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SPATIO-TEMPORAL ANALYSIS OF PARTICULATE MATTER AND IT'S HEALTH EFFECT ON THE RESIDENTS OF NIGERIA

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Abstract

Spatio temporal analysis of and health impact assessment of Particulate matter with diameter less than or equal to 2.5 micrometer (PM2.5) has been carried out for certain locations in Nigeria. The data covered a period of one year. ARIMA model was used to forecast $PM_{2.5}$ concentration for year 2023. Forecast showed that average values were; Anyigba 31.12µg/m^3, Ibadan 4.12µg/m^3, Auchi 4,993.88µg/m^3, Lekki, Lagos State 1.15µg/m^3, Benin 60.28µg/m^3, Kebbi 87.84µg/m^3. The health impact assessment for 2023 shows that for long term effect, Benin was forecasted to have the highest casualty. Adults 30+ years most likely to die due to natural causes are 4,180, those likely to die due to lung cancer are 5,640, children 0-5years likely to die due to ALRI are 4,590, mortality due to chronic obstructive pulmonary disease (COPD) are 3,804, mortality due to ischemic heart disease is 3,885, mortality due to stroke for adults are 3,561. It was similar for short term effects. According to the estimation for Benin, Hospital admissions due to respiratory diseases will be 1,030, which could rise to 2,082 if the concentration of PM 2.5 is not controlled below 10µg/m^3. Hospital admissions due to cardiovascular diseases (CVDs) including stroke, will be 504 and could rise to 905. Mortality due to all natural causes (adults 30+ years) will be 677 and could rise to 1,087. Restricted activity in days (RADs) for all ages will be 2,399 and could rise to 2,671 days.

Keywords: Auchi; $PM_{2.5}$; pulmonary; cancer; Ischemic; assessment.

1.0 Introduction

The term "environment" refers to the entirety of the physical environment in which a person lives, encompassing both living and non-living elements including air, light, soil, water, and other organisms like animals, plants, and bacteria. Man's existence depends heavily on the environment, which also serves as the foundation for his socioeconomic development, including that of his industrial, agricultural, and commercial sectors. (Osimobi et al., 2019). During the past decades, this socio-economic development has transformed the air around us by making it fatal. Toxic matters have been sent into the air in different forms and sizes. These harmful substances contained in an aerosol can aggravate existing respiratory and cardiac diseases as well as cause infections-induced asthma, breathing difficulties, wheezing, and coughing. Poor air quality has wide-ranging consequences on human health, mostly affecting the cardiovascular and respiratory systems of the body (Shehu et al., 2019). The effects of particulate matter on health are related to how deeply it can enter the respiratory system. Those who already have a respiratory condition are particularly at risk. The Health Effect Institute (HEI 2020) published global patterns in particulate matter with diameter less than or equal to 2.5 micrometre (PM2.5) burden of disease for the year 2019, the report stated that in sub-Saharan Africa, the top 10 countries with the highest burden are led by Nigeria (68,500 deaths, 95% UI: 41,000 to 102,000) followed more distantly by South Africa, Ghana, the Democratic Republic of the Congo, Cameroon, Ethiopia, Cote d'Ivoire, Tanzania, Angola, and Kenya. In South Asia, three countries account for most of the PM2.5-attributable deaths: India (980,000, 955 UI: 770,000 to 1,192,000), Pakistan (114,000, 95% UI: 78,500 to 151,000), and Bangladesh (74,000, 95% UI: 48,000 to 102,000). "Health Impact Assessment (HIA) is a linked set of approaches and tools for estimating, in advance of their occurrence, the implications for human health of proposed policies, programs, actions or events" (Mueller *et al.* 2020). There has not been a PM2.5 pollution health impact and risk assessment carried out in the locations under consideration, it is imperative for this research to be carried out. This research will give environmental stakeholders in Cross River State of Nigeria an insight of the number of deaths and hospital admissions that could be avoided if the concentration of pollutants is kept below the WHO guidelines. It will also provide a blue print for Nigeria as a country.

Several authors have carried out health impact assessments. Abe and Miraglia (2016) carried out a Health Impact assessment due to $PM_{2.5}$ in Sao Paulo in Brazil between 2009 – 2011. Riojas-Rodriguez *et al.* (2014) carried out a health impact assessment due to Ozone in Mexico City, the authors estimated that 2000 cases of hospitalization due to respiratory diseases could be avoided with (95% CI 249 -3,608), also 430 cases of hospitalization due to cardiovascular diseases could be avoided with (95% CI 185 – 612). Todorovic *et al.* (2019) carried out health impact assessment of Ozone in Serbia between the year (2011 – 2015). The authors found out that an estimated 1,411 (CI 685 – 2086) cases of mortality was attributed to Ozone within that study period. Fang *et al.* (2013) found out that an estimated 6,300 (1,600 – 10,400) deaths due to respiratory disease occurred due to $PM_{2.5}$. Arranz *et al.* (2014) carried out an impact assessment based on $PM_{2.5}$pollution in Valladolid, Spain between the year (1999 – 2008). The result showed that attributable deaths due to natural causes were 326 (CI 217 – 422) this affected the age group of 30+years. Attributable death cases due to lung cancer were 51 (CI 74 –

