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Evaluation of Spatial Distribution of $PM_{2.5}$ Pollution and Its Health Effects in Nigeria

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Abstract: *This study presents the annual spatial distribution of Particulate Matter whose diameter is 2.5 microns or less ($PM_{2.5}$) and its health impacts in Nigeria. Temperature and $PM_{2.5}$ data were obtained from both the National Aeronautics and Space Administration (NASA) and the Nigerian Meteorological Agency (NiMet) Abuja. The results of this study showed that there is an increasing temperature trend in Nigeria, and the warming effects have contributed to the increase in $PM_{2.5}$ pollutants in the atmosphere in Nigeria. The average annual concentration of the $PM_{2.5}$ pollutants in Nigeria is 41.5 µg/m^3, and the minimum and maximum annual concentrations are 17 µg/m^3 and 79 µg/m^3 respectively. The results showed that the annual concentration of $PM_{2.5}$ is much more than the WHO guideline value of 10 µg/m^3. The concentration of $PM_{2.5}$ is higher in industrial and commercial areas and their sources were identified to be anthropogenic. They are caused by emissions from the combustion of fossil fuel devices. The extreme northern part of Nigeria is also heavily polluted by $PM_{2.5}$ due to the combined emissions from automobiles and Particulate matter loading from the Sahara Desert. The elevated concentration of $PM_{2.5}$ in Nigeria was identified as the major cause of health complications such as lung cancer, asthma, stroke, and other cardiovascular diseases associated with air pollution. $PM_{2.5}$ are known to constitute heavy metals such as Lead, Nickel, Cadmium, Arsenic and Chromium which are capable of causing kidney and liver complications when ingested. Given the adverse health risks associated with air pollution by $PM_{2.5}$, this study was focused on raising public awareness of the adverse health effects of air pollution by $PM_{2.5}$.*

Keywords: *$PM_{2.5}$, concentration, pollutants, anthropogenic, Nigeria, health risks, temperature*

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1.0 Introduction

Quality air is very important to good health and well-being of the public. The issue of adverse health effects associated with elevated fine Particulate matter has become a subject of serious concern due to the high morbidity and mortality witnessed in both developed and developing countries in recent times. Fine Particulate matter whose aerodynamic diameter is less than 2.5 µg/m^3 is referred to as $PM_{2.5}$. $PM_{2.5}$ has attracted much interest from both public and scientists due to its radiative forcing, albedo conditions, adverse health effects and chemical composition. Long-term exposure to elevated $PM_{2.5}$ concentration is associated with premature death, particularly in people who are suffering from chronic heart or lung complications. Older adults with respiratory or cardiovascular complications, children and asthmatic patients are mostly affected when exposed to elevated $PM_{2.5}$. $PM_{2.5}$ is not a single pollutant, it is composed of a mixture of different chemicals which may contain inorganic ions, metallic compounds, elemental carbon, organic compounds and compounds from the earth's crust. WHO in 2016 reported that air pollution is responsible for the death of about two (2) million people yearly. More than 50% of this death occur in developing countries such as Nigeria where there is no effective air quality monitoring management system.

Emissions from industries, vehicles, power plants and generators constitute the largest proportion of the anthropogenic emissions. The oil and gas industries in Nigeria contribute a large amount of $PM_{2.5}$ pollutants into the atmosphere through gas flaring (Ologunorisa, 2001; EIA, 2012), thereby causing severe air pollution. The concentration of $PM_{2.5}$ is higher in cities than in rural areas. The higher concentration is due to high energy consumption, presence of heavy industries, high volume of transportation and secondary production of $PM_{2.5}$. The understanding of the sources, characteristics and adverse health effects of air pollution, especially $PM_{2.5}$ will help in the proper management and control of air pollution in our environment. Air quality in most cities and towns in Nigeria is fast deteriorating due to inadequate monitoring and poor environmental sanitation. WHO 2018 also reported that about 91% of the world's population lives in places where the air quality is above the WHO limits for particulate matter (PM_{10} and $PM_{2.5}$). Particulate matter such as PM_{10} and $PM_{2.5}$ have been identified by many researchers as dangerous health hazards (Chen *et al*. 2015; Ezeh *et al*., 2014; Alani *et al*., 2019). Health complications associated with $PM_{2.5}$ are broad but they are mostly linked to respiratory and cardiovascular systems (WHO, 2006). Fossil fuel devices, wood fuels and their combustion as well as other biomass fuels have been identified as an important source of Particulate matter ($PM_{2.5}$) in the atmosphere. According to scientific literature, the annual mean concentration of $PM_{2.5}$ is 10µg/m^3 (WHO, 2005). Although $PM_{2.5}$ at levels below 10µg/m^3 may also cause adverse health effects. The adverse health effects of $PM_{2.5}$ is aggravated by the presence of heavy metals such as cadmium, arsenic, lead, nickel, chromium and iron.

