue	149	98	Moderate
	Nasarawa	147	97	Moderate
	Niger	175	111	Unhealthy
	Kogi	154	100	Moderate
	Kwara	145	96	Moderate
	Plateau	137	92	Moderate
	FCT	151	99	Moderate

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

2022	Benue	154	100	Moderate
2022	Nasarawa	165	106	Unhealthy
	Niger	179	113	Unhealthy
	Kogi	169	108	Unhealthy
	Kwara	161	104	Unhealthy
	Plateau	139	93	Moderate
	FCT	145	96	Moderate

Table 1-4, represents the Mean Concentration and AQI of both Direct and Indirect Particulate Matter ($PM_{2.5}$ and PM_{10}) concentration. The PM_{10} concentration (µg/m^3) for all locations in year 2020, 2021 and 2022 is above Standard recommendations. According to the WHO Standard, Niger State exceeded the "moderate" limit, because it recorded the Particulate Matter (PM_{10}) concentration values of 103µg/m^3, 101µg/m^3 and 103µg/m^3 for years 2020, 2021 and 2022 respectively. The health concern is said to be "unhealthy for sensitive groups" which implies people with respiratory or heart diseases and children are the groups most vulnerable. This result is a reflection of the data used in plotting the graphs displayed in Figure 2-7, which is the graphical represe concentration of PM_{10} around Study Area in 2020, 2021 and 2022. The corresponding modelled result with Particulate Matter (PM_{10}) concentration is 113µg/m^3, 111µg/m^3 and 113µg/m^3 for years 2020, 2021 and 2022 respectively. The $PM_{2.5}$ concentration (µg/m^3) for all locations in year 2020, 2021 and 2022 is above Standard recommendations. According to the WHO Standard, Niger State was moderate with Particulate Matter ($PM_{2..5}$) Concentration values of 51µg/m^3, 53µg/m^3 and 56µg/m^3 for years 2020, 2021 and 2022 respectively. The health concern is said to be "moderate" which implies people with respiratory or heart diseases and children may operate in the locations with health challenges. This result is a reflection of the data used in plotting the graphs displayed in Figure 2-7, which is the graphical representation of the concentration of $PM_{2.5}$ around Study Area in 2020, 2021 and 2022. The corresponding modelled result with Particulate Matter ($PM_{2.5}$) concentration is 53µg/m^3, 62µg/m^3 and 52µg/m^3 for years 2020, 2021 and 2022 respectively. Niger State recorded the highest concentration. The high concentration of the particles is not unconnected to the anthropogenic activities of farming, mining, constant vehicular movement, industrialization and so on. These activities increase the velocity of Wind Speed of the particles around the locations. The modelled results for Particulate Matter (PM_{10}) concentration shows the particles are unhealthy for human presence, this is because it exceeds 100µg/m^3 annual limit set by WHO. Fig.8-11, represents graphs for the Table 1-4. Also, Table 5 is the Performance Indicator for the model.