280). Attributable deaths due to respiratory diseases was 5 (CI 2 – 13) while attributable deaths due to cardiovascular diseases was 30 (CI 8 – 51). Forsberg *et al.* (2005) did a comparative Health Impact assessment due to particulate matter (PM) pollution in Scandinavia. The result shows that PM causes 3,700 (CI 2,649 – 4783) deaths per year for Swedish population and 1800 deaths is brought forward each year. Fang *et al.* (2013) found out that an estimated 100,000 premature deaths occurred due $PM_{2.5}$. Borrego-Hernandez et at (2014) carried out a health impact assessment due to ozone in Mexico City from 1991 to 2011. They found out that in 1992 – 2011, the total mortality was 2,897, number of hospital admissions due to respiratory diseases was 11,107, hospital visitations due to asthma attack was 3,233, minimum restricted activities in days were 19439159 while the number of days kids were out of school was 35549150. Naddafi *et al.* (2012) carried out a health impact assessment in Tehran, Iran. The result showed that ozone caused 819 excess cases of total mortality in Tehran, Iran. The main aim of this research is to carry out a health impact assessment of PM2.5 pollution for certain locations in Nigeria for the year 2023.

2.0 Methodology

2.1 Materials

The data used for this study was obtained from the purple air website using python programming language. The cities considered for the study include Anyingba, Kogi state with latitude 7° 15'N and longitude 7° 11'E. Ibadan, Oyo state with latitude 7° 24'47''N and longitude 3° 55'0''E. Auchi, Edo state with latitude 7° 04'N and longitude 6° 16'E. Lekki, Lagos state with latitude 6° 29'36''N and longitude 3° 43'14''E and Kebi, Kebi state with latitude 11° 30'47''N and longitude 4° 00'E. The data covered a period of one year (April 2021 to April 2022). The health impact assessment was done using the AirQ+ software developed by the World Health Organization (WHO). Visualizations were done using Tableau software together with python.

2.2 Method

The AirQ+ software was developed by the WHO to help in the creation of air quality impact assessment. When the software was launched, the create new impact assessment button launched the create new analysis dialog box. Here the analysis type was selected as ambient, time perspective was selected either as long- or short-term effect. $PM_{2.5}$ was selected as the pollutant of choice. The parameters used in the analysis properties page were; the mean concentration of $PM_{2.5}$, the total population, area size (km^2), latitude and longitude. The incidence (per 100, 000 population at risk per year) was set to 900, log-linear method was used for the calculation. Relative risk was set to 1. The cut off value (WHO standard for $PM_{2.5}$) was set to 10.

2.2.1 ARIMA model

Autoregressive model (AR), moving average model (MA) and autoregressive integrated moving average models (ARIMA) model: An autoregressive model of order P, AR(p) has the form

$$y_t = c + \mu_1 y_{t-1} + \mu_2 y_{t-2} + \cdots + \mu_p y_{t-p} + \varepsilon_t \qquad 1$$

Each AR term uses lagged values of residual in the forecasting equation.

The values $y_{t-1}, y_{t-2}\ldots y_{t-p}$are past time series values. μ_1, μ_2, μ_p are unknown parameters that relate to $y_{t-1}, y_{t-2}\ldots y_{t-p}$.

C is a constant. ε_t is white noise.

A moving average forecasting model uses lagged values of the forecast errors to improve the current forecast.

An MA(q) has the form

$$y_t = c + \alpha_1\varepsilon_{t-1} + \alpha_2\varepsilon_{t-2} + \cdots + \alpha_p\varepsilon_{t-p} + \varepsilon_t \qquad 2$$

where $\varepsilon_t, \varepsilon_{t-1}, \varepsilon_{t-2}, \varepsilon_{t-q}$ are the past errors while $\alpha_1, \alpha_2, \alpha_q$ are unknown parameters relating to y_t.

Arima (p,q) is given as

$$y_t = c + \mu_1 y_{t-1} + \mu_2 y_{t-2} + \cdots + \mu_p y_{t-p} + \varepsilon_t + \alpha_1\varepsilon_{t-1} + \alpha_2\varepsilon_{t-2} + \cdots + \alpha_p\varepsilon_{t-p} \qquad 3$$

2.3 Locations of study

The cities considered for the study include: Anyingba, Kogi state is located at latitude 7^o 15’N and longitude 7^o 11’E. The city has an area of 420km^2 with a population of 189, 976 inhabitants. Ibadan, Oyo state with latitude 7^o 24’47’’N and longitude 3^o 55’0’’E. The city has an area of 6800km^2 with a population of 3,649,000 inhabitants. Auchi, Edo state with latitude 7^o 04’N and longitude 6^o 16’E. The city has an area of 755km^2 with a population of 500,000 inhabitants. Lekki, Lagos state with latitude 6^o 29’36’’N and longitude 3^o 43’14’’E. The city has an area of 755km^2 with a population of 401,270 inhabitants. and Kebi, Kebi state with latitude 11^o 30’47’’N and longitude 4^o 00’E. The city has an area of 36,800km^2 with a population of 3,256,541 inhabitants.