One fundamental issue in air quality research is the identification of the source of the pollutants and the factors influencing air pollution (Chen et al., 2016). The variation and spatial distribution of $PM_{2.5}$ concentration have been investigated by some researchers (Oluwole *et al*., 1996; Ogugbuaja and Barisa, 2001; Osuji *et al*., 2005; Hopkins *et al.*, 2009; Owoade *et al*., 2013; Ede and Edokpa, 2015). Chen *et al*., (2017) investigated the influence of meteorological factors on $PM_{2.5}$ concentrations in Beijing-Tianjin-Hebei region and they observed that solar radiation, humidity, and wind are the major meteorological factors that significantly affect the concentration of $PM_{2.5}$. Oluwole *et al*., (1996) investigated the impact of Petroleum industries on air quality in Nigeria and they observed that the levels of volatile oxides of Carbon, Sulphur, and Nitrogen exceeded the Federal Environmental Protection Agency (FEPA) limits. Ede and Edokpa (2015) investigated the regional air quality of Nigeria's Niger Delta, and they found that the Particulate load in the Niger Delta region exceeded the WHO specification for both $PM_{2.5}$ and PM_{10}. The results of the measurement and analysis of suspended particulate matter in northeastern Nigeria by Ogugbuaja and Barisa (2001), showed that the air in the area was polluted by a variety of trace metals. $PM_{2.5}$ fine Particulates are mostly composed of heavy metals such as chromium, lead, arsenic, cadmium and nickel. Some of these heavy metals are carcinogenic and therefore are deleterious to human health when ingested through inhalation or consumption of contaminated food items.

Given the adverse health risks associated with elevated concentrations of $PM_{2.5}$, the objectives of this study are to investigate the spatial distribution of $PM_{2.5}$ and its associated health impacts in Nigeria to raise public awareness on the adverse health impacts of $PM_{2.5}$ pollution.

2.0 *Materials and Method*

2.1 *Study Area*

The study area is the entire Nigeria. Nigeria is located in West Africa on the Gulf of Guinea. It has a population of about 216 million people and a total area of 923.768 km^2.

Nigeria has borders with Benin in the west, Chad and Cameroon in the east, Niger in the north, and borders the Gulf of Guinea in the south. The Inter-tropical Discontinuity (ITD) movement controls the weather system in Nigeria. Nigeria is characterized by three ecological zones: the tropical rain forest in the south, savannah in the middle belt, and semiarid in the north. Nigeria has a tropical climate characterized by varying rainy and dry seasons. The rainy season starts from March to November in the southern part and it starts from June to September in the north. The rainfall decreases from the southern part of the country to the northern part as one moves from the south to the northern part of Nigeria.

Fig. 1: Map of Nigeria showing the 36 states of Nigeria and the FCT, Abuja

2.2 *Data collection*

The data for this study was obtained from the websites: The Nigerian Meteorological Agency (NiMet) and https://avdc.gsfc.nasa.gov/pub/tmp/WHO_PM2.5_COUNTRY_DATA/. The temperature data between1981 – 2020 were analyzed to see if there is a warming effect in Nigeria, which could cause an increase in the concentration of $PM_{2.5}$ in the atmosphere. The trend in the temperature was analyzed using time series analysis. The $PM_{2.5}$ data were obtained from satellite datasets and surface meteorology.

