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Air Quality Parameters and Human Health Risk Assessment in Nigeria

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ABSTRACT

One of the challenges in assessing air quality parameters in Nigeria is the lack of comprehensive data due to limited monitoring stations across the country. Seven sampling stations (Lagos, Port Harcourt, Enugu, Makurdi, Kano, Maiduguri and Abuja) were chosen across the six geographical zones in Nigeria to monitor five parameters (PM, CO, NO_2, SO_2, and O_3) for ninety days consecutively, using remote sensing techniques. The results obtained shows that the general pattern of these pollutants in ascending order is: Port Harcourt < Maiduguri < Makurdi < Lagos < Enugu < Abuja < Kano. The low values of NO_2 (6.76 μg/m^3) and SO_2 (1.77 μg/m^3) indicates that the accumulation of potential acid-forming particles known as acid rain is highly limited in Nigeria. The high values of particulates, PM_{10} (85.0 μg/m^3) and $PM_{2.5}$ (50.2 μg/m^3) are beyond the standards and therefore, can accumulate in the lungs, interfering with their ability to exchange gases. The effects of these pollutants are crucial for policymakers, researchers, and practitioners to develop effective strategies that minimize air pollution and safeguard public health. Hence, we recommend public awareness campaigns, green transportation initiatives, and public health interventions as essential for sustainable air quality management.

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***Keywords*:** Air Quality, Risk Assessment, Particulate Matters, Human Health, Remote Sensing, Nigeria

1. INTRODUCTION

Air pollution is a pressing global concern, with detrimental effects on human health and the environment. Nigeria, a country with a rapidly growing population and industrial development, faces persistent challenges regarding air quality. Urban areas, in particular, experience high levels of air pollution. Around the world, five major types of substances are released directly into the atmosphere in their unmodified forms in sufficient quantities to pose a health risk and are called primary air pollutants. These are particulate matter (PM), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and volatile organic compounds (VOCs). Primary air pollutants may interact with one another in the presence of sunlight to form new compound such as ozone (O_3) as secondary air pollutants that often exceeds the recommended limits set by international standards. This poses a significant risk to the health of the world population.

The sources of air pollution in Nigeria are diverse and include both stationary and mobile sources. Industrial emissions, especially from oil refineries, power plants, and manufacturing facilities, contribute to a substantial proportion of air pollution. Additionally, vehicular emissions, open burning of waste and biomass, household cooking and heating activities using solid fuels are significant contributors to poor air quality. Understanding these sources is crucial for effective pollution control and mitigation strategies.

Several researchers had reported heavy metal pollution levels in the atmosphere. Mafuyai *et al.* (2015) investigated heavy metals contamination on roadside dust along major traffic roads in Jos Metropolitan Area, Nigeria. Ameh *et al.* (2015) monitored the assessment of some gaseous emissions in traffic areas in Makurdi metropolis, Benue State, Nigeria. Eneji *et al.* (2014) has reported assessment of heavy metals in indoor settled harmattan dust within the University of Agriculture Makurdi, Nigeria. Mafuyai *et al.* (2014) reported the concentration of heavy metals in respirable dust in Jos metropolitan area, Nigeria. Oyareme and Osaji (2022) reported environmental air quality parameters monitoring information assessments and its health implications on biotic factors in Banjul metropolis, Gambia. Tajudeen *et al.* (2023) investigated concentrations and health risks of particulate matter ($PM_{2.5}$) and associated elements in the ambient air of Lagos, Nigeria. Abulude *et al*. (2022) monitored air quality with satellite-based sensor for four towns in Southeast, Nigeria. Ipeaiyeda and Adegboyega (2017) monitored assessment of air pollutant concentrations near major roads in residential, commercial and industrial areas in Ibadan City, Nigeria.

Poor air quality in Nigeria has profound implications for respiratory health. The inhalation of polluted air, especially particulate matter and harmful gases, can lead to respiratory issues such as asthma, bronchitis, and other chronic obstructive pulmonary diseases (COPD). Children, the elderly, and individuals with pre-existing respiratory conditions are particularly vulnerable. Air pollution not only affects the respiratory system but also poses significant risks to cardiovascular health. Studies have shown that long-term exposure to air pollutants increases the incidence of heart attacks, strokes, and other cardiovascular diseases.