Fig 1 Map of Nigeria showing locations of study

3.0 RESULTS AND DISCUSSION

3.1 Concentration of $PM_{2.5}$

The World Health Organization (WHO) has set the threshold for $PM_{2.5}$ concentration to be 10µg/m^3. If the concentration of $PM_{2.5}$ is overshooting this threshold, the air in the location is considered unsafe for breathing. Fig2 shows a calendar plot of $PM_{2.5}$ concentration at The Center for Atmospheric Research located in the University of Ibadan.

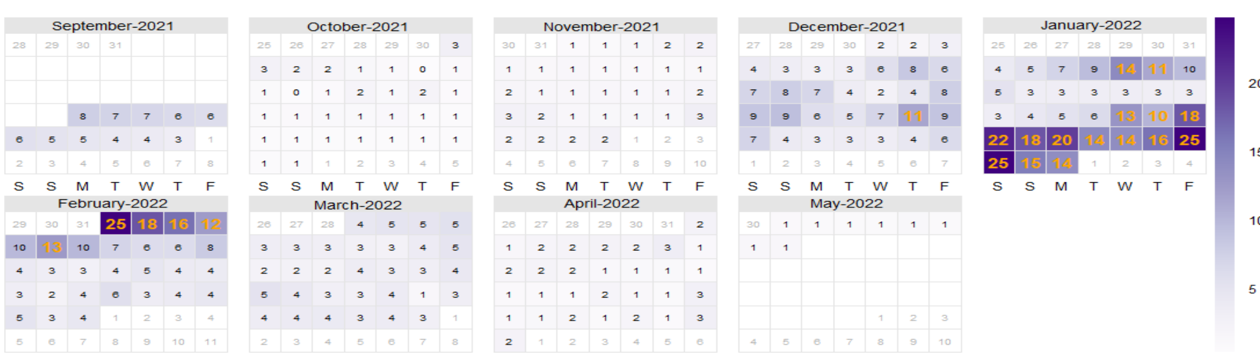

Fig2 Calendar plot of PM2.5 for Ibadan

The diagram shows days of elevated $Pm_{2.5}$ concentration were above 10µg/m^3. January 2022 had the highest number of elevated $PM_{2.5}$ concentration. Fig 3 shows time variation plot of $PM_{2.5}$ for Ibadan. The plots show monthly and weekly plots of concentrations. The monthly plot shows that on the average, $PM_{2.5}$ was low throughout the period of study except in January. Examining the weekday plot, it can be seen that average concentration was below the WHO threshold at 95% confidence interval

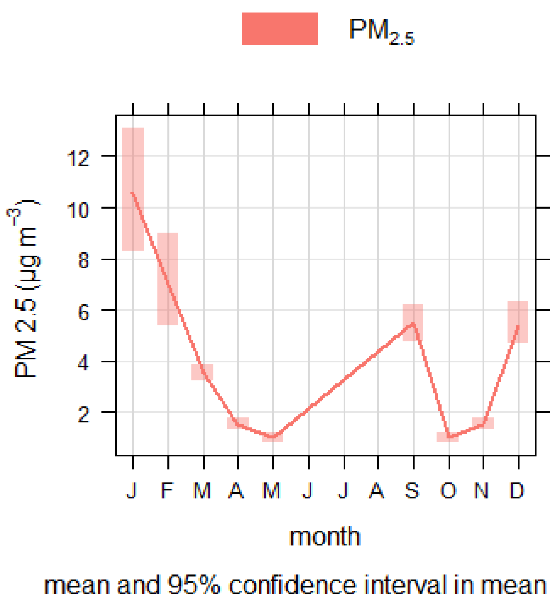

Fig3 Time variation plot of PM2.5 for Ibadan

Fig4 shows a calendar plot of $PM_{2.5}$ concentrations at The Federal Polytechnic Auchi.

The diagram shows days of elevated $Pm_{2.5}$ concentrations were above 10µg/m^3. The concentration of PM2.5 in Auchi was above the WHO threshold on the average. However, there were very high concentrations in 2022.

Fig 5 shows time variation plot of $PM_{2.5}$ for Auchi. The plots show monthly and weekly plots of concentrations. The monthly plot shows that on the average, $PM_{2.5}$ was high during the months of February up to June. There was a sharp decline I July and August. Examining the weekday plot, it can be seen that average concentration was high.