2.3 *Data analysis*

Time series analysis and basic statistics such as maximum, minimum, mean and standard deviation were used to evaluate the data obtained. The Standardized Anomaly Index (SAI) was calculated using equation (1),

$$SAI = \frac{x_i - x_m}{\sigma} \quad (1)$$

where, x_i is the mean temperature for each year and x_m is the long-term mean temperature. σ is the standard deviation of the annual maximum temperature for the long term. Periods below the long-term average were considered cooling periods and periods above the long-term average were considered warming periods. The standardized anomaly index of the temperature was compared to the threshold risk levels in Table 1.

Table 1. Standardized Temperature Anomaly Index (Source: Marck, 2015)

S/N	Event	Interpretation
1	$SAI \geq 2.0$	Extremely hot
2	$SAI \geq 1.5 < 2$	Very hot
3	$SAI \geq 1.0 < 1$	Moderately hot
4	$SAI < 1.0 > -1.0$	Near normal
5	$SAI \leq -1.0 > -1.5$	Moderately cold
6.	$SAI \leq -1.5 > -2.0$	Very cold
7.	$SAI \leq -2.0$	Extremely cold

3.0 *Results and Discussion*

The standardized temperature anomaly index of Nigeria (Fig. 2) showed that Nigeria's climate is warming. The results of the time series analysis showed an increasing temperature trend (Fig. 2).

The increase in temperature trend in Nigeria will positively influence the formation of $PM_{2.5}$ particles and photochemical reactions between $PM_{2.5}$ precursors (Fig. 2). This enhances the concentration of $PM_{2.5}$ in the atmosphere. The warming effects in Nigeria have exacerbated adverse health effects such as respiratory and cardiovascular diseases associated with elevated concentrations of $PM_{2.5}$ in the atmosphere.

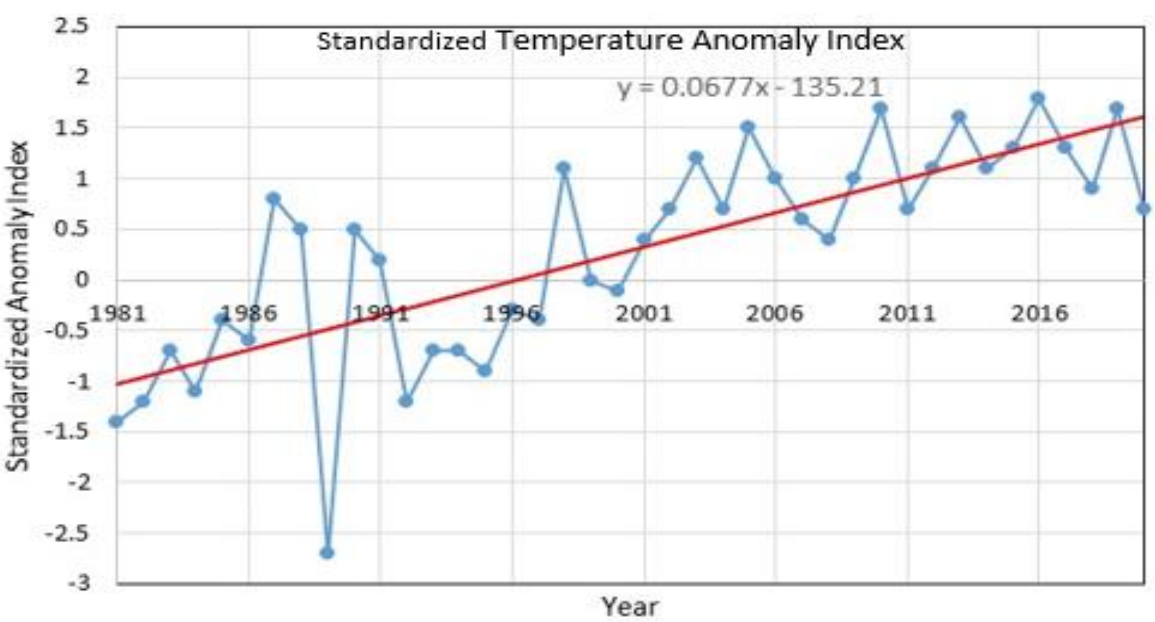

Fig. 2: Standardized maximum temperature anomaly index from 1981 to 2020 showing an increasing temperature trend in Nigeria

