GAS Journal of Engineering and Technology (GASJET)
Volume 3 | Issue 5, 2026 Homepage: https://gaspublishers.com/gasjet-home/ ISSN: 3048-5800

Assessment of Ambient Air Quality within the Vicinity of a Charcoal Production Site in Ogwanja, Sapele Main Market, Sapele, Delta State

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Received: *10.04.2026* | ***Accepted:*** *02.05.2026* | ***Published:*** *04.05.2026*

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DOI: *10.5281/zenodo.20028021*

Abstract **Case Studies**

This study was carried out to determine the air quality at a charcoal production site at Ogwanja, Sapele main market and environs in the Niger Delta area of Nigeria. To determine the air quality, an Aerocet 5315 and Aeroqual series-500 air quality monitor was used. A Garmin E-Trex 10, Wind vane and Anemometer were used to determine geographical location, wind direction and wind speed respectively. The air quality was analysed at 0, 525, 810, 1150, and 2050m from the vicinity of the charcoal production sites in Ogwanja, Sapele main market at a height of 1.5m above the ground surface. The study revealed that the concentration of NO_2 were all above the WHO limit of 25µg/m^3 except for stations S4 and S5 with readings 23 and 17.7 µg/m^3 respectively. Similarly. The results obtained revealed the concentration of SO_2 were all above the WHO limits of 40µg/m^3 except for S4 and S5 with readings of 32.3 and 18µg/m^3 respectively. The results for CO, $PM_{2.5}$ and PM_{10} showed that they were all above the acceptable limits of 4µg/m^3, 15µg/m^3 and 45µg/m^3 respectively. The results obtained were subjected to ANOVA analysis and the findings revealed that there was no significant difference in the air quality between the sampling stations indicating that all air at sampling sites are polluted. The Pearson correlation analysis also showed a strongly positive relation greater than +0.9 between the parameters indicating that all pollutants could be originating from the same source. The study recommends that policies are urgently needed to ensure secure clean energy source for urban households and improved charcoal production facilities with noxious emission reduction features be adopted.

Keywords: Charcoal, Ambient Air, Air Quality, Vicinity, Pollutant Level.

Introduction

One of the necessities and requirements of human existence is clean and wholesome air (Hassan and Abdullahi, 2012). Deteriorated air quality threatens human health and contributes to environmental damage such as climate change and acid rain thereby leading to immense economic loss (Akpoghelie, Irerhievwie, Agbaire, and Orisaremi, 2016). Emissions from biomass burning and charcoal production is known to generate a large number of air pollutants such as particulate matter(PM), carbon monoxide (CO), nitrogen oxides (NO), sulphur oxides (SO), formaldehyde, benzene 1,3-butadiene, polycyclic aromatic hydrocarbon (PAH) and other toxic organic compounds that can damage human health (Ezzati et al, 2000; Mishra and Rutherford 2007). Exposure to high levels of air pollution can cause a variety of adverse health outcomes. The resultant effect of the discharge of such air pollutant into the atmosphere includes respiratory infections like lung cancer, asthma, cancer of the naso-pharynx and larynx, tuberculosis, and diseases of the eye such as cataract. (Bruce et al 2000; Ezzati and Kammen 2001).

Globally, the use of energy in the form of biomass and biofuel such as firewood, charcoal, petroleum, kerosene and gas are becoming competitive depending on the level of development of each nation. Reports shows that the pressure in developing countries, on forest natural resources is more acute because nearly 70% of the populace are involved in subsistence-based ventures and live in rural communities (World Bank, 2004). In recent times there has been a major shift from the use of petroleum products and electricity due to increase in pricing and the epileptic power supply to the use of charcoal in both the rural and urban canters in Nigeria. This shift has resulted in high demand for biomass and charcoal though not without its attendant environmental and health effect.

Charcoal is a wood fuel produced in mainly rural areas and consumed in both rural and urban areas. Charcoal has advantages as fuel when contrasted to biomass as it has a high heating value and simple storage (Antal and Gronli, 2003). Other factors influencing the choice of using charcoal instead of firewood includes charcoal has a higher calorific value per unit weight than firewood, more economical to transport over longer distances as compared to firewood due to weight differences, wood being heavier. The storage of charcoal takes less room as compared to firewood (Antar and Gronli, 2003). Charcoal is not liable to deterioration by insects and fungi as compared to firewood. Charcoal is almost smokeless and sulphur-free, as such it is an ideal fuel for use in towns and cities.