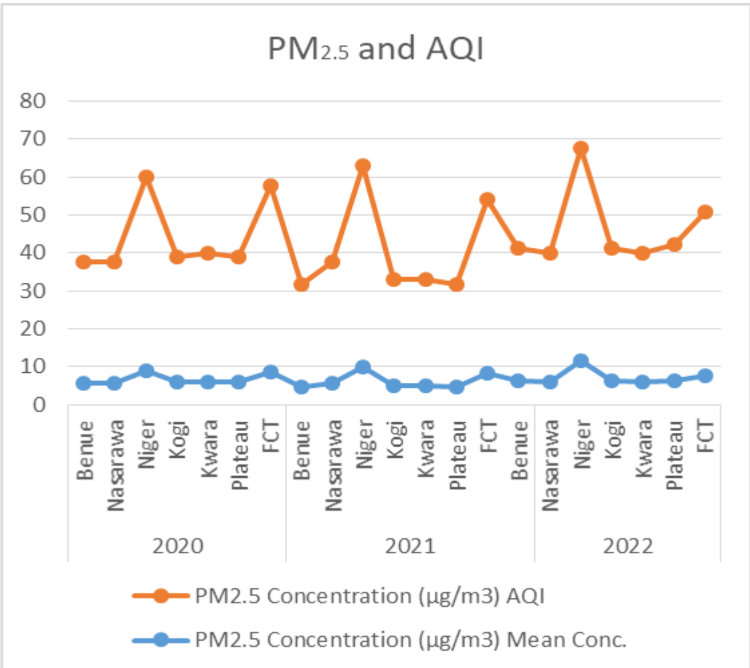

Fig. 8: Graph of $PM_{2.5}$ and AQI from 2020 to 2022

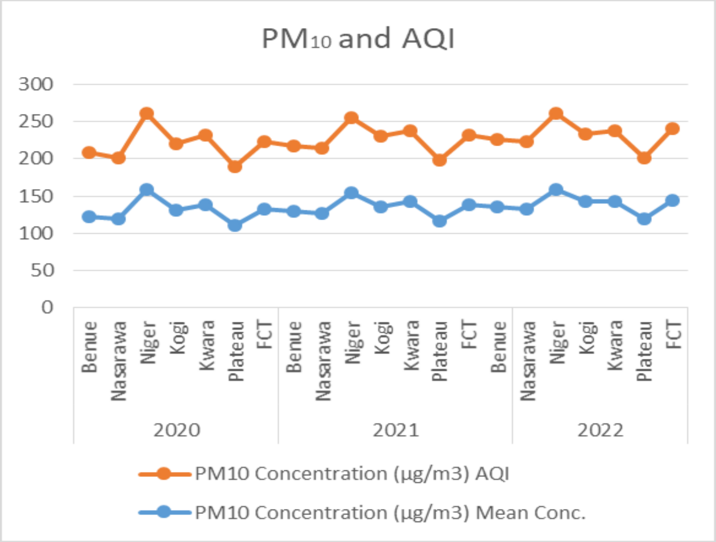

Fig. 9: Graph of PM_{10} and AQI from 2020 to 2022

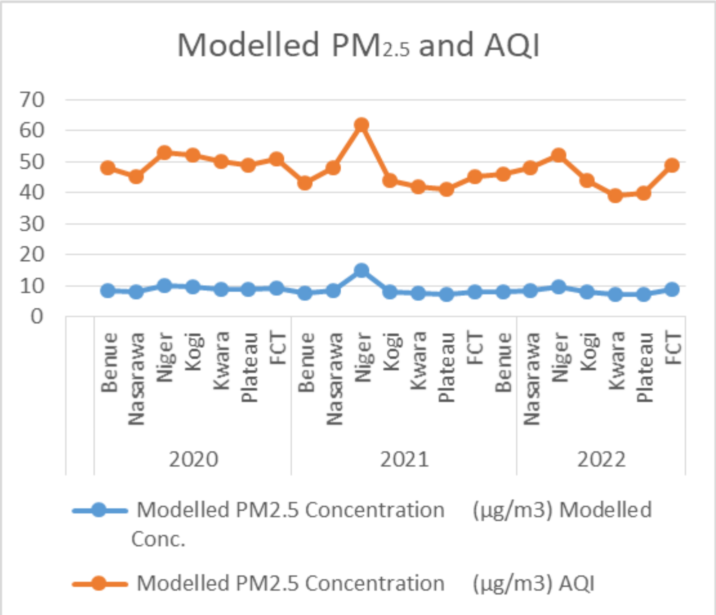

Fig. 10: Graph of Modelled $PM_{2.5}$ and AQI from 2020-2022

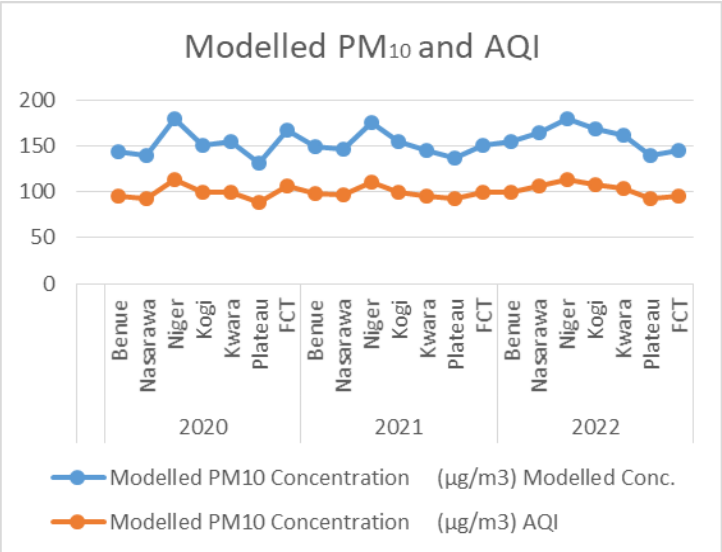

Fig. 11: Graph of Modelled PM_{10} and AQI from 2020 to 2022.