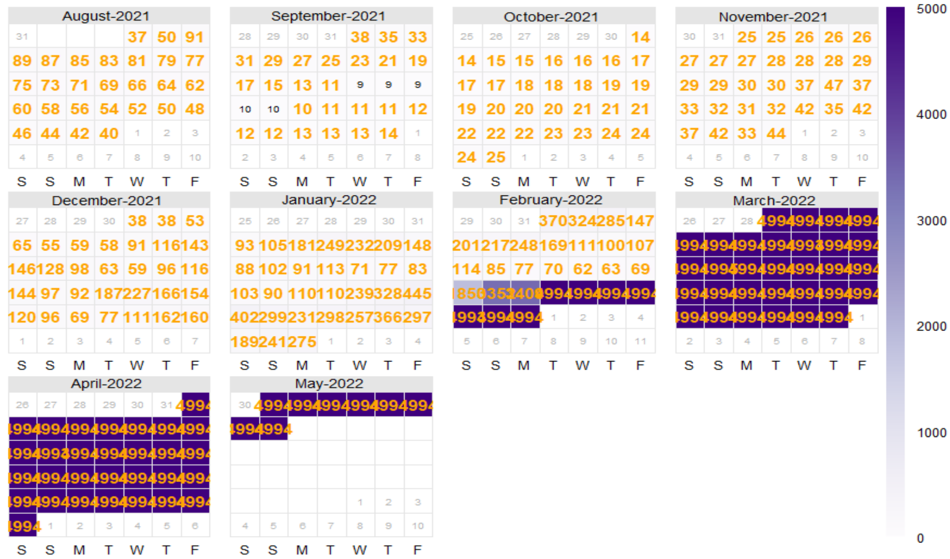

Fig4 Calendar plot of PM2.5 for Auchi

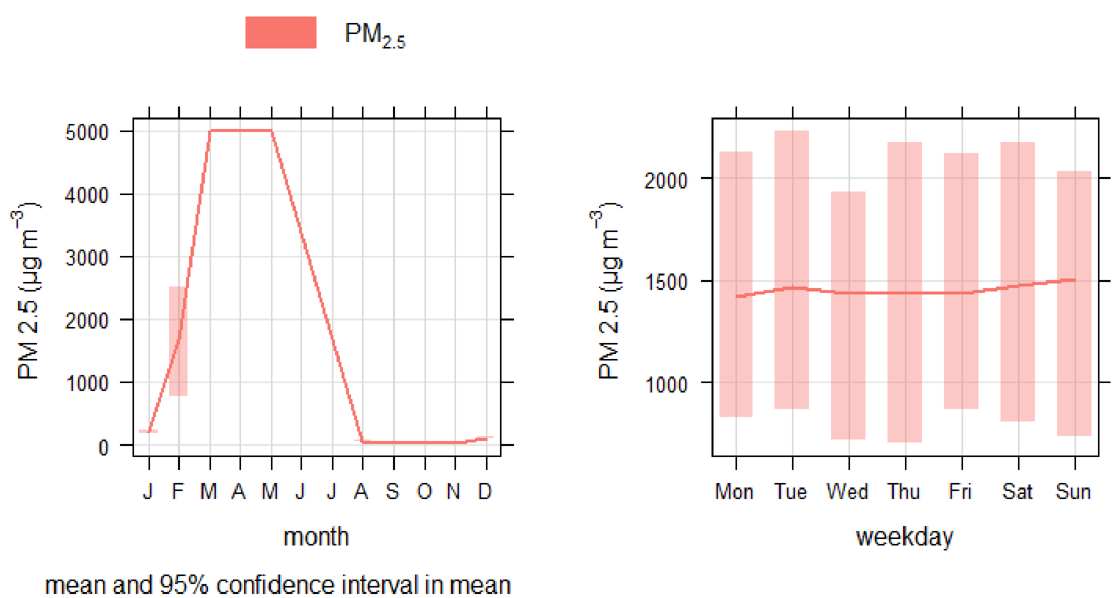

Fig5 Time variation plot of PM2.5 for Auchi

Fig6 shows a calendar plot of $PM_{2.5}$ concentrations at the Centre for Atmospheric Research (CAR) Kogi State. The diagram shows days of elevated $Pm_{2.5}$ concentrations were above $10\mu g/m^3$. The concentration of PM2.5 in Kogi was above the WHO threshold on the average. However, there were very high concentrations in 2022. Fig 7 shows time variation plot of $PM_{2.5}$ for Kogi. The plots show monthly and weekly plots of concentrations. The monthly plot shows that on the average, $PM_{2.5}$ was low during the months of March up to October. There was a sharp increase in July and August. Examining the weekday plot, it can be seen that average concentration was high on Thursday.