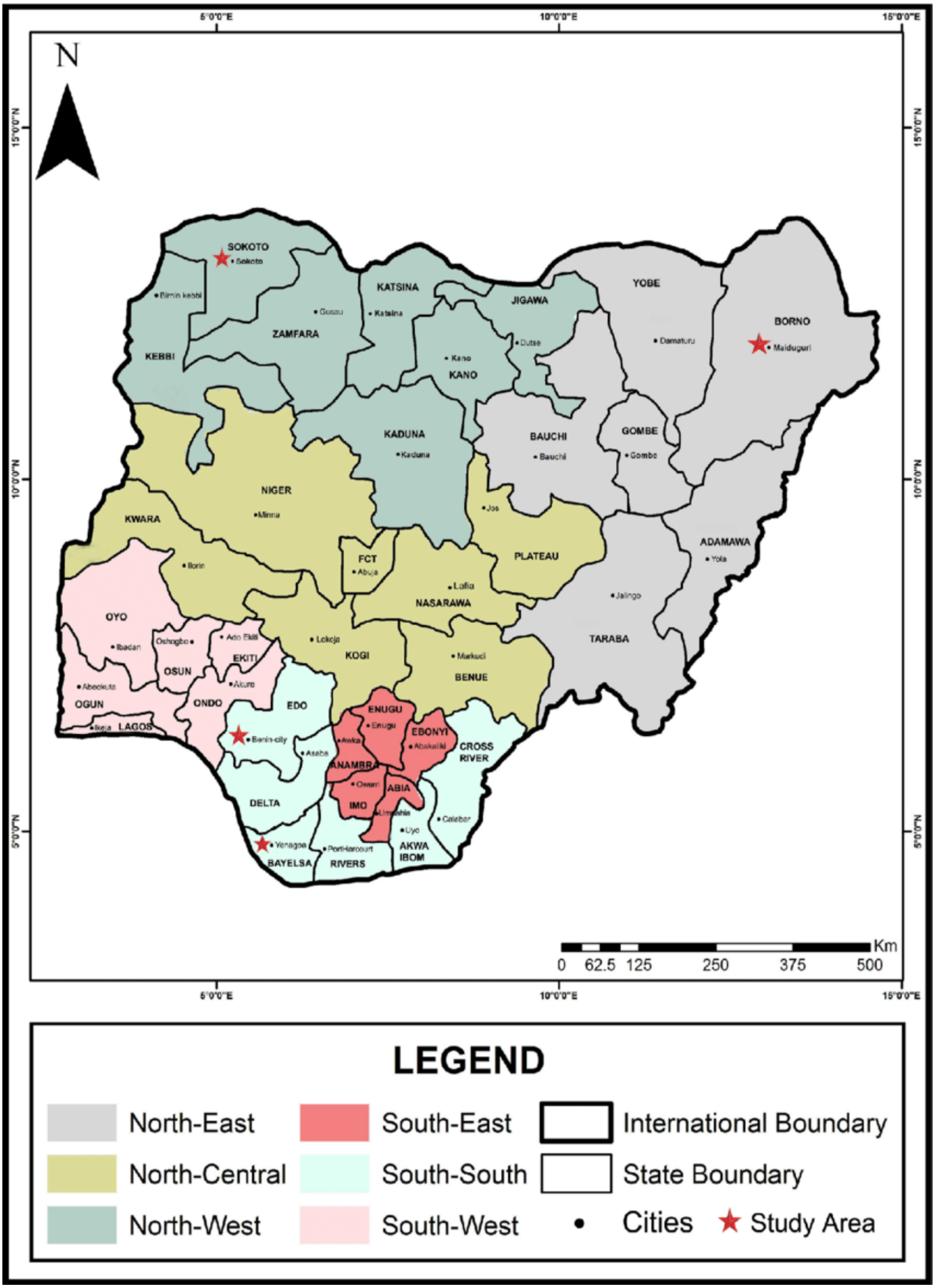

Figure 1. Map of Nigeria showing Geopolitical Zones.

Additionally, air pollution has been linked to adverse effects on pregnancy outcomes, neurological health, and even an increased risk of certain cancers. Therefore, addressing air pollution becomes imperative for safeguarding the overall health of the Nigerian population. Understanding the current state of knowledge surrounding these pollutants is vital for devising effective strategies to mitigate their adverse effects. This article aims at providing an in-depth understanding of air quality parameters and human health risk assessment in Nigeria. It will also explore the current state of air quality in the country, identify major sources of pollution, examine the human health risk assessment frameworks in Nigeria.

Methods and Approaches for Assessing Air Quality Parameters

To assess air quality parameters, various monitoring and measurement techniques are employed. This includes the use of air quality monitoring stations equipped with sensors and instruments capable of measuring pollutants such as PM, NO_2, SO_2 and O_3. Air quality monitoring was investigated for ninety (90) days consecutively between October, 2023 to January, 2024 in the six geopolitical zones (Lagos, Port Harcourt, Enugu, Makurdi, Kano, Maiduguri) including Abuja as shown in Figure 1.

In addition to ground-based monitoring, remote sensing techniques, satellite imagery, and mobile monitoring units are also utilized to provide a comprehensive understanding of air quality across different regions. Analysing air quality data is crucial to identify patterns, trends, and potential sources of pollution. Data analysis techniques, such as statistical analysis and geographical information systems (GIS), help in evaluating the spatial distribution of pollutants and their correlation with health outcomes.

2. RESULTS/EXPERIMENTAL (MATERIALS AND METHODS)

Air pollution is a pressing issue that poses significant environmental and health risks globally. Table 1 shows the mean and standard deviations of various pollutants, including particulate matter (PM), carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2), that contribute to the deterioration of air quality in Nigeria. Each of the air pollutant is represented in chart along with the recommended standards as shown in Figures 2 – 8.

Table 1. Mean Concentrations of Air Quality Parameters Across Some Cities in Nigeria

	Makurdi	Abuja	Lagos	P/H	Enugu	Kano	Maiduguri
Temp (°C)	29.6±3.3	28.9±3.6	28.9±2.2	24.8±3.0	28.5±3.3	26.81±4	28.47±4
SW	7.54±7.9	6.90±2.8	10.5±5.0	7.13±4.1	6.51±3.1	10.1±5.3	10.1±4.2
Humidity	58.3±26	54.7±24	79.3±10	79.7±15	65.1±23	36.11±20	30.8±17
UV	2.91±2.5	3.51±2.9	3.42±2.6	4.50±3.1	3.32±3.0	4.06±3.0	4.39±3.1
Visibility	10.9±3.0	9.63±2.3	8.04±2.9	9.91±3.1	10.3±2.9	8.14±3.3	11.7±4.0

Air pressure	1010±3.0	1012±2.0	1011±2.0	1010±2.2	1021±9.6	1119±9.8	1011±2.0
AQI	101±43	117±34	87.5±49	89.3±40	107±43	143±36	100±31
$PM_{2.5}$	41.4±30	51.0±31	35.7±26	32.2±25	46.2±31	74.8±39	70.0±62
PM_{10}	76.1±54	99.5±49	61.8±49	49.6±40	78.2±47	148±72	81.9±41
CO	0.670±0.5	0.890±0.5	0.710±0.2	0.770±0.4	0.820±0.4	1.34±1.0	0.440±0.3
SO_2(μg/m^2)	1.11±0.4	1.89±1.1	1.43±0.5	1.08±0.2	1.85±1.2	3.97±2.8	1.06±0.2
NO_2(μg/m^2)	1.68±1.1	16.1±15	7.48±3.6	3.20±1.6	2.83±1.9	10.8±9.0	5.21±3.9
O_3(μg/m^2)	119±49	75.5±30	88.4±44	66.6±30	68.9±25	66.3±26	60.6±19

Particulate Matters (PM): It is a complex mixture of solids and liquids, including carbon, complex organic chemicals, sulphates, nitrates, mineral dust and water suspended in the air that originates from both natural and anthropogenic sources, including combustion processes, industrial activities, and transportation emissions. PM is categorized based on size and composition, where fine particles ($PM_{2.5}$) have a diameter ≤2.5 μm and coarse particles (PM_{10}) have a diameter ≤10 μm. The pattern of PM among the cities investigated in ascending order is as follows: *Port Harcourt < Lagos < Makurdi < Enugu < Abuja < Maiduguri < Kano*. PM can be generated from industry, transport and agriculture, and due to light weight, can also be carried on air currents from one place another. The size of the particle is very important in determining their behavior in air, the distance and the height upon which they will be carried by air currents and the effect they will have on the organism inhaling them or on plants which have to exchange gases through their stomata (Asthana and Asthana , 2016).