Fig. 8-11, represents graphs of Particulate Matter ($PM_{2.5}$ and PM_{10}) concentration and Air Quality Index (AQI) for the 3 years under study. Particularly, Fig. 10-11 represents modelled Particulate Matter ($PM_{2.5}$ and PM_{10}) concentration in 2020, 2021 and 2022. The similarities in the graphs show that both the PM concentration and AQI aligned. The graphs of the direct data and the indirect data were similar, though with <5% difference in their features which constitutes a high degree of accuracy. The performance indicators used are the Root Mean Square Error (RMSE) and the value of coefficient of determination (R^2). The highest RMSE/R2 recorded for the years under study; 2020, 2021 and 2022 were 299.6660/0.1727, 300.4340/0.2477 and 300.0657/0.3398 for Nasarawa, Niger and Kwara States respectively. The error in the model was evaluated based on RMSE and the accuracy was assessed using R^2. The increasing values of R^2 and decreasing value of RMSE in each location indicates that the Particulate Matter ($PM_{2.5}$ and PM_{10}) is very well explained by the input variable in the model being developed. It's either RMSE was decreasing and increasing or R^2 increased and decreased for each location. The indicator showed that the calculated indirect or modelled AQI and concentration can be relied on across the locations in the absence of direct data from Polar Satellites. Table 5 and Fig. 12-14 further explains the performance indicator test carried out. The Temperature (K) was a major meteorological factor used as downloaded alongside the PM concentration. S, the error, ε was obtained from each of the values of temperature across the months throughout the years under study.