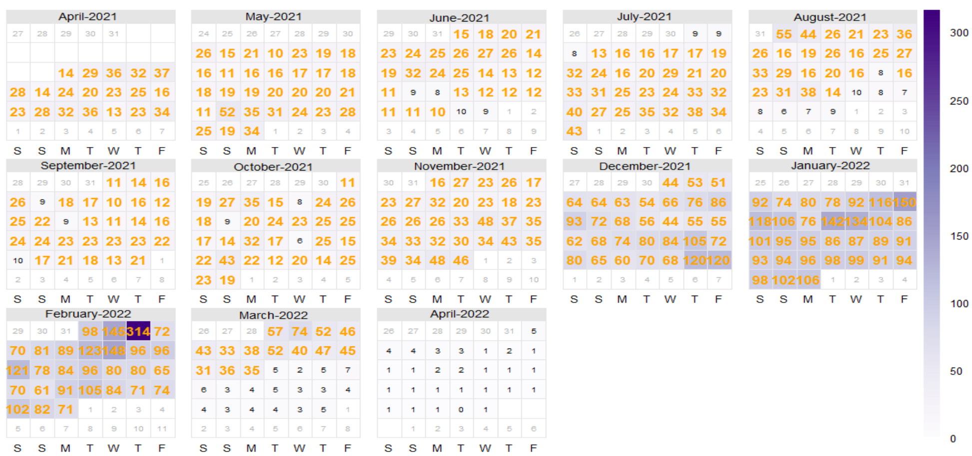

Fig6 Calendar plot of PM2.5 for Anyigba, Kogi

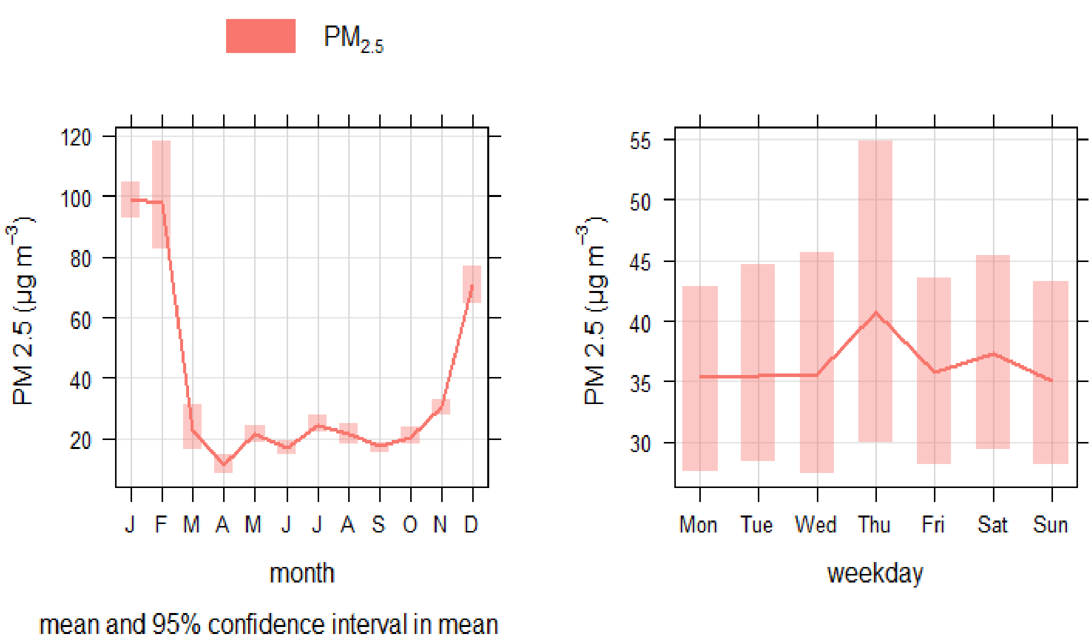

Fig7 Time variation plot of PM2.5 for Kogi

Fig8 shows a calendar plot of $PM_{2.5}$ concentration at the Nigerian Meteorological Agency (NIMET), Benin, Edo State. The diagram shows days of elevated $Pm_{2.5}$ concentration were above $10\mu g/m^3$. The concentration of $PM_{2.5}$ in Benin was above the WHO threshold on the average. However, there were very high concentrations in 2022.

Fig 9 shows time variation plot of $PM_{2.5}$ for Benin. The plots show monthly and weekly plots of concentrations. The monthly plot shows that on the average, $PM_{2.5}$ was low during the months of January up to April. There was a sharp increase in June, July and December. Examining the weekday plot, it can be seen that average concentration was high on Wednesdays and Fridays.