Total suspended particulate (TSP)refers to particulates with a diameter greater than 10 microns (um), such as dust, soot, dirt or smoke that are larger or dark enough to be seen with the naked eye. But the most damaging particles are the smaller particles, known as PM_{10} and $PM_{2.5}$. PM10 refers to particles with a diameter less than 10 um. PM2.5 refers to particles with a diameter less than 2.5 um, and these are known as fine particles. The smallest fine particles, less than 0.1 um in diameter are called ultrafine particles (Abulude, 2016).

Table 1 displays the mean concentrations of PM2.5 and PM10 for all air quality at all places understudy. The mean concentration of PM2.5 and PM10 over Makurdi was 41.4 ug/m3 and 76.1 ug/m3; Abuja was 51.0 μg/m^3 and 99.5 μg/m^3; PH was 32.2 μg/m^3 and 49.6 μg/m^3; Enugu was 46.2 μg/m^3 and 78.2 μg/m^3; Kano was 74.5 μg/m^3 and 148 μg/m^3 and Maiduguri was 70.0 μg/m^3 and 81.9 μg/m^3, respectively. In all places under investigation, the mean for PM2.5 valves were highest in Kano (74.8 μg/m^3) followed by Maiduguri (70.0 μg/m^3) and the lowest value in PH (32.2 μg/m^3). While the mean for PM_{10} values were highest in Kano (148 μg/m^3), followed by Abuja (99.5 μg/m^3) and then Maiduguri (81.9 μg/m^3) and the lowest value in PH (49.6 μg/m^3). Higher values of PMs could be due to emissions from industries and the various traffic activities at these locations. It could be also due to time of monitoring prevailing meteorological parameters, probably the methodology of monitoring. The allowable limit for $PM_{2.5}$ according to Nigerian (NAAQS) is 35 μg/m^3. this shows that only PH did not exceed the exposure limit while places like Makurdi, Abuja, Lagos, Enugu, Kano and Maiduguri exceeded the exposure limit. In a similar vein, the Nigerian (NAAQS)allowable limit for PM_{10} is 150 μg/m^3 and compared with the data from this study showed that all the places understudy did not exceed the Nigerian allowable limit. The mean values obtained in this study are lower than that 121 μg/m^3 in Beijing except Kano which was higher (148 μg/m^3) for PM10, but higher than those reported for Tokyo (23 μg/m^3), Nikolouzou (28.84 μg/m^3) obtained by Liang *et al*. (2019).

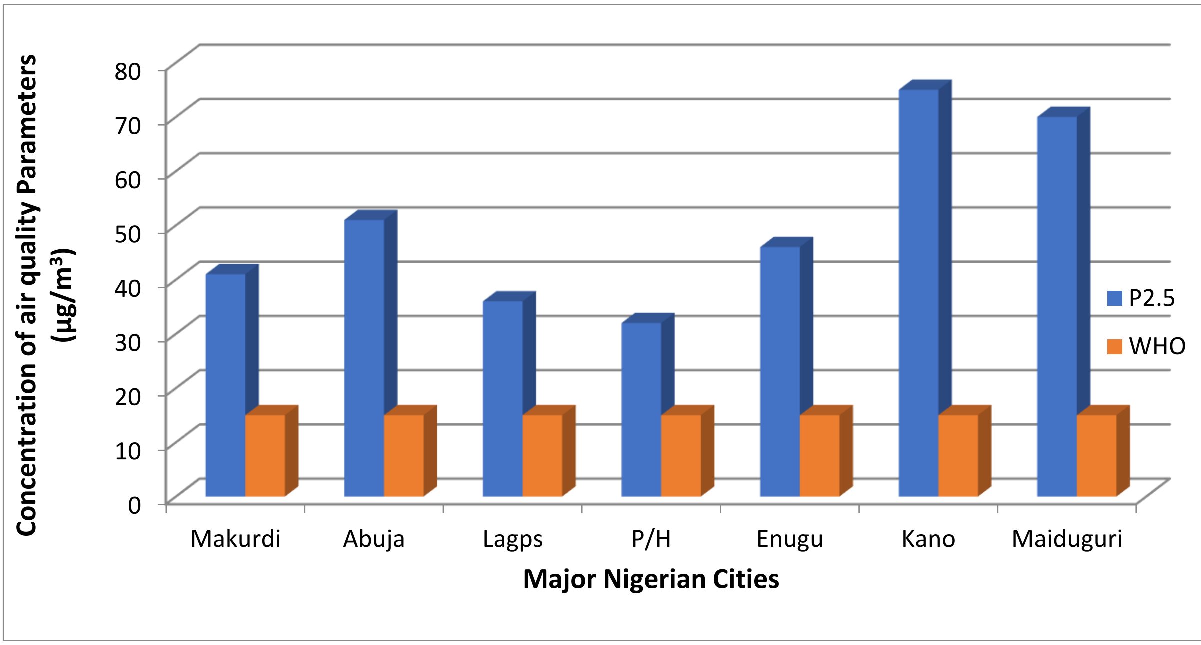

Figure 2. Distribution of $PM_{2.5}$ and WHO Standard across Nigerian Major Cities