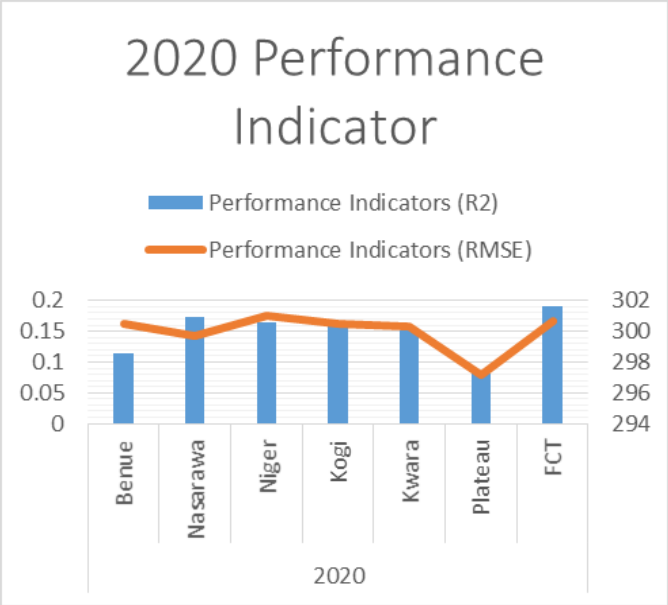

Fig. 12: The Performance Indicator for 2020

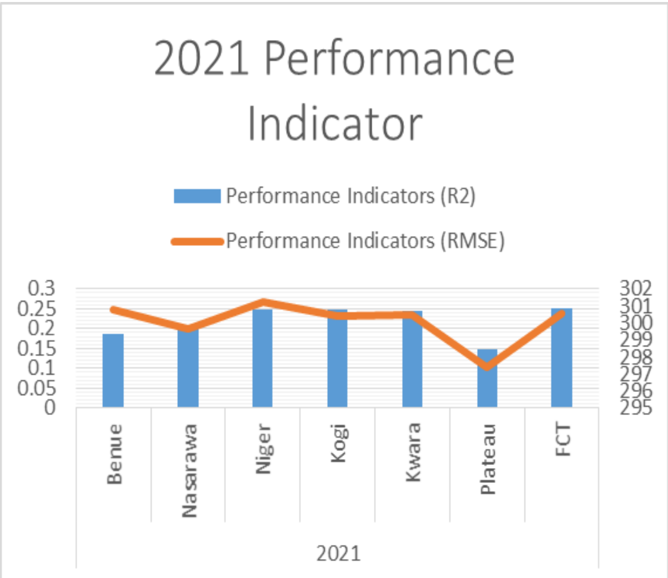

Fig. 13: The Performance Indicator for 2021

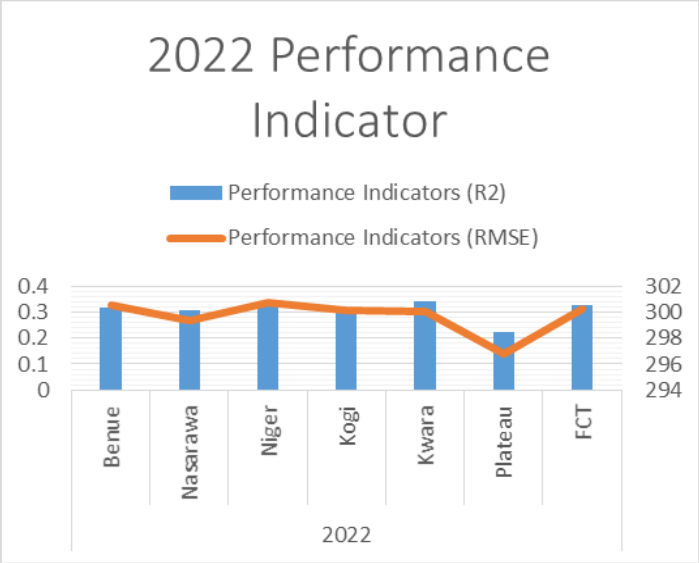

Fig. 14: The Performance Indicator for 2022.

CONCLUSION

The results show that seasonal variation has great impact on Particulate Matter ($PM_{2.5}$ and PM_{10}) concentration. The two identified seasons (Wet and Dry) had different features in the concentration. The temperature variations in these seasons was distinct. There was higher particulate concentration during the dry seasons due to increase in velocity of the particles. The result explains increase in the speed of the wind conveying the particles. The impact of temperature on the locations is the outcome seen as high particulate matter concentration. The Multiple Linear Regression (MLR) model was applied to predict Particulate Matter ($PM_{2.5}$ and PM_{10}) concentration and Air Quality Index prediction in Six States and the Federal Capital Territory, Abuja, has two main seasons (Dry and Wet) in 2020, 2021 and 2022.

The meteorological variables (of temperature) for the average of 12 Months was used to model the concentration. The Air Quality Index was calculated with the indirect data and it showed a percentile difference of about 5% between direct and indirect Particulate Matter concentration. At high Particulate Matter concentration, the Air Quality Index (AQI) for both direct and indirect Particulate Matter ($PM_{2.5}$ and PM_{10}) increased. The calculated AQI around the Study Area in some locations exceeded the WHO Annual World Standard. The AQIs with highest concentration for all the years under study exceeded the WHO World Annual Standard for the category of moderate health impact on both $PM_{2.5}$ and PM_{10} which is <50 $\mu g/m^3$ and <100 $\mu g/m^3$ respectively. It shows the high concentration results obtained are unhealthy for the locations and is a contributing factor to cases of cardiopulmonary and lung disease mortality around the region. This is an indication that people who live in these location may have been affected or are liable to be affected by some diseases caused by these fine and coarse particles that has the ability to penetrate the lungs as inhaled during respiration. In fact, long-term exposure to these pollutants may lead to a marked reduction in life expectancy due to increase in cardiopulmonary and lung disease mortality.

The decline in the concentration was in late April of each years under study and as well there was a sharp rise around late October of each of the years. The period between April and early October is said to be the Wet Season in these locations. The concentration went high in each of the years during January to March and as well as late October to December, which represented the Dry Season. Particulate Matter concentration became more prevailing in this season (Dry Season) for each of the locations in the Study Area.

ACKNOWLEDGMENT

We appreciate the entire Members of Staff in the Department of Physics, Nasarawa State University, Keffi for the opportunity granted us to carry out this research and publish. We are particularly grateful to the Head of Department, Professor Ibrahim Umaru. We are deeply grateful for the contribution of Associate Professor

Samson D. Yusuf, Dr. A.A. Mundi, Dr. M.M.Idris and Mr.Ejiofor Okechukwu. Thank you so much. Our appreciation goes to the National Space Research and Development Agency (NASRDA) Members of Staff; Dr. Liade Aderoju and Mr. James Adah for providing us with the secondary data and useful information needed to carry out this research work.