Charcoal is produced in kilns from wood pyrolyzing under high temperature in deficiency of air (Tippayawang et al 2019). Charcoal production varies in design size. These charcoal kilns are usually not equipped with any control measure or design to curb air pollution. Large-scale charcoal production, primarily in sub–Saharan African, has been a growing concern due to its threats of air quality deterioration, deforestation and climate change impacts. It is estimated that about five tons of wood is required to produce one ton of charcoal. This charcoal production process will drastically increase the risk of short- and long-term exposure to air pollutants with associated health impacts such as respiratory infections, heart disease and lung cancer. (WHO, 2021). Global warming impact from charcoal production may be much greater than the benefits of biomass and charcoal use in replacing fossil fuels. The use of cleaner, more efficient technologies in charcoal production could significantly cut pollutant emissions, and at the same time bring huge health benefits. Given the environmental and occupational impacts caused by charcoal production, this study was designed to determine the air quality of the surrounding environment of charcoal production sites by investigating the concentration and distribution over distances of selected air pollutants discharged from the production of charcoal in Ogwanja, main market, Sapele.

Methodology

Study Area

The GPS Garmin E-Trex 10 and Anemometer BT 100 equipment’s were used in determining the coordinates, wind speed and direction at the air sampling stations and the results are presented in Table 1.

Table 1. Distance, geographical location, wind speed and direction of wind.

Site	*Distance from production site (m)*	*Geographical coordinates*	*Average Wind speed (m/s)*	*Wind direction*
S1	*0*	05°51.019’N, 05°43.551’E	1.1	NE

S2	525	05°51.296’N, 05°43.598’E	1.3	NE
S3	810	05°51.574’N, 05°43.643’E	0.9	NE
S4	1150	05°51.851’N, 05°43.681’E	1.0	NE
S5	2050	05°52.129’N, 05°43.711’E	1.0	NE