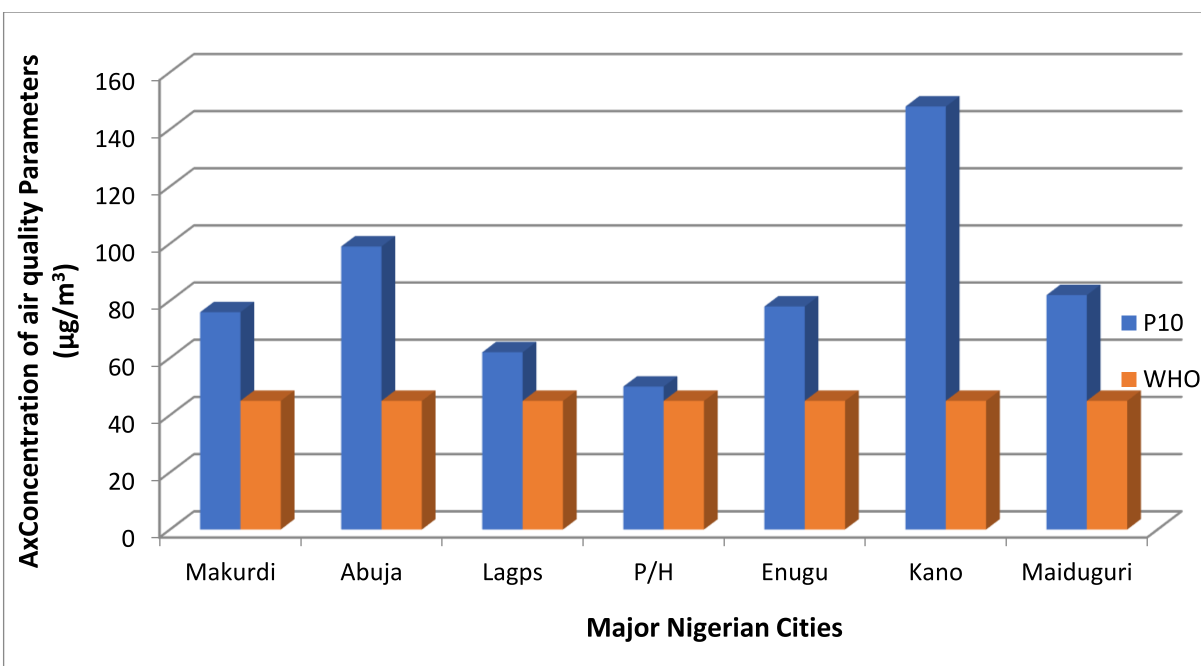

Figure 3. Distribution of PM_{10} and WHO Standard across Nigerian Major Cities

Carbon monoxide (CO): The major source of carbon monoxide, hydrocarbons, nitrogen oxides is the internal combustion engine, which is used to provide most of our transportation. The more concentrated the number of automobiles, the more concentrated the pollutants. As carbonaceous fuels like wood, gasoline, charcoal, natural gas, and kerosene fail to completely burn, they release carbon monoxide, a poisonous gas that is colourless, odourless, and tasteless (WHO, 2022).

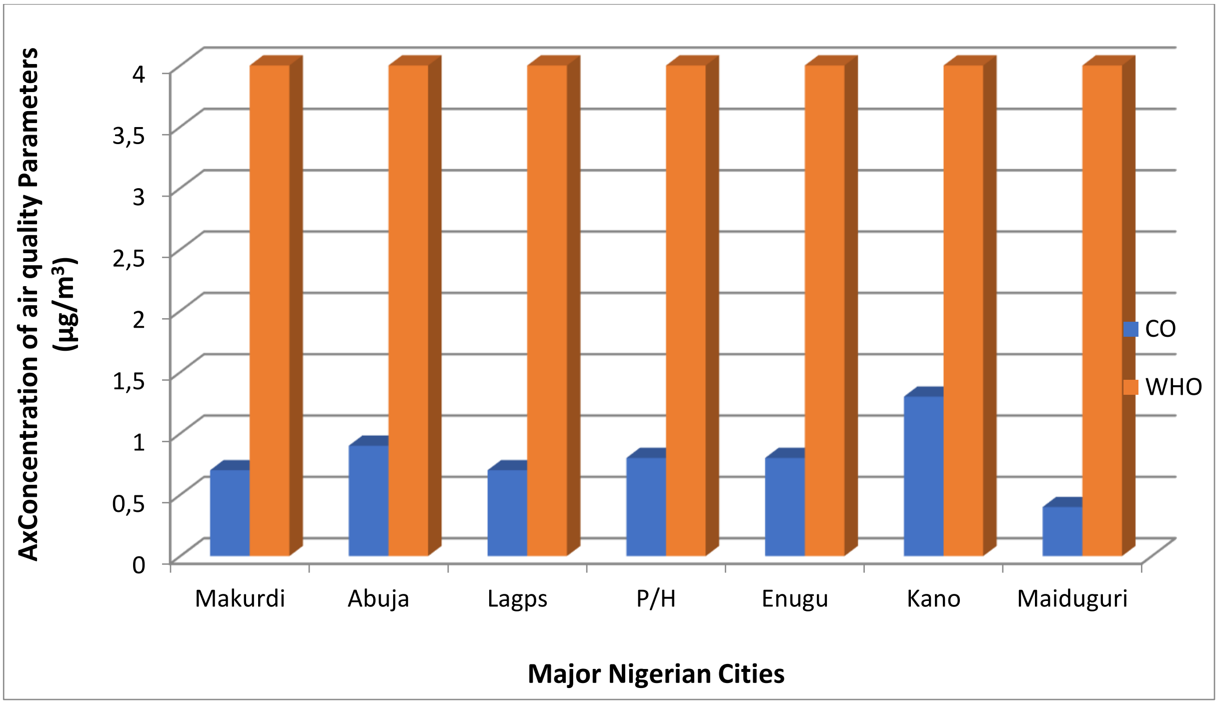

Figure 4. Distribution of CO across Nigerian Major Cities

The pattern of CO concentrations among the cities investigated in ascending order is as follows: Maiduguri < *Makurdi* < *Lagos* < *Port Harcourt* < *Enugu* < *Abuja* < *Kano*. A staggering 99% of the population breaths air that exceeds safe quality limits set by the World Health Organization (WHO). This polluted air, filled with fine particulate matter from various sources like fossil fuel combustion, wildfires, and construction sites, poses significant health risks – notably, an increased risk of cancer (Ukpebor *et al*., 2010). The monitored CO values were within the WHO limit of 12.3 mg/m^3 (Ukpebor *et al*., 2010). The continued exposure to low and moderate levels of CO could be dangerous to vulnerable persons, especially children and those with underlying respiratory illnesses. Furthermore, these values were lower than CO concentrations documented by Balogun and Orimoogunje (2015), who investigated polluted gases from vehicular exhaust around Benin axis. Carbon monoxide is dangerous because it binds to the hemoglobin in blood and makes the hemoglobin less able to carry oxygen. Several hours of exposure to air containing only 0.001 percent of carbon monoxide can cause death. The amount of carbon monoxide produced in heavy traffic can cause headache, drowsiness and blurred vision. Fortunately, carbon monoxide is not a persistent pollutant, because it readily combines with oxygen in the air to form carbon dioxide.

Sulfur dioxide (SO_2): SO_2 are primarily emitted by fossil fuel combustion, coal burning and industrial emissions. The mean SO_2 concentration for all sampling locations range from 1.06±0.2 reported in Maiduguri to 3.97±2.8 (µg/m) obtained in Kano. The lowest level of SO_2 in Maiduguri sampling station, is because of lower commercial and vehicular density compared to Kano. The mean SO_2 concentrations obtained at all sampling locations was far below the concentration obtained in most urban outdoor air, which is within the range of 20-90 µg/m) (Ipeaiyeda and Adegboyega, 2017).