REFERENCES

1. Abam, F.I. & Unachukwu, G.O. (2009). Vehicular Emission and Air Quality Standards in some selected Areas of Calabar, Nigeria. European Journal of Scientific Research, 34 (4), 550-560.
2. Abiye, O. E., Imoh, B. O. & Godwin, C. E.(2013). Elemental Characterization of Urban Particulates at Receptor Locations in Abuja, North-Central Nigeria. Atmospheric Environment, 81 (2013), 695-701.
3. Abdullah, S., Ismail, M., Fong, S. Y. & Ahmed, A. L. (2016). Evaluation for Long Term PM_{10} Concentration Forecasting using Multi-Linear Regression (MLR) and Principal Component Regression (PCR) Models. Environment Asia, 9(2), 101-109.
4. Abulude, F.O., Fagbayide, S.D., Elisha, J.J., Makinde, O.E. & Akinnusotu, A. (2019). Particulate Matter and Source Identification: A Case Study of Nigeria. Engineering & Applied Science Research, 46(2), 133-145.
5. Adeniran, J. A., Yusuf, R. O. & Olajire, A. A. (2017). Exposure to Coarse and Fine Particulate Matter at and around Major Intra-Urban Traffic Intersections of Ilorin Metropolis, Nigeria. Atmospheric environment, 166(1), 383-392.
6. Ahmad, W., Sobia, N., Muhammad, N. & Rahib, H. (2013); Assessment of Particulate Matter (PM_{10} & $PM_{2.5}$) and Associated Health Problems in Different Areas of Cement Industry, Hattar, Pakistan Haripur, published by National Centre of Excellence in Geology, University of Peshawar. 25(1), 20-35.
7. Akinfolarin, O.M., Boisa, N. & Obunwo, C.C. (2017). Assessment of Particulate Matter- Based Air Quality Index in Port Harcourt, Nigeria. J. Environ Anal Chem. 4(2), 224- 255.
8. Akpofure, R. (2015). An Assessment of Indoor Air Quality in Selected Households in Squatter Settlements Warri, Nigeria. Journal of Advances in Life Sciences. 5(1), 1-11.
9. Akuro, A. (2012). Air Quality Survey of some Locations in the Niger Delta Area; Nigeria Remediation Head Assurance & Governance, Shell Petroleum Development Company of Nigeria Ltd. J. Appl. Sci. Environ. Manage, 16 (1), 137 -146.
10. Atta, A. (2014). Manure Management Specialist: Alberta’s Agricultural Food, and Rural Development. Alberta’s Agriculture Industry (AAI), Canada. 12(3), 729-782.
11. Beychok, M. R. (2005). Fundamentals of Stack Gas Dispersion (4th ed.). Author-Published. ISBN 0-9644588-0-2, 2(1), 3-12.
12. Biswas, S., Anindita, .D. & Shyam, K.M. (2015). Study of Urban Air Quality in Kolkata: Kolkata Air Quality Information System, West Bengal Pollution Control Board Report by University of Calcutta, Kolkata India.15(1), 1-74.
13. Boucher, O. (2015). Solar Interaction with Atmospheric Aerosols; a Review of Geophysics Journal. 38(1), 513-543, doi: 10.1007/978-94-017-9649-1-2.
14. Briggs, G.A. (1965). A Plume Rise Model Compared with Observations. JAPCA, 15(2),433–438.
15. Briggs, G.A. (1968). CONCAWE Meeting: Discussion of the Comparative Consequences of Different Plume Rise Formulas. Atmos. Envir., 2(2), 228–232.
16. Briggs, G.A. (1972). Discussion: Chimney Plumes in Neutral and Stable Surroundings. Atmos. Envir., 6(1), 507–510.
17. Chou, C.M., Chen, Y.C., Lee, M.T., Chen, G.D., Lu, I.C., Chen, S.T. & Huang, C.J. (2006). Expression and Characterization of a Brain-Specific Protein Kinase BSKI46 from Zebrafish. Biochemical and Biophysical Research Communications, 340(3), 767-775.
18. Christopher, S. A., Fahey, D. W., Isaksen, I. S. A., Jones, T. A., Kahn, R. A., Loeb, N., Quinn, P., Remer, L., Schwarz, J. P. & Yttri, K. E. (2009). Modelled Radioactive Forcing of the Direct Aerosol Effect with Multi-Observation Evaluation. Atmos. Chem. Phys. 9(1), 1365-1392, doi: 10.5194/acp-9-l365.
19. Daly, A., & Zannetti, .P. (2007). An Introduction to Air Pollution Definitions, Classifications, and History. Arab School for Science and Technology (ASST) and the Environ Comp Institute. 32(1), 1760-1830.