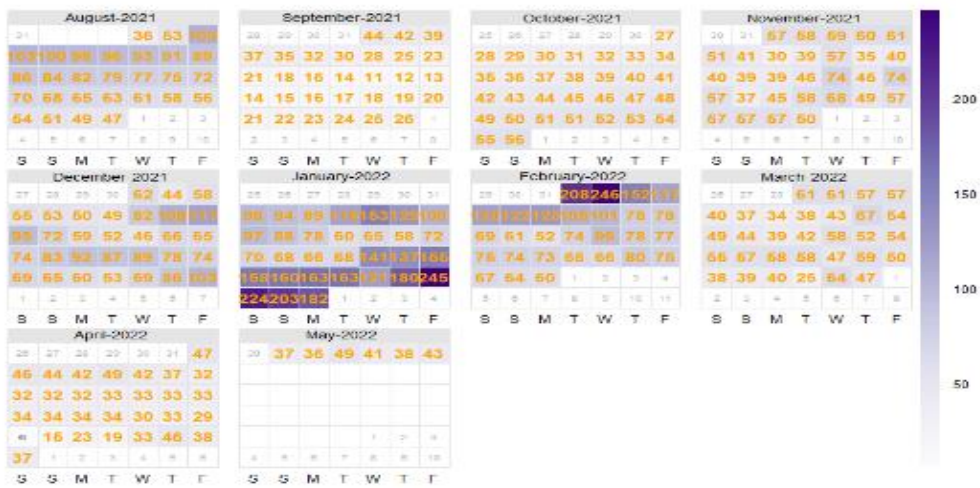

Fig8 Calendar plot of PM2.5 for Nimet Benin

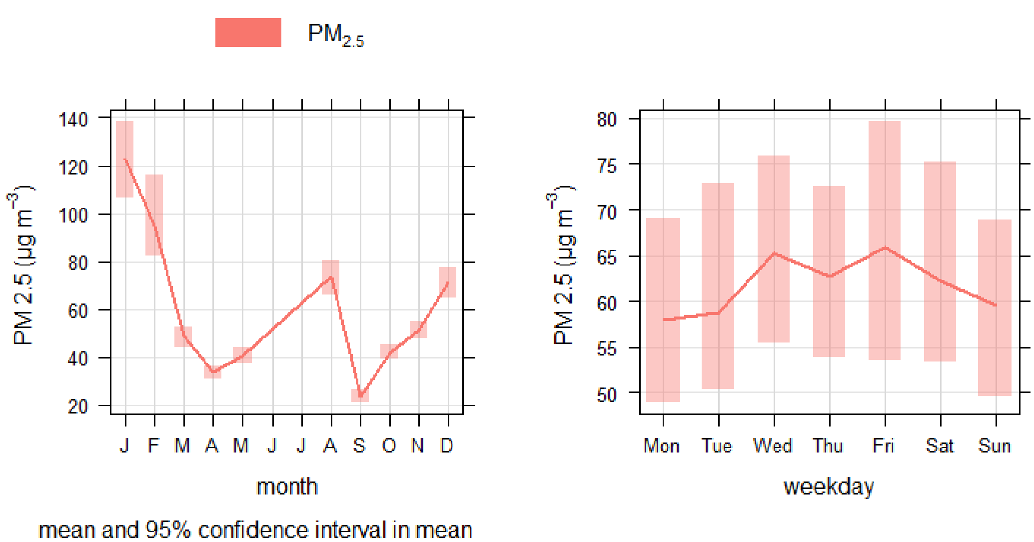

Fig9 Calendar plot of PM2.5 for Nimet Benin

Fig10 shows a calendar plot of $PM_{2.5}$ concentration at Birnin Kebbi, Kebbi State. The diagram shows days of elevated $Pm_{2.5}$ concentration were above 10µg/m^3. The concentration of $PM_{2.5}$ in Birnin Kebbi, was above the WHO threshold on the average. Fig 11 shows time variation plot of $PM_{2.5}$ for Birnin Kebbi. The plots show monthly and weekly plots of concentrations. The monthly plot shows that on the average, $PM_{2.5}$ was high during the months of February up to April. Examining the weekday plot, it can be seen that average concentration was low Wednesdays to Fridays.