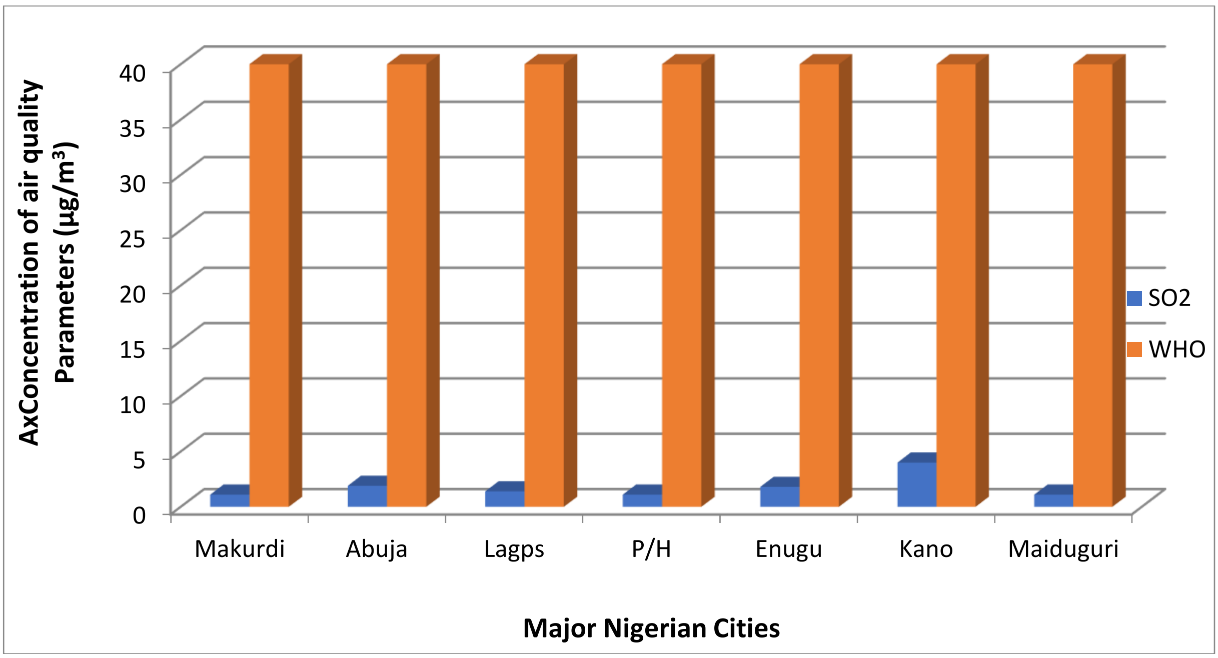

Figure 5. Distribution of SO_2 across Nigerian Major Cities

The pattern of SO_2 concentrations among the cities investigated in ascending order is as follows: Maiduguri < *Port Harcourt* < *Makurdi* < *Lagos* < *Enugu* < *Abuja* < *Kano.* Sulfur dioxide is produced when sulfur – containing fossil fuels are burned. It has a sharp odour, irritates respiratory tissue and aggravates asthmatic and other respiratory conditions. It also reacts with water, oxygen and other materials in the air to form sulfur-containing acids. The acids can become attached to particles that, when inhaled, are very corrosive to lung tissue. These acid-containing particles are also involved in the acid deposition.

Nitrogen dioxide (NO_2): Another air quality parameter of concern in Nigeria is nitrogen dioxide (NO_2). This gas is mainly produced by burning fossil fuels, such as in vehicles and power plants. High levels of NO_2 can irritate the respiratory system and make it more difficult for people with respiratory conditions to breathe. Prolonged exposure to NO_2 has also been linked to increased respiratory infections and reduced lung function. Lagos, Abuja and Kano exhibited relative high levels NO_2, with Makurdi, Enugu, Port Harcourt and Maiduguri showing levels of NO_2 that substantially decreased. Burning of fossil fuels in Kano, Lagos, and Abuja produce significant NO_2, nevertheless, traffic is regarded as primary source of NO_2 in these cities (Mahmud *et al.*, 2023).