The environmental warming effects are most severe in the extreme northern part of Nigeria where a series of drought events have occurred in recent times due to climate change (Figure 3). The results of this study showed that some areas in Kano, Jigawa, Yobe and Borno states have high concentrations of $PM_{2.5}$ due to high aerosol loading from the Sahara Desert (Fig. 3). $PM_{2.5}$ in Kano and its environs ranges from 45 - 75 µg/m^3, this high concentration is enhanced by the emissions from industries and vehicular operations (Fig. 3). The $PM_{2.5}$ concentration in both northeastern and northwestern parts of Nigeria is relatively very high and this might be the reason why the number of patients with air pollution related diseases is very high in both regions. The findings of this study agree with the report of Doris 2018, which stated that Children in northeastern Nigeria are mostly affected by Acute Respiratory Infections (ARI). The Middle Belt of Nigeria is also characterized by high $PM_{2.5}$ concentration but not as much as that of the northern part of the country. The concentration of $PM_{2.5}$ in most parts of the southeast and southwest are also high but a little lower than that of the Middle Belt in Nigeria. The ecological nature of the southeast and southwest must have influenced the concentration of aerosol in the atmosphere. Southern Nigeria is a rainforest zone, its climatic peculiarity suggests that the high concentration of $PM_{2.5}$ in the zone are due to emissions from household generators, power plant, industrial and vehicular emissions. The concentrations of $PM_{2.5}$ in most industrial and commercial cities such as Onitsha, Aba, Calabar, Maiduguri, Kano, Lagos, Port Harcourt, Warri, Ibadan and Jos are very high and they reflected the level of pollution caused by industrial and economic activities.