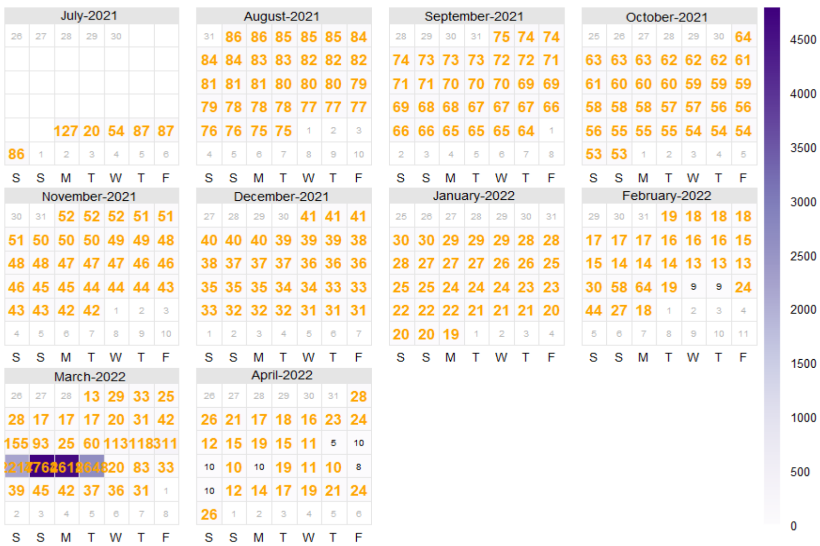

Fig10 Calendar plot of PM2.5 for Bernin Kebbi

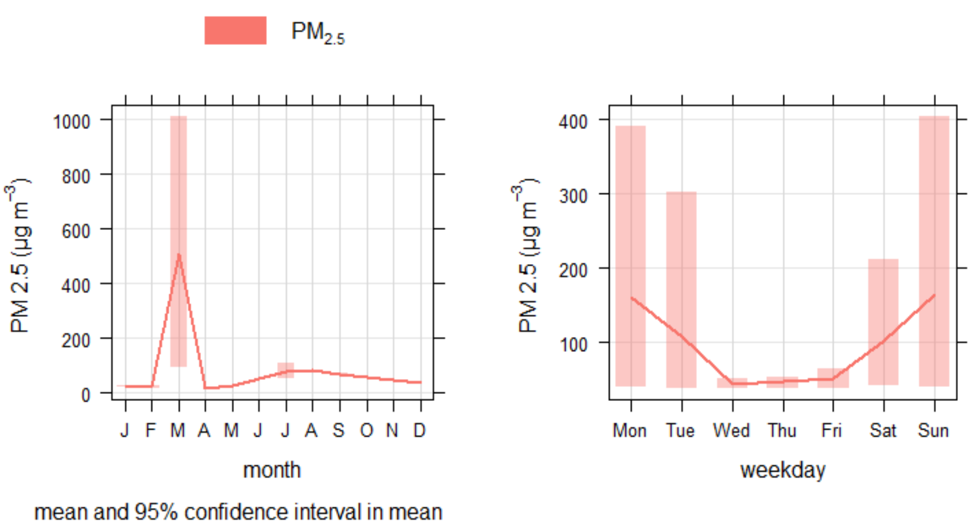

Fig 11 Time Variation plot of PM2.5 for Bernin Kebbi

Fig12 shows a calendar plot of $PM_{2.5}$ concentration at Lekki, Lagos State. The diagram shows days of elevated $Pm_{2.5}$ concentration were above 10µg/m^3. The concentration of $PM_{2.5}$ in Lekki, Lagos State, was above the WHO threshold on the average. Fig 13 shows time variation plot of $PM_{2.5}$ for Lekki, Lagos State. The plots show monthly and weekly plots of concentrations. The monthly plot shows that on the average, $PM_{2.5}$ was high during the months of April to June. It also repeated from September to December. Examining the weekday plot, it can be seen that average concentration was high Tuesdays to Saturdays.