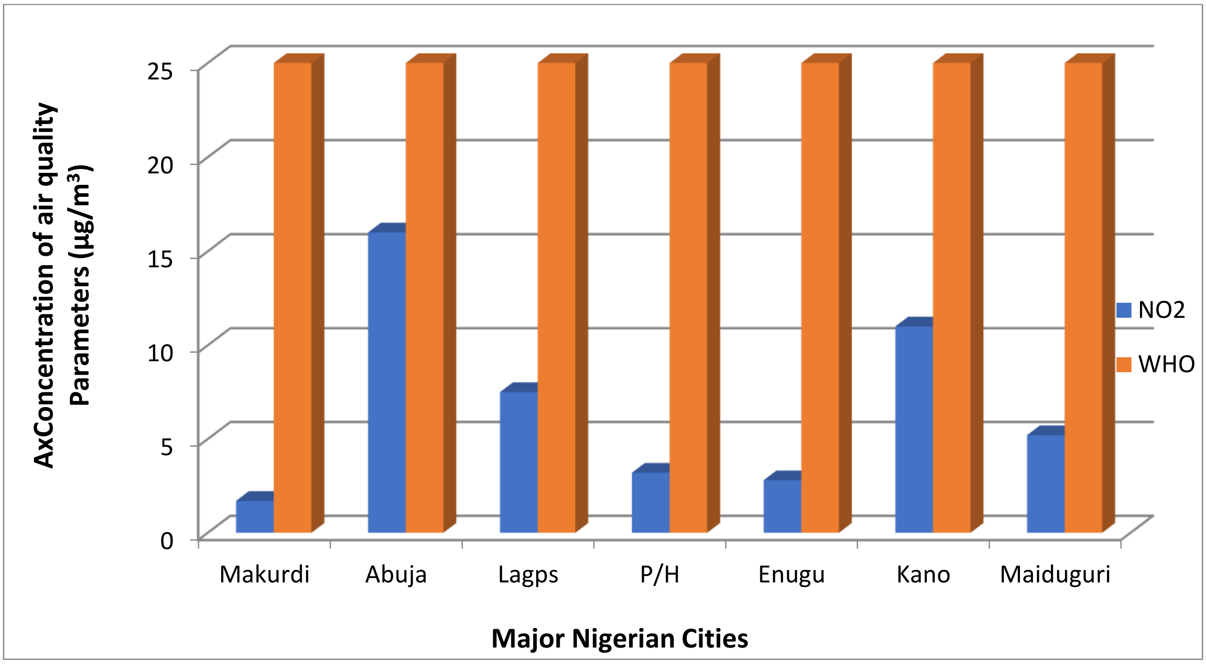

Figure 6. Distribution of NO_2 across Nigerian Major Cities

The pattern of NO_2 concentrations among the cities investigated in ascending order is as follows: *Makurdi < Enugu < Port Harcourt < Maiduguri < Lagos < Kano < Abuja*. Nitrogen dioxide is associated with adverse respiratory effects, especially in asthmatic individuals. Sulfur dioxide, emitted by industrial activities, can irritate the respiratory tract, causing respiratory symptoms and reducing lung function. The burning of fossil fuels by the automobile engine produces a mixture of nitrogen-containing compounds namely nitrogen monoxide (NO) and nitrogen dioxide (NO_2) which is secondary pollutant. Nitrogen dioxide is a reddish brown, highly reactive gas that is responsible for much of haze seen over cities, causes respiratory problems. Also, an important component of acid precipitation and as well as in the production of photochemical smog.

Ground-level ozone (O_3): Ozone is formed through chemical reactions between sunlight and pollutants like nitrogen oxides (NOx) and volatile organic compounds (VOCs). Ozone is a molecule that consists of three oxygen atoms bonded to one another. The levels of ozone in some selected cities that was investigated are in the range 60.6 to 119 μgm^{-3} with the highest value recorded in Makurdi and the lowest value recorded in Maiduguri as presented in Figure 7.

The pattern of ozone levels among the cities investigated in ascending order is as follows: Maiduguri < *Kano < Port Harcourt < Enugu < Abuja < Lagos < Makurdi.* The high level of ozone recorded in Makurdi could be transported by wind far from precursor gases like oxides of nitrogen and volatile organic compounds that are responsible for ozone formation in the presence of heat and sunlight. Also, warmer temperatures could increase ozone formation and the average temperature recorded in Makurdi (29.6 ± 3.3 ^{0}C) could be one of the reasons for the high level of ozone. Exposure to high levels of ozone could cause premature death especially in combination with other risk factors like asthma, respiratory infections and pulmonary inflammations (Abaje *et al*., 2020). The ozone level in the cities investigated revealed that only Makurdi is unhealthy for sensitive groups 101 – 150 μgm^{-3}, Abuja, Lagos, Port – Harcourt, Enugu, Kano and Maiduguri are moderate for sensitive groups 51 – 100 μgm^{-3}.

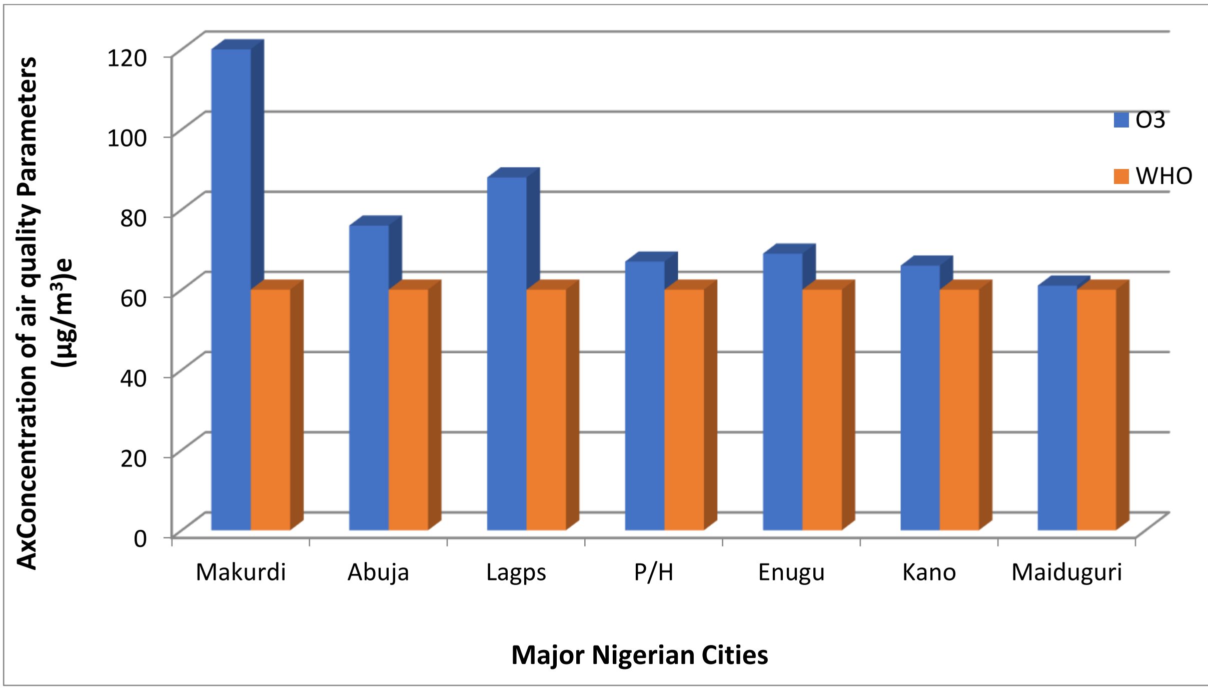

Figure 7. Distribution of O_3 across Nigerian Major Cities

The pattern of ozone levels among the cities investigated in ascending order is as follows: Maiduguri < *Kano* < *Port Harcourt* < *Enugu* < *Abuja* < *Lagos* < *Makurdi*. The high level of ozone recorded in Makurdi could be transported by wind far from precursor gases like oxides of nitrogen and volatile organic compounds that are responsible for ozone formation in the presence of heat and sunlight. Also, warmer temperatures could increase ozone formation and the average temperature recorded in Makurdi (29.6 ± 3.3 ^{0}C) could be one of the reasons for the high level of ozone. Exposure to high levels of ozone could cause premature death especially
in combination with other risk factors like asthma, respiratory infections and pulmonary inflammations (Abaje *et al*., 2020). The ozone level in the cities investigated revealed that only Makurdi is unhealthy for sensitive groups 101 – 150 μgm^{-3}, Abuja, Lagos, Port – Harcourt, Enugu, Kano and Maiduguri are moderate for sensitive groups 51 – 100 μgm^{-3}.