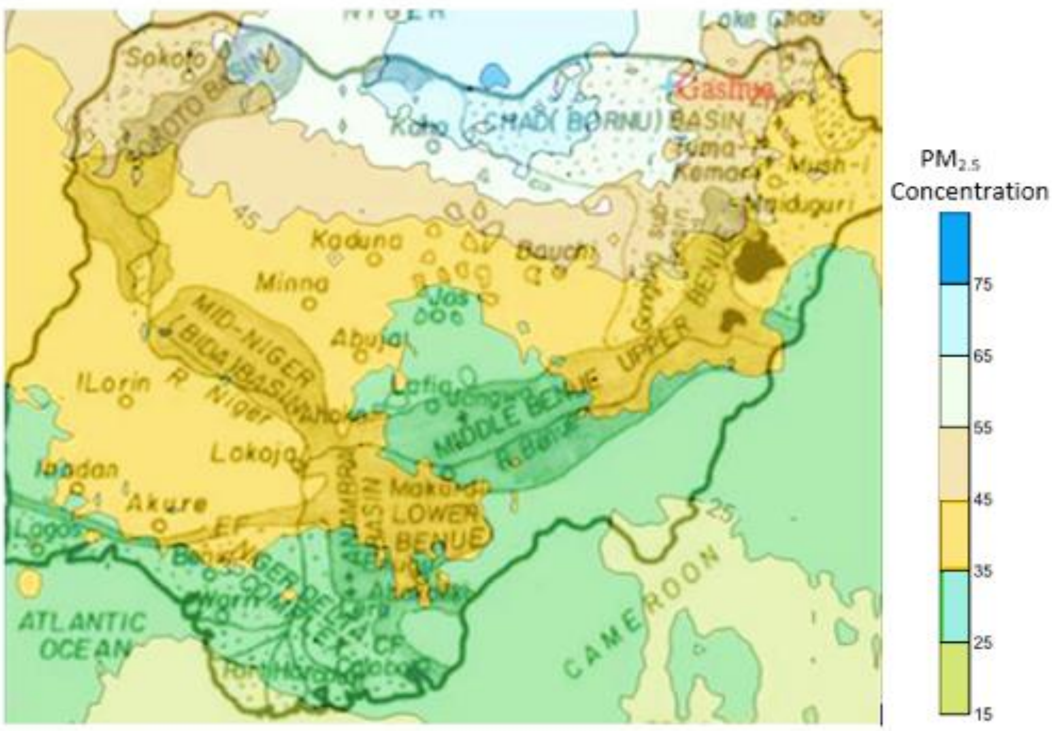

Fig. 3. Spatial distribution of annual $PM_{2.5}$ concentration in microgram per meter cube ($\mu g/m^3$) in Nigeria

The average annual $PM_{2.5}$ concentration in Nigeria is 41.5 $\mu g/m^3$ which is much more than the World Health Organization current guideline value of 10 $\mu g/m^3$. The results of this study showed that the atmosphere in Nigeria is polluted by $PM_{2.5}$, and this is responsible for the increasing trend in lung, cardiovascular and respiratory diseases in Nigeria. The spatial distribution of the annual $PM_{2.5}$ concentration in Nigeria showed that the mass concentration and the composition of the $PM_{2.5}$ vary with economic activities, climate and location (Figure 3). Higher $PM_{2.5}$ concentration in cities and industrial towns showed that most of the

$PM_{2.5}$ pollution is anthropogenic. The maximum annual concentration of $PM_{2.5}$ at the time of this study is 79 µg/m^3 and the annual minimum concentration is 17 µg/m^3.

The findings of this study have shown that both cities and towns in Nigeria are polluted by $PM_{2.5}$. The results of this study also agree with the report of Ogugbuaja and Barisa (2001) on the basis that northeastern Nigeria is polluted by particulate matter. The findings of this study is also in consonance with the observation of Ezeh *et al*., 2014 that the Niger Delta region is polluted by the emissions from the Oil and Petrochemical industries in the area, and Alani *et al*., 2019 on the air quality status of Lagos. Considering the magnitude of the $PM_{2.5}$ pollution in Nigeria, there is a need for strict enforcement of gaseous emission regulations and air pollution control in order to reduce morbidity and mortality associated with $PM_{2.5}$ pollution in Nigeria. A reduction in air pollution will help the public to have a relief on the burden of diseases from stroke, lung cancer, respiratory diseases such as asthma and other cardiovascular infections.

4.0 Conclusion

This study investigated the spatial distribution of $PM_{2.5}$ and its adverse health effects in Nigeria. The results showed that climate and economic activities contribute to $PM_{2.5}$ pollution in Nigeria. The concentration of the $PM_{2.5}$ varies from one geographical location to another depending on the economic activities of the area and the ecological disposition. The findings of the study showed that both cities and towns in Nigeria are polluted by $PM_{2.5}$. The air pollution is more intense in industrial and commercial cities across Nigeria due to emissions from fossil fuel-consuming devices. The concentration of the $PM_{2.5}$ ranged from 17 µg/m^3 to 79 µg/m^3 with an average value 41.5 µg/m^3. The $PM_{2.5}$ concentration in Nigeria is much greater than the World Health Organization (WHO) annual guideline value of 10 µg/m^3. The elevated concentration of $PM_{2.5}$ in the country indicate that the air is polluted, and this pollution might have caused severe lung, and cardiovascular diseases in the most affected areas in the country. Adequate monitoring of air pollutants such as $PM_{2.5}$ and PM_{10} will help to reduce incidences of cancer and kidney infections caused by heavy metals such as lead, chromium, cadmium, nickel and arsenic that are associated with chemical constituents of $PM_{2.5}$. Therefore, there is an urgent need to stem the tide of air pollution in Nigeria. The public, private agencies and the government should collaborate to ensure that emission regulations and air pollution control are strictly implemented to reduce air pollution by Particulate matter such as $PM_{2.5}$ and other atmospheric pollutants.

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6.0 *References*

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