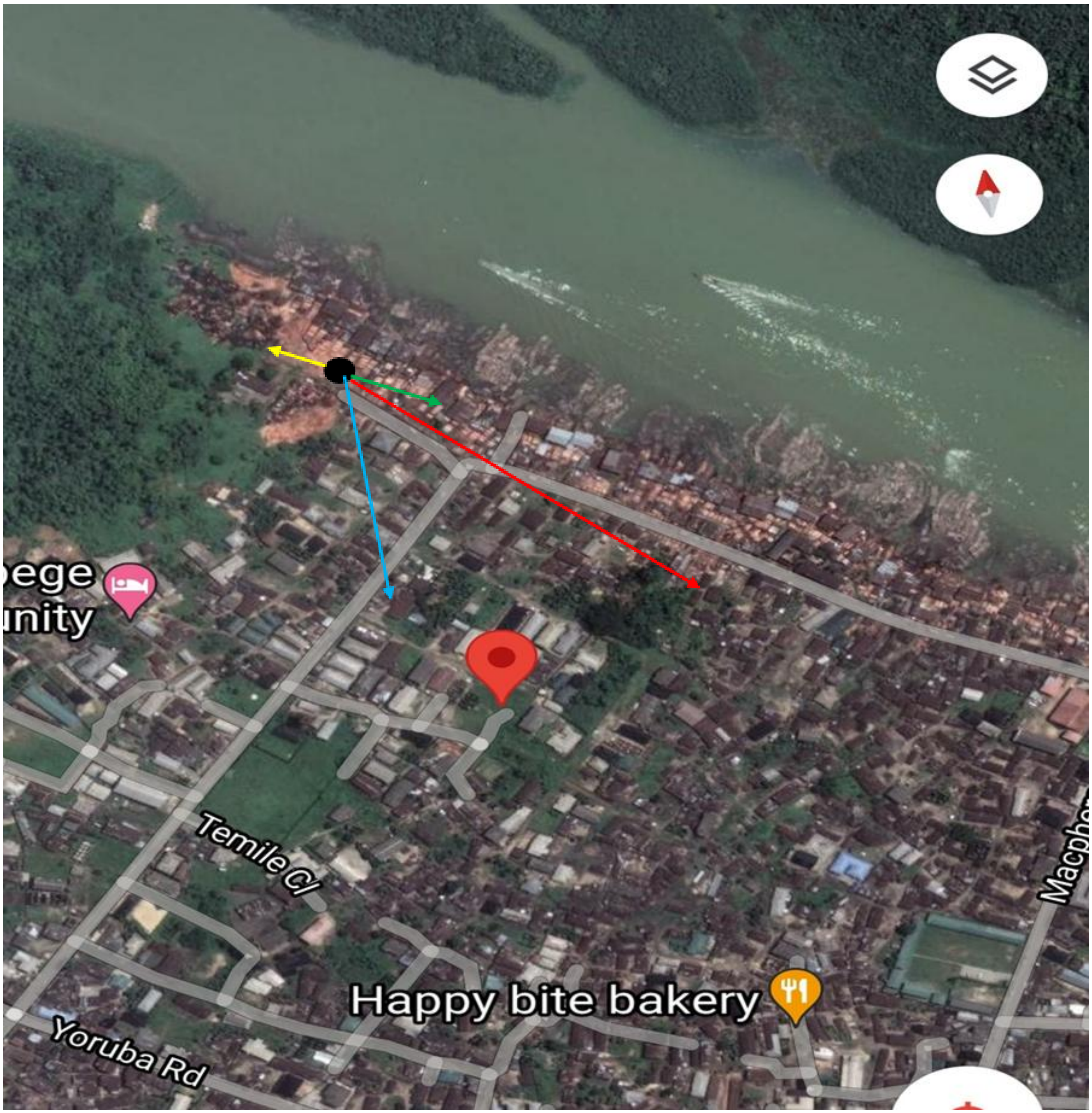

Fig 1. Areal map showing sampling locations

Key

- S1 (Point of charcoal production)
- S2 (525 metres)
- S3 (810 metres)
- S4 (1150 metres)
- S5 (2050 metres)

Table 2. Characteristics of the sampling area

Sampling site	Characteristics of sampling site
S1	Multiple charcoal production site, with few residential buildings, shops and petty trading around. No visible vegetation. The sky is very smoky and choky environment.
S2	Multiple sawmills, wood storage sites, and few residential buildings. No visible vegetation. Smoky sky.
S3	Multiple sawmills, wood storage sites, more residential buildings. Few vegetation. Clear sky.
S4	Main road, many residential buildings, shops, motor parking lot. Few vegetation. Clear sky.
S5	Main road, many residential buildings, shops, motor parking lot. Few vegetation. Clear sky.

Average concentrations of pollutants in air

In assessing air quality at the various sampling locations, the air quality monitoring devices Aerocet 531S (for particulate matter ($PM_{2.5}$, PM_{10}), Aeroqual series-500 (for Nitrogen dioxide, Sulphur dioxide) and Fluke meter (for carbon monoxide) monitoring were used to obtain concentrations of the pollutants in air. Air quality measurements were carried out thrice at 1.5 m above the natural ground level at each of the sampling site. The average values obtained were recorded as levels of air pollutants available. The measurement was conducted in the afternoon during the peak charcoal production activities and the average results obtained over a period of 6 days are presented in Table 3

Table 3. Average concentration of pollutants in air

	Concentration(µg/m^3)				
Site	**NO_2**	**CO**	**SO_2**	**$PM_{2.5}$**	**PM_{10}**
S1	37	100.3	106.7	344.7	310.3

S2	26.3	38	42.7	174.3	138.7
S3	27	42	62.7	206.7	173.3
S4	23	7.3	32.3	80.7	75.3
S5	17.7	5.3	18	64.3	61.3
WHO (2021)	25	4	40	15	45

5 Discussion of Results

Nitrogen oxide

The average nitrogen oxide concentration in the air at and around the charcoal production site at Ogwanja, Sapele Delta State during the study period are presented in Figure 2.