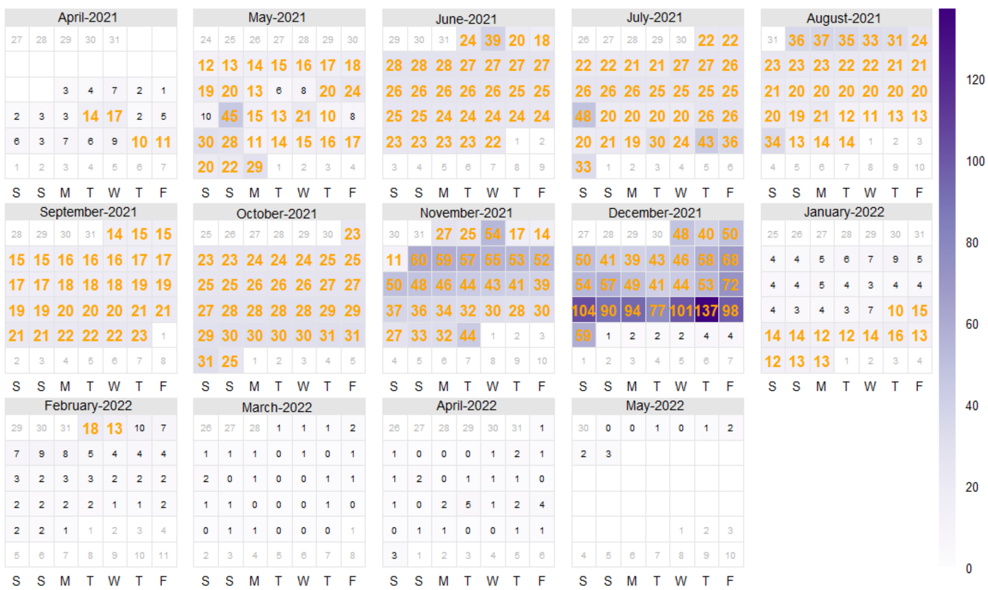

Fig 12 Calendar plot of PM2.5 for Lekki, Lagos

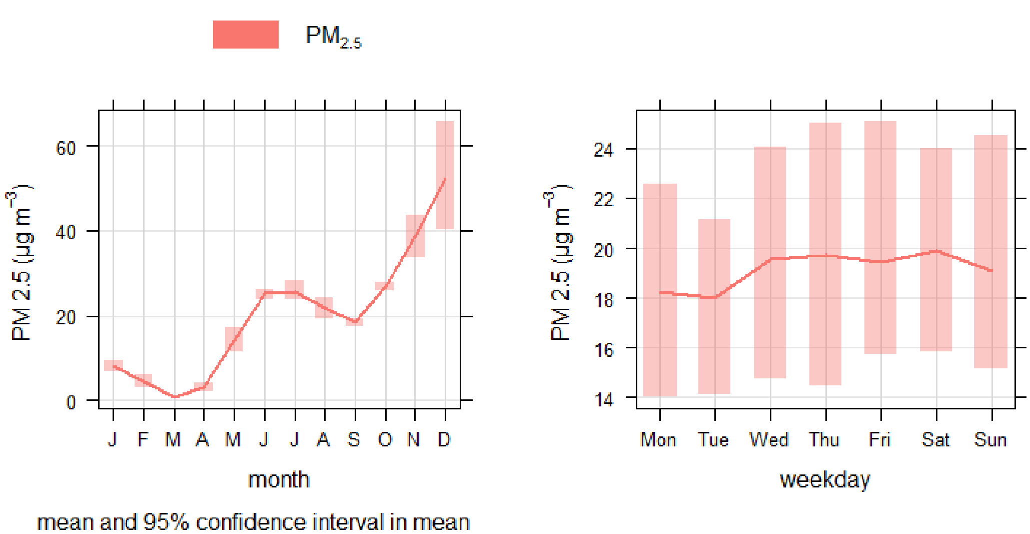

Fig 13Time variation plot of PM2.5 for Lekki, Lagos

3.2 Health impact assessment

3.2.1 Long Term Effects of PM2.5 Pollution

The long-term health effects of PM 2.5 were calculated using average forecast values for the year 2023. The autoregressive, Integrated and Moving average (ARIMA) model was used to carry forecast PM2.5 values for the different locations. Autocorrelation function (ACF) and partial autocorrelation function (PACF) plots were used to select the appropriate ARIMA model. Average forecasted values were; for Anyigba 31.12µg/m^3, for Ibadan 4.12µg/m^3, for Auchi 4,993.88µg/m^3, for Lekki, Lagos State 1.15µg/m^3, for Benin 60.28µg/m^3, for Kebbi 87.84µg/m^3. The health impact assessment shows that in Anyibga, adults 30+ years most likely to die due to natural causes are 249, those likely to die due to lung cancer are 345, children 0-5years likely to die due to ALRI are 326, mortality due to chronic obstructive pulmonary disease (COPD) are 273, mortality due to ischemic heart disease is 300, mortality due to stroke for adults are 263. In Auchi, adults 30+ years most likely to die due to natural causes are 1,350, those likely to die due to lung cancer are 1350, children 0-5years likely to die due to ALRI are 770, mortality due to chronic obstructive pulmonary disease (COPD) are 880, mortality due to ischemic heart disease is 687, mortality due to stroke for adults are 710. In Kebbi, adults 30+ years most likely to die due to natural causes are 1,232, those likely to die due to lung cancer are 1,610, children 0-5years likely to die due to ALRI are 1,174, mortality due to chronic obstructive pulmonary disease (COPD) are 978, mortality due to ischemic heart disease is 958, mortality due to stroke for adults are 522. In Benin, adults 30+ years most likely to die due to natural causes are 4,180, those likely to die due to lung cancer are 5,640, children 0-5years likely to die due to ALRI are 4,590, mortality due to chronic obstructive pulmonary disease (COPD) are 3,804, mortality due to ischemic heart disease is 3,885, mortality due to stroke for adults are 3,561. Since Ibadan and Lekki had forecasted PM2.5 values less than the standard cut off value of 10µg/m^3, the result of the health impact assessment was 0 in all cases.

3.2.2 Short term effects OF PM 2.5 pollution

For the short-term effects, the result shows that for Ayingba in Kogi State, Hospital admissions due to respiratory diseases will be 35, which could rise to 73 if the concentration of PM 2.5 is not controlled below 10µg/m^3. Hospital admissions due to cardiovascular diseases (CVDs) including stroke, will be 17 and could rise to 31. Mortality due to all natural causes (adults 30+ years) will be 23 and could rise to 37. Restricted activity days (RADs) for all ages will be 85 and could rise to 95 days. For Auchi in Edo State, Hospital admissions due to respiratory diseases will be 1,350, if the concentration of PM 2.5 is not controlled below 10µg/m^3. Hospital admissions due to cardiovascular diseases (CVDs) including stroke, will be 1,335 and could rise to 1.350. Mortality due to all natural causes (adults 30+ years) will be 1,347 and could rise to 1,350. Restricted activity days (RADs) for all ages will be 1,350 days. For Benin, Hospital admissions due to respiratory diseases will be 1,030, which could rise to 2,082 if the concentration of PM 2.5 is not controlled below 10μg/m^3. Hospital admissions due to cardiovascular diseases (CVDs) including stroke, will be 504 and could rise to 905. Mortality due to all natural causes (adults 30+ years) will be 677 and could rise to 1,087. Restricted activity days (RADs) for all ages will be 2,399 and could rise to 2,671 days. For Bernin Kebi, Hospital admissions due to respiratory diseases will be 368, which could rise to 723 if the concentration of PM 2.5 is not controlled below 10μg/m^3. Hospital admissions due to cardiovascular diseases (CVDs) including stroke, will be 182 and could rise to 324. Mortality due to all natural causes (adults 30+ years) will be 244 and could rise to 387. Restricted activity days (RADs) for all ages will be 826 and could rise to 913 days. Since Ibadan and Lekki had forecasted PM2.5 values less than the standard cut off value of 10μg/m^3, the result of the health impact assessment was 0 in all cases.

4.0 Summary and Conclusion

Health impact assessment of $PM_{2.5}$ has been calculated for certain locations in Nigeria. The values obtained are for the year 2023. The results show that $PM_{2.5}$ concentration was above the WHO standard of 10μg/m3. As a result, health impacts associated with this are severe. For the long-term effect, Benin was forecasted to have the highest casualty. According to the calculation, adults 30+ years most likely to die due to natural causes are 4,180, those likely to die due to lung cancer are 5,640, children 0-5years likely to die due to ALRI are 4,590, mortality due to chronic obstructive pulmonary disease (COPD) are 3,804, mortality due to ischemic heart disease is 3,885, mortality due to stroke for adults are 3,561. It was similar for short term effects. According to the estimation for Benin, Hospital admissions due to respiratory diseases will be 1,030, which could rise to 2,082 if the concentration of PM 2.5 is not controlled below 10μg/m^3. Hospital admissions due to cardiovascular diseases (CVDs) including stroke, will be 504 and could rise to 905. Mortality due to all natural causes (adults 30+ years) will be 677 and could rise to 1,087. Restricted activity in days (RADs) for all ages will be 2,399 and could rise to 2,671 days.

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