20. EPA. (2014a). Hazelwood Coal Mine Fire PM Health Protection Protocol; Department of Health and EPA Victoria.12 (1), 145-155.
21. EPA. (2014b). Bushfire Smoke, Air Quality and Health Protocol; Department of Health and EPA Victoria. 12(2), 156-162.
22. EPA. (2015a). Community Smoke, Air Quality and Health Protocol; Department of Health. EPA Victoria and Emergency Management Victoria. 13(1), 177-179.
23. EPA. (2015b). Rapid Deployment of Air Quality Monitoring for Community Health Guideline; Department of Health and Human Services and Emergency Management Victoria. EPA-Victoria, State Government of Victoria. 13(2), 180-182.
24. Facchini, M.C., Rinaldi, .M., Decesari, .S., Carbone, C., Finessi, E., Mircea, M., Fuzzi, S., Ceburnis, .D, Flanagan, R., Nilsson, E.D., De-Leeuw, G., Martino, M., Woeltjen, J. & O'Dowd, C.D. (2008). Primary Submicron Marine Aerosol Dominated by Insoluble Organic Colloids and Aggregates. Geophys. Res. Lett. 35(1), 178-197. doi: 10.1029/2008GL03 4210.
25. Filip, G.M. & Brezoczki, V.M. (2017). Particulate Matter Urban Air Pollution from Traffic Car; Engineering Faculty, Mineral Resource and Environment Engineering Department, Baia Mare, Romania. 70(1), 2000-2027. doi:10.1088/1757-899X/200/1/012027.
26. Fu, P. & Rich, P.M. (2000). The Solar Analyst 1.0 Manual. Helios Environmental Modelling Institute (HEMI), USA. 15(1), 23-29.
27. Gayle, L. & Miller, D.V.M. (2013). An Introduction to Applied Epidemiology and. Biostatistics, Principles of Epidemiology. Jefferson County Department of Health and Environment, Colorado. 144(1), 224-287.
28. Gobo, A.E., Ideriah, T.J., Francis, T.E. & Stanley, H.O. (2012). Assessment of Air Quality and Noise around Okrika Communities, Rivers State, Nigeria. J. Appl. Sci. Environ. Manage .16(2), 75-83.
1. 29. Gullet, N.P., Rahul-Amin, A.R.. Bayraktar, S., Pezzutb, J.M., Shin, D.M., Khuri, F.R., Aggarwal, B.B., Surh, Y J. & Kukuk, O. (2010). Cancer Prevention with Natural Compounds; Department of Radiation Oncology, Winship Cancer Institute, Emory University, Atlanta, GA 30322, USA. 37(3), 258-81. doi:10.1053/j. seminoncol 2010.06.014.
29. Hatzianastassiou, N., Matsoukas, C., Drakakis, E., Stackhouse, P. W., Koepke, P., Fotiadi, A. , Pavlakis, K. G. & Vardavas, I. (2007). The Direct Effect of Aerosols on Solar Radiation Based on Satellite Observations, Re-Analysis Datasets, and Spectral Aerosol Optical Properties from Global Aerosol Data Set (GADS). Atmos. Chem. Phys., 7(1), 2585-2599.
30. Iheanyichukwu, O. A., Chizoruo, I. F., Chukwuemeka, N. P., Ikechukwu, A. J. & Kenechukwu, E. C. (2016). Geospatial and Geostatistical Analyses of Particulate Matter (PM_{10}) Concentrations in Imo State, Nigeria. International Letters of Natural Sciences, 57(1), 222-256.
31. Ito, K., Mathes, .R., Ross, .Z., Nadas, .A,, Thurston, G. & Matte, T. (2011). Fine Particulate Matter Constituents Associated with Cardiovascular Hospitalizations and Mortality in New York City. Environ. Health Prospect, 119(2), 467 - 473. doi: 10.1289.ehp. 1002667.
32. Jaenicke, R. (2005). Abundance of Cellular Material and Proteins in the Atmosphere. Science Direct, 10(1), 73-308.
33. Jelili, M. O., Gbadegesin, A. S. & Alabi, A. T. (2020). Comparative Analysis of Indoor and Outdoor Particulate Matter Concentrations and Air Quality in Ogbomoso, Nigeria. Journal of Health and Pollution, 10(28), 201-205.
34. Kanee, R. B., Adeyemi, A., Edokpa, D. O. & Ede, P. N. (2020). Particulate Matter-Based Air Quality Index Estimate for Abuja, Nigeria: Implications for Health. Journal of Geoscience and Environment Protection, 8(5), 313-321.
35. Kelly, F.J. & Fussell, J.C. (2015). Air Pollution and Public Health: Emerging Hazards and Improved Understanding of Risk in London. Environ Geochem Health, 37(1), 631- 649. doi: 10.1007/sl0653-015-9720-1.
36. Kim, S.Y., Peel, J.L., Hannigan, M.P., Dutton, S.J., Sheppard, L. & Clark, M.L. (2012). The Temporal Lag Structure of Short-Term Associations of Fine Particulate Matter Constituents and Cardiovascular and Respiratory Hospitalizations. Environ Health prospect, 120(1), 1094-1099. doi:10.1289/ehp. 1104721.
37. Kreyling, J., Beierkuhnlein, C. & Jentsch, A. (2010). Effects of Soil Freeze-Thaw Cycles Differ between Experimental Plant Communities. Basic Appl. Ecol., 11(1), 65—75.