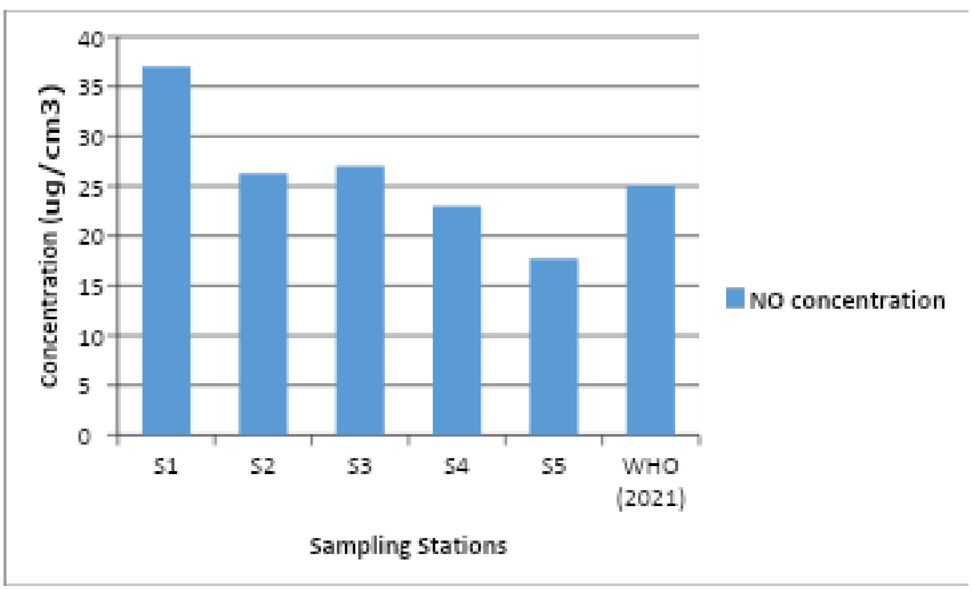

Fig 2. Average concentration nitrogen oxide in air at and around charcoal production site Ogwanja, Sapele.

The results of mean concentration of nitrogen oxide at sampling station S1, S2 and S3 during the sampling are higher than the acceptable limits of 25µg/m^3 set by WHO 2021. While sampling stations

S4 and S5 recorded concentrations that were lower than the acceptable limits of WHO 2021. Within the 5 sampling stations S1 recorded the highest concentration of 37µg/m^3. This high concentration could be attributed to the fact that the sampling Station S1 was at the production site. Similarly, the lowest concentration was 17.7µg/m^3 and recorded at S5. This low concentration could be attributed to the distance of 2050m away from the charcoal production vicinity where there was no charcoal production. The study of Umunnakwe and Aharanwa (2018) also reported higher concentrations of NO_2 (0.108 ppm) in Owerri municipal road, Imo State, Nigeria and that of Okunola et al (2012). in Kano State, Nigeria but not in accordance with the research work carried out by Antai et al (2016) which gave lower values of NO_2.

Carbon monoxide

The results of average carbon monoxide concentration in the air at and around the charcoal production site at Ogwanja, Sapele Delta State during the study period are presented in Figure 3.

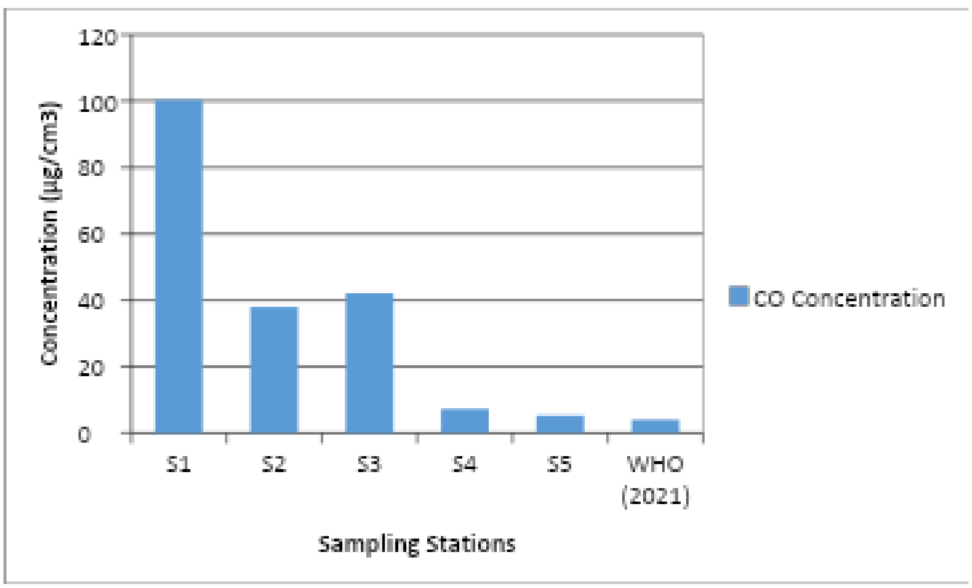

Fig 3. Average concentration carbon monoxide in air at and around charcoal production site Ogwanja, Sapele.