Tajudeen *et al.* (2023) investigated the concentrations and health risks of particulate matter (PM2.5) and associated elements in the ambient air of Lagos in ten (10) locations and reported the average ozone level in the range 14.06 – 32.11 μgm^{-3} which is lower than the values recorded in this work probably due to variations in temperature and climatic conditions. Oyareme and Osaji (2022) determined air quality parameters in Banjul metropolis, The Gambia, and statistically revealed that the mean ozone concentration in the morning as 57.39 μgm^{-3} and 64.40 μgm^{-3} in the evening with average temperatures 25.57^{0}C and 28.76^{0}C respectively which indicate that ozone level increases with increase in temperature as reflected in this research but the result recorded is lower compared to this work probably due to anthropogenic activities. Abulude *et al.* (2022) monitor air quality with satellite-based sensor in the morning and evening in four towns in Southeast, Nigeria reported the ozone level in Anambra (Awka); 13.00 and 35.00 μgm^{-3}, Imo (Owerri); 14.00 and 29.00 μgm^{-3}, Enugu (Nsukka); 16.00 and 18.00 μgm^{-3} and Abia (Aba); 18.00 and 28.00 μgm^{-3} respectively which are lower than the values recorded in this work and could be as a result of climatic conditions and time of sampling. Ozone is an extremely reactive molecule that irritates respiratory tissues and can cause permanent lung damage. Ozone, a potent oxidant is beneficial in the upper atmosphere, however at ground level it becomes a harmful pollutant. Breathing in elevated levels of ozone can lead to coughing, throat irritation, and worsen existing respiratory conditions like inflammation, and exacerbating asthma. Long-term exposure may even result in permanent lung damage. It also damages plants and reduces agricultural yields. Ozone is a secondary pollutant that is formed as a component of photochemical smog. For ozone, the sensitive group includes children and adults who are active outdoors because they are more likely to be at elevated ventilation rates for sufficiently long periods of time when ozone levels are high to experience effects. People with lung diseases are also included in this group because they often have poorer lung function to begin with, so that any additional reduction is more likely to result in symptoms, and also ozone can aggravate their underlying diseases.

Air Quality Index (AQI): Air Quality Index studied shows that the quality of air has some health issues recorded in the various states. Figure 8 shows the result of AQI in the ascending order of cities in terms of pollutants: Lagos < Port Harcourt < Maiduguri < Makurdi < Enugu < Abuja < Kano.

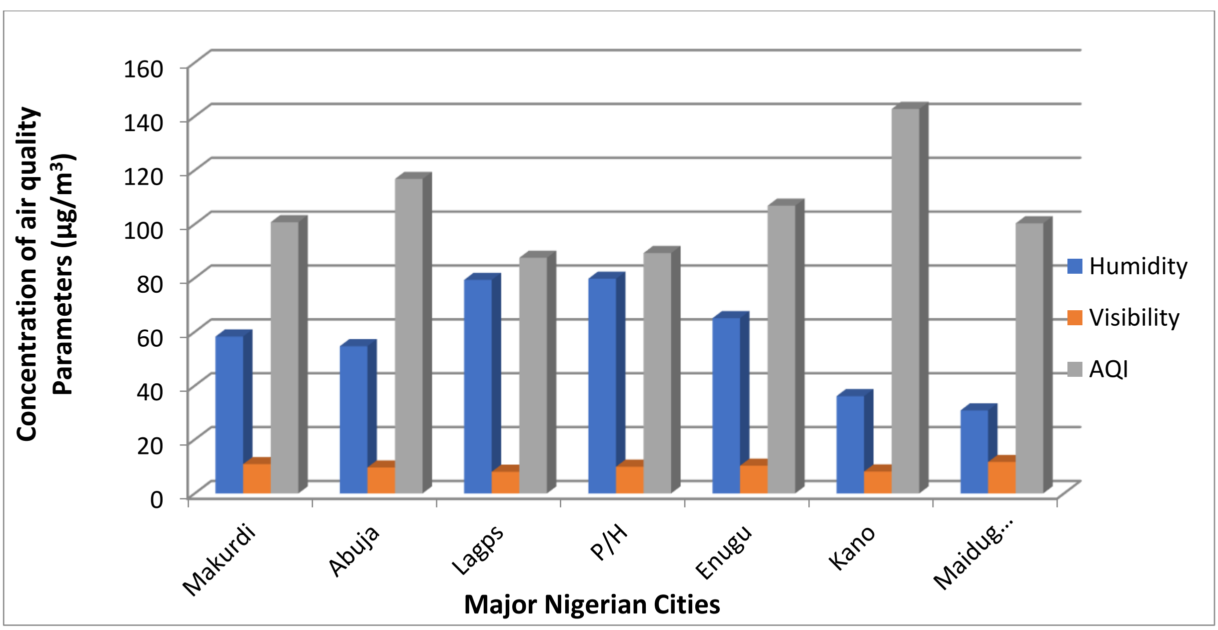

Figure 8. Mean Concentration of Air Quality Index in Nigerian Major Cities.

The air quality index in Lagos and Port-Harcourt ranges from 87.5 to 89.35 falling within Moderate" (51 - 100). Air quality is acceptable; however, there may be some health concern for a small number of unusually sensitive individuals. Although, air quality was given ranges, posing difficulty in identifying the groups of people that are at greater risk. However, active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion. The air quality index at Maiduguri, Makurdi, Enugu, Abuja, and Kano ranges from 100 – 143 falling within the "Unhealthy for Sensitive Groups" (101 – 150). At this range, people that are included in a sensitive group, whether the sensitivity is due to medical conditions, exposure conditions, or inherent susceptibility, may experience the effects described above when engaged in outdoor activities. However, exposures to ambient concentrations in this range are not likely to result in effects in the general population. The air pollutant standards were compared with Nigerian air quality average in major cities as presented in Table 2.