38. Kumar, A.P. & Krishna, K. (2017). Urban Climate Research, India: Department of Remote Sensing, Birla Institute of Technology, Mesra Ranchi 835215, Jharkhand. 20(1), 94-119.
39. Lala, M. A., Onwunzo, C. S., Adesina, O. A. & Sonibare, J. A. (2023). Particulate Matter Pollution in Selected Areas of Nigeria: Spatial Analysis and Risk Assessment. Case Studies in Chemical and Environmental Engineering, 7(1), 100-288.
40. Laws & Edward .(2018). Aquatic Pollution: An Introductory Text (4th Edition). Hoboken, N,J.John Wiley & Sons.23(1), 345-377.
41. Lazaridis, M. & Colbeck, I. (2010). Human Exposure to Pollutants via Dermal Absorption and Inhalation; Environmental Pollution Book Series. EPOL, Volume 17, 12(1), 24-36.
42. Leek, C. & Bigg, E.K. (2008). Comparison of Sources and Nature of the Tropical Aerosol with the Summer High Arctic Aerosol. Tellus. 60(1), 118-126.
43. Lympson, F.P. (2015). Carbon Monoxide Emission : its Impact on Human Health in Abuja, Nigeria. 27(6), 278-580. doi:10.13140/RG.2.1. 2067.3441
44. Magdalena, R. & Katarzyna, J.R. (2016). Article on Explanation of the High PM_{10} Concentrations Observed in Polish Urban Areas. 9(1), 517-531. doi 10.1007/s11869-015-0358-z.
45. Meister, K., Johansson, C. & Forsberg, B. (2032). Estimated Short-Term Effects of Coarse Particles on Daily Mortality in Stockholm: Sweden. Journal of Environ. Prospect. 120(3), 431-436.
46. Ming-Dah, C., Po-Hsiung, L., Po-Lun, M. & Ho-Jiunn, L. (2006). Effects of Aerosols on the Surface Solar Radiation in a Tropical Urban Area Surface. Journal of Geo¬physical Research. Vol. Ill, 19(1), 220-267. doi: 10.1029/2005jd006910.
47. Naidja, L., Ali-Khodja, H. & Khardi, S. (2018). Sources and Levels of Particulate Matter in North African and Sub-Saharan Cities: a Literature Review. Environmental Science and Pollution Research, 25(1), 12303-12328.
48. Nathanson, J.A. (2016). A Geogenic Source of Indoor Air Pollution in Radon32, Environmental Technology, Water Supply, Waste Disposal, and Pollution Control. Cranford, New Jersey, Union County College. Vol.1, 10(1), 114-134.
49. Ngele, S. O., & Onwu, F. K. (2015). Measurements of Ambient Air Fine and Coarse Particulate Matter in Ten South-East Nigerian Cities. Research Journal of Chemical Sciences, 22(3), 1606-1674.
50. NIMET, (2017) Nigerian Meteorological Agency, Seasonal Solar Energy Prediction. Annual Report, 13(1), 233-244.
51. Nordin, M., Rafee, .M. & Ho-Chin, S. (2015). UTM-Low Carbon Concentration: Johor Bahru, Asian Research Centre, Faculty of Building Environment Universiti Telcnologi Malaysia. Vol.1, 110(1), 233-250.
52. Nwaogazie, I.L & Zagha, O. (2015). Roadside Air Pollution Assessment in Port Harcourt, Nigeria. Standard Scientific Research and Essays, 3(1), 66-74.
53. Obioh, I. B., Ezeh, G. C., Abiye, O. E., Alpha, A., Ojo, E. O. & Ganiyu, A. K. (2013). Atmospheric Particulate Matter in Nigerian Mega Cities. Toxicological & Environmental Chemistry, 95(3), 379-385.
54. Offor, I. F., Adie, G. U. & Ana, G. R. (2016). Review of Particulate Matter and Elemental Composition of Aerosols at Selected Locations in Nigeria from 1985–2015. Journal of Health and Pollution, 6(10), 1-18.
55. Ogundele, L. T., Owoade, O. K., Hopke, P. K. & Olise, F. S. (2017). Heavy Metals in Industrially Emitted Particulate Matter in Ile-Ife, Nigeria. Environmental Research, 156(12), 320-325.
56. Okudo, C. C., Ekere, N. R. & Okoye, C. O. B. (2022). Evaluation of Particulate Matter (PM2. 5 and PM_{10}) Concentrations in the Dry and Wet Seasons As Indices of Air Quality in Enugu Urban, Enugu State, Nigeria. Journal of Chemical Society of Nigeria, 47(5), 345-355.
57. Osueke, C. O., Uzendu, P. & Ogbonna, I. D. (2013). Study and Evaluation of Solar Energy Variation in Nigeria. International Journal of Emerging Technology and Advanced Engineering, 3(6), 2250-2459.
58. Ougbuaja, V. O. & L. Z. Barsisa. Atmospheric Pollution in North-East Nigeria: Measurement and Analysis of Suspended Particulate Matter. Bulletin of the Chemical Society of Ethiopia, 15(2), 109-118.
59. Owoade, O. K., Olise, F. S., Ogundele, L. T., Fawole, O. G. & Olaniyi, H. B. (2012). Correlation between Particulate Matter Concentrations and Meteorological Parameters at a site in Ile-Ife, Nigeria. Journal of Science, 14(1), 83-93.
60. Penner, J.E., Houghton, .I T., Ding, Y., Griggs, D.J., Noguer, M., Dai, .P.J. & Vander, L. (2001). Direct and Indirect Effects of Aerosol, their Impact on Climate Change, the Scientific Basic, London. The

Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.Vol.1, 11(1), 23-56.

61. Perri, T. O., Weli, V. E., Poronakie, B. & Bodo, T. (2022). Distribution of Respiratory Tract Infectious Diseases in Relation to Particulate Matter ($PM_{2.5}$) Concentration in Selected Urban Centres in Niger Delta Region of Nigeria. Journal of Geographical Research, 5(1), 1-11.
62. Pope, C.A., Burnett, R.T. & Thun, M.J. (2002). Lung Cancer, Cardiopulmonary Mortality, and Long-Term Exposure to Fine Particulate Air Pollution. Journal on American Medical Association, 287(1), 1132—1141.
63. Reizer, M. (2013). Methodology for Identification of the Causes of Particulate Matter, Warsaw, Poland. House of Warsaw University of Technology Press.Vol.1, 14(1), 556-578.
64. Ruckerl,.R., Schneider, A., Breitner, S., Cyrys, J. & Peters, A. (2011). Health Effects of Particulate Air Pollution: A Review of Epidemiological Evidence, 23(10), 555-592. doi: 10.3109/08958378.2011.593587.
65. Slade, D.H. (1968). Meteorology and Atomic Energy 1968. Air Resources Laboratory, U.S. Dept. of Commerce.Vol.1, 45(2), 506-522.
66. Sutton, O.G. (1974). The Problem of Diffusion in the Lower Atmosphere and the Theoretical Distribution of Airborne Pollution from Factory Chimneys. QJRMS, 73(1), 426-455.
67. Turner, D.B. (1994). Workbook of Atmospheric Dispersion Estimates: an Introduction to Dispersion Modeling (2nd Ed.). CRC Press, 23(1), 334-339.
68. Ugwuanyi, J. U., Tyovenda, A. A. & Ayua, T. J. (2016). Fine Particulate Distribution and Assessment in Nasarawa State-Nigeria. IOSR Journal of Applied Physics, 8(2), 32-38.
69. Unger, N., Tami, C. B., James, S.W., Dorothy, M.K, Surabi, M,, Drew, T.S. & Susanne, B. (2010). Attribution of Climatic Forcing to Economic Sectors. Proc. Natl. Acad. of Sci, USA. 107 (8), 3382-3387. doi: 10A073/pnas.0906548107.
70. US-EPA. (2014) Climate Change Indicators in the United States; U.S. Environmental Protection Agency, Third edition. EPA 430-R-14-004. www.epa.gov/climatechange/indicators.
71. Uzoekwe, S. A. & Iniaghe, P. O. (2024). Distribution, Levels, Potential Sources and Human Health Risk Assessment of Trace Metals in Atmospheric Particulate Matter in Ogbia Communities of Bayelsa State, Niger Delta, Nigeria. Journal of Applied Sciences and Environmental Management, 28(3), 917-923.
72. Wambebe, N. M. & Duan, X. (2020). Air Quality Levels and Health Risk Assessment of Particulate Matters in Abuja Municipal Area, Nigeria. Atmosphere, 11(8), 817-833.
73. William, H.B. (2012). METEO 300, Fundamentals of Atmospheric Science by a Distinguished Professor of Meteorology, College of Earth and Mineral Sciences.Vol.2, 10(1), 44-47.
74. US-EPA. (2009) B. A Guide to Air Quality and Your Health. Environmental Protection Agency Office of Air Quality Planning and Standards Outreach and Information Division Research Triangle Park, NC EPA-456/F-09-002.Vol.3, 77(2), 59-68.
75. US-EPA. (2014). Air Quality Guidelines Global Update, World Health Organization. Vol.4, 33(2), 356-377.
76. WHO, Geneva. (2008). Air Quality and Health Fact Sheet; World Health Organization, No. 313. (1), 224-343. Air Quality and Health. www.who.int.retrieved 2011-11-26.