The results of mean concentration of carbon monoxide at sampling station S1, S2, S3, S4 and S5 during the sampling were all higher than the acceptable limits of 4µg/m^3 set by WHO 2021. Within the 5 sampling stations S1 recorded the highest concentration of 100.3µg/m^3, while S5 recorded the lowest concentration of 5.3 µg/m^3. These high concentrations could be attributed to the fact that the sampling Station S1 was at the production site. Similarly, the lowest concentration was 17.7µg/m^3 and could be attributed to the distance of 2050m away from the charcoal production vicinity where there was no charcoal production. The results obtained in this study were in support with the findings by Adelagun et al (2012). who reported high concentration of CO (30-70 ppm) in Okobaba (Ebute-Meta, Lagos), Nigeria but not in line with that of Antai et al (2016). who reported lower concentrations of CO (0.30- 0.76 ppm) in Uyo metropolis, Akwa Ibom State, Nigeria.

Sulphur dioxide

The average sulphur dioxide concentration in the air at and around the charcoal production site at Ogwanja, Sapele Delta State during the study period are presented in Figure 4.

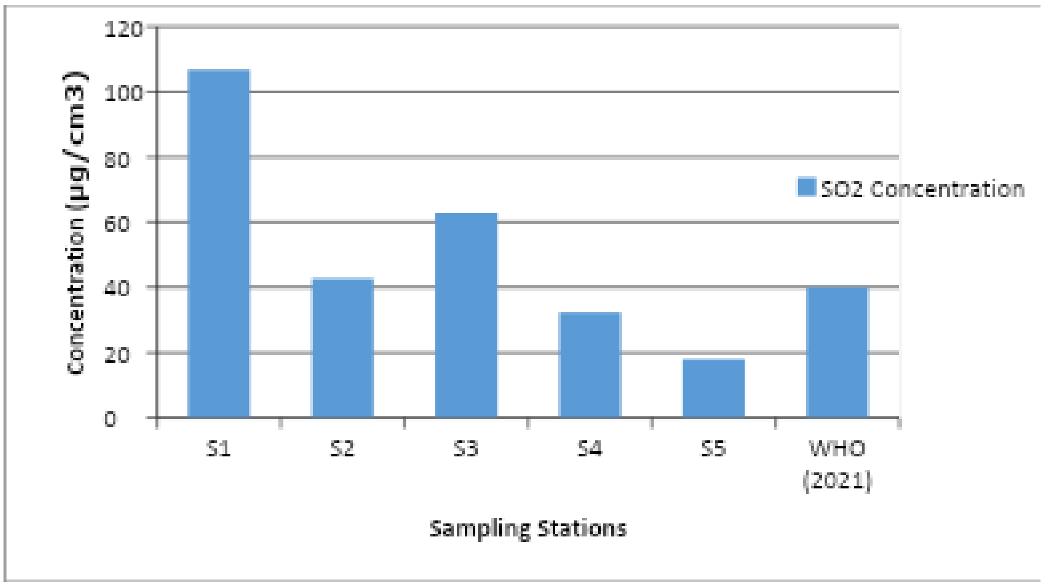

Fig 4.4. Average concentration sulphur dioxide in air at and around charcoal production site Ogwanja, Sapele.