Table 2. Air Pollutant Standards along with Nigerian Air Quality for 90-days average

Air Pollutant	Measurement Period	U.S. National Ambient Air Quality Standards	European Union Air Quality	Nigerian Air Quality 90 days average
Carbon monoxide (CO)	8-hour average 1-hour	10,000 μg/m^3 40,000 μg/m^3	10,000 μg/m^3	806 μg/m^3
Nitrogen dioxide (NO_2)	Annual mean 1 hour	100 μg/m^3	40 μg/m^3 200 μg/m^3	6.76 μg/m^3
Ground-level ozone (O_3)	8-hour average 1-hour average	157μg/m^3 235 μg/m^3	120 μg/m^3	77.9 μg/m^3
Sulfur dioxide (SO_2)	Annual mean 24-hour average 3 – hour average 1-hour average	78 μg/m^3 365 μg/m^3 1,300 μg/m^3	125 μg/m^3 350 μg/m^3	1.77 μg/m^3
Particulate matter (PM_{10})	Annual mean 24-hour average	50 μg/m^3 150 μg/m^3	20 μg/m^3	85.0 μg/m^3
Particulate matter ($PM_{2.5}$)	Annual mean 24-hour average	15 μg/m^3 65 μg/m^3	50 μg/m^3	50.2 μg/m^3

3. CONCLUSION

Considering the distribution of the main air quality parameters, it is evident that World Health organization's (WHO) standards were much higher than the mean concentration values for CO, SO_2, and NO_2 across all the major Nigerian cities investigated. These are the main air pollutants of highest priority to human health and well being. These represent 50 % of the total air quality parameters of major concern carried out in this work. In terms of $P_{2.5}$, P_{10} and O_3 mean values were all higher than WHO recommendation, except for the level of O_3 in Maiduguri being at par with standard value. This calls for concern towards conscious efforts at mitigating present and future surge. This is done by ensuring modern agricultural practices, road construction with recourse to work ethics, fires through bush/wood burning and soil erosion being primary sources of particulate matter should be curtailed to the barest minimum, while reduction of SO_2, NO_2, CO invariably reduces the secondary sources produced in the atmosphere through interactions. Using of catalyst-inverted cars for reduction of emissions, chimneys in industrial boilers and power plants, reduction of gas flaring in refineries by trapping and conversion to secondary products would ameliorate ground level ozone. These would restore health confidence and environmental sustainability.

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References

[1] Oyareme, V. and Osaji, E.I.O. (2022). Environmental Air Quality Parameters Monitory Information Assessments and Its Health Implications on Biotic Factors in Banjul Metropolis, Gambia. *Open Access Library Journal*, 9, 1-21. doi: 10.4236/oalib.1108428

[2] Tajudeen, Y., Mohammed, U.F., Mohammed, Z.A., Abdulazeez, A., Abdulagafar, I.B., Musa, B. and Adedayo, J. (2023). Concentrations and health risks of particulate matter (PM2.5) and associated elements in the ambient air of Lagos, SouthWestern Nigeria. *Journal of Biological Research and Biotechnology*, 21(3): 2141-2149

[3] World Health Organization (2021). Global air quality guildlines. Particulate matter ($PM_{2.5}$) and (PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization. 290pp.

[4] Abulude, O. F., Acha, S., Arifalo, M. K., Akinnusotu, A., Oluwagbayide, D. S., AlShoumik, A. B. and Gbotoso, O. A. (2022). Monitoring of air quality with satellite-based sensor: the case of four towns in Southeast, Nigeria. *Asean Journal of Science and Engineering*, 3(1): 39-46

[5] Abaje, I. B., Bello, Y. and Ahmad, S. A. (2020). A review of air quality and concentrations of air pollutants in Nigeria. *Journal of Applied Science and Environmental Management*, 24(2): 373-379

[6] Ipeaiyeda, A. R., and Adegboyega, D. A. (2017). Assessment of Air Pollutant concentrations Near Major Roads in Residential, Commercial and Industrial Areas in Ibadan City, Nigeria. *Journal of Health Pollution*, 7(13): 11-21.

[7] Mahmud, K., Mitra, B., Sakib, M., Hridoy, A. E., Aina, Y. A., Rimi, I., Masiur, S., Leong, M., and Rahman, M. (2023). Temporal assessment of air quality in major cities in Nigeria using satellite data. *Atmospheric Environment: X*, 20, 100227. https://doi.org/10.1016/j.aeaoa.2023.100227

[8] World Health Organization. Ambient (Outdoor) Air Pollution. (2018) Available online: https://www.who.int/ 300 pp. (Accesed March 24, 2022).

[9] Ukpebor, E. E., Ukpebor, J. E., Eromomene, F., Odiase, J. I. and Okoro, D. (2010). Spatial and DiurnalVariations of Carbon Monoxide (CO) Pollution from Motor Vehicles in an Urban Space. *Polish Journal Environmental Studies*, 19, 817-823

[10] Balogun, V. S. and Orimoogunje, O. I. O. (2015). Geo-Spatial mapping of air pollution in Benin City, Nigeria, *Journal of Geography, Environment and Earth Science International*, 3(3):1-17.

[11] Mafuyai, G. M., Kamoh, N. M., Kangpe, N. S., Ayuba, S. M. and Eneji, I. S. (2015). Heavy Metals Contamination in Roadside Dust along Major Traffic Roads in Jos Metropolitan Area, Nigeria. *Journal of Environment and Earth Science*, 5(5): 48–57.

[12] Eneji, I. S., Itodo U. Adams and Kadili A. Julius (2015): Assessment of HeavyMetals in Indoor Settled Harmattan Dust within the University of Agriculture Makurdi, Nigeria. *Open Journal of Air Pollution*, 4: 198–207

[13] Ameh, J. A., Tor-Anyiin, T. A. and Eneji, I. S. (2015). Assessment of Some Gaseous Emissions in Traffic Areas in Makurdi Metropolis, Benue State, Nigeria, *Open Journal of Air Pollution*, 4: 175-183

[14] Mafuyai, G. M., Eneji, I. S. and Sha'Ato, R. (2014). Concentration of Heavy Metals in Respirable Dust in Jos Metropolitan Area, Nigerian, *Open Journal of Air Pollution (OJAP)*, 3:10-19.

[15] Eldon D. Enger and Bradley F. Smith (2006). Environmental Sciences: A case study of Interrelationships. Mc Graw Hill Publisher, Tenth Edition, New York, NY 10020. Pp 390 – 395

[16] Abulude, F O. (2016). Particulate matter; An approach to air pollution. *Preprints* 2016, 2016070057. https://doi.org/10.20944/preprints201607.0057.v1, pp14.

[17] Asthana, D. K. and Asthana, M. (2006). Environment: problems and solutions. 2nd Revised Edition, S Chand and company Ltd, New Delhi, India, 279pp.

[18] Liang, L., Cong, N., Li, Z., Zhao, Y. and Chen, Y. (2019). Assessment of personal exposure to particulate air pollution: the firstresult of city Health outlook (CHO) project. *BMC Public Health*, 19: 711