The results of mean concentration of sulphur dioxide at sampling station S1, S2 and S3 during the sampling were all higher than the acceptable. While S4 and S5 fell below the acceptable limits of 40µg/m^3. Within the 5 sampling stations S1 recorded the highest concentration of 106.7µg/m^3, while S5 recorded the lowest concentration of 32.3µg/m^3. These high concentrations could be attributed to the fact that the sampling Station S1 was at the production site. Similarly, the lowest concentration was 17.7µg/m^3 and could be attributed to the distance of 2050m away from the charcoal production vicinity where there was no charcoal production. The range of SO_2 concentration was found to be 0.037 – 0.097 ppm and this is lower than ranges of 0.04 – 0.15 ppm, 3.21 - 5.18 ppm, 7.4 – 15.5 ppm, and 16 – 64 ppm as reported in similar studies conducted by Abam and Unachukwu (2009), Ayodele and Abubakar (2010), Ettouney et al. (2010), and Kalabokas et al. (1999), in selected area in Calabar, Lagos, Port-Harcourt and Greece respectively, but was higher than the range of 0.03 - 0.09 ppm reported in Kano metropolis Nigeria (Okunola et al., 2012). This was slightly higher when compared with the Federal Environment Protection Agency limit especially the lower limit standard.

Particulate matter ($PM_{2.5}$)

The average particulate matter ($PM_{2.5}$) concentration in the air at and around the charcoal production site at Ogwanja, Sapele Delta State during the study period are presented in Figure 5

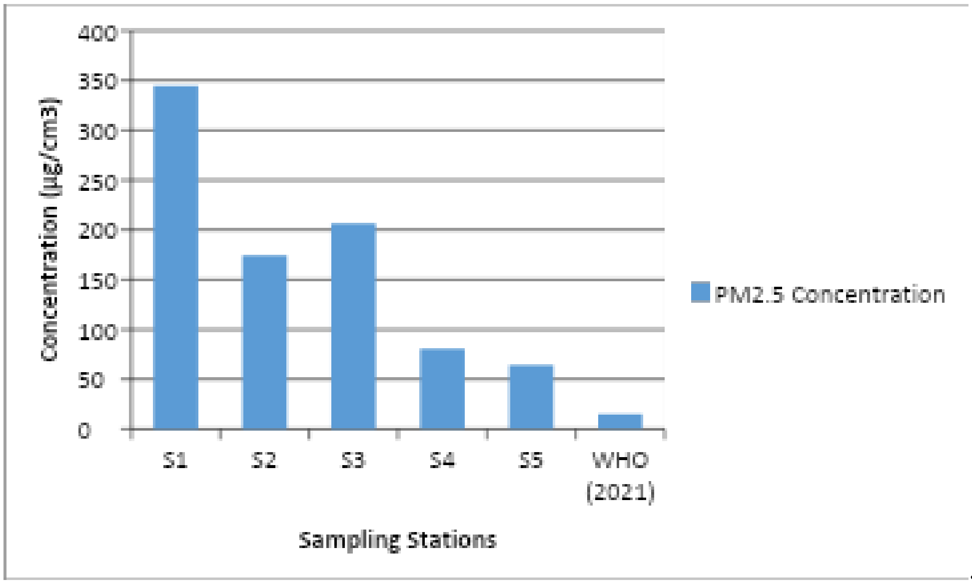

Fig 5. Average concentration particulate matter ($PM_{2.5}$) in air at and around charcoal production site Ogwanja, Sapele.

The results of mean concentration of $PM_{2.5}$ at sampling station S1, S2, S3, S4 and S5 during the sampling were all higher than the acceptable limits of 15 µg/m^3 set by WHO 2021. Within the 5 sampling stations S1 and S5 recorded the highest and lowest concentrations of 344.7µg/m^3 and 64.3 µg/m^3 respectively. These high concentrations indicating high particulate matter in the air could be attributed to the fact that the sampling stations are all close to the production site with S1 being the closest.

Particulate matter (PM_{10})

The average particulate matter (PM_{10}) concentration in the air at and around the charcoal production site at Ogwanja, Sapele Delta State during the study period are presented in Figure 6.

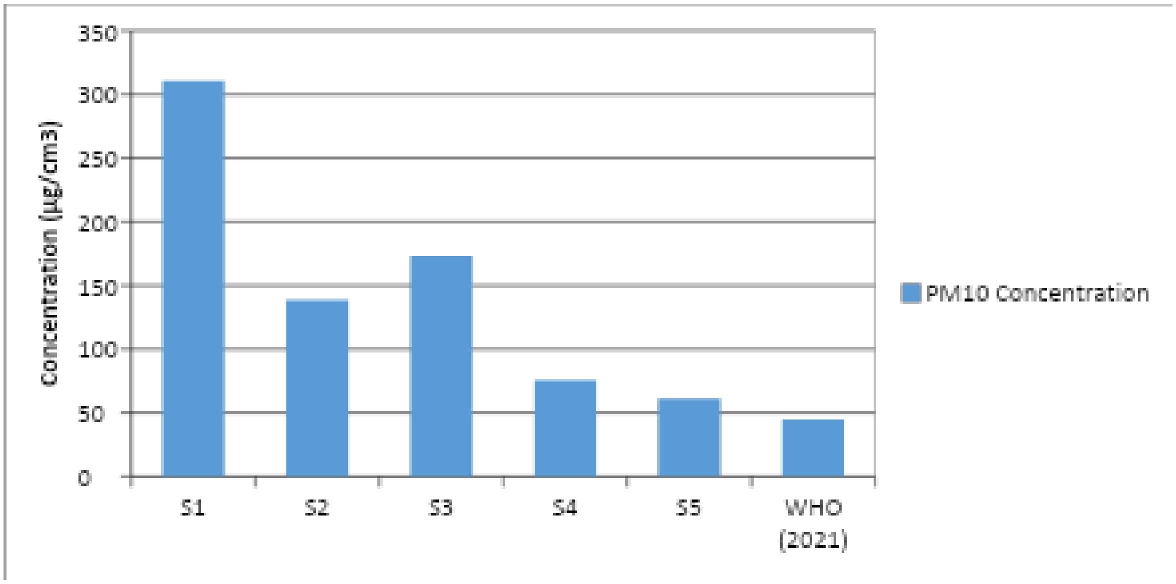

Fig 6. Average concentration particulate matter (PM_{10}) in air at and around charcoal production site Ogwanja, Sapele.

The results of mean concentration of PM_{10} at sampling station S1, S2, S3, S4 and S5 during the sampling were all higher than the acceptable limits of 45µg/m^3 set by WHO 2021. Within the 5 sampling stations S1 and S5 recorded the highest and lowest concentrations of 310.3µg/m^3 and 61.3µg/m^3 respectively. These high concentrations indicating high particulate matter in the air could be attributed to the fact that the sampling stations are all close to the production site with S1 being the closest. Comparing the results obtained in this study with the findings by Nicholas and Ukoha (2022) who reported higher values of particulate matter, $PM_{2.5}$ (113.00±7.00-133.00±36.07 µg/m^3) and PM_{10} (153.30±9.07 - 179.67±48.01 µg/m^3) in their study carried out in Okpanam and Warri, Delta State, Nigeria and Okudo et al (2022). who also reported higher values of particulate matter; $PM_{2.5}$ (23.06±1.53 - 153.23±28.73 µg/m^3) and PM_{10} (37.49±3.75 - 336.49±47.05 µg/m^3) in their research work in Enugu Urban, Enugu State, Nigeria.

Test of Hypothesis

H_O - There is no significant variation in the concentration of air pollutant investigated within the sampling sites.

Analysis of variance shows that *F* (2.6423) is less than the *F*-critical (2.866) at 0.05 level of significance. It can thus be concluded that the hypothesis which states that there is no significant variation in the concentration of air pollutant investigated within the 5 stations was accepted. While the hypothesis stating that there is a significant variation in the concentration of air pollutant investigated within the sampling sites was rejected at 5% level of significance.

Table 4. Correlation Analysis

	NO2	*CO*	*SO2*	*PM2.5*	*PM10*
NO2	1				
CO	0.968583	1			
SO2	0.977098	0.97664	1		
PM2.5	0.971928	0.992405	0.98188	1	
PM10	0.972336	0.995783	0.991033	0.995367	1

Table 4 shows the correlation matrix between the air pollutants at and around the charcoal production vicinity at Ogwanja Sapele Delta State. The correlation matrix shows that the strongest relation existed between PM_{10} and CO (0.995783). While the weakest relationship existed between CO and NO_2 (0.968583). This result shows that an increase in the concentration of one parameter will result in the increase in the other parameter by 99.5783% and 96.8583% in the first and second instance respectively. This results also shows all the parameters under investigation were all positively correlated, this also reveals that the five-sampling station are being likely affected by the same source of pollution.

Conclusion and Recommendation

Charcoal production is a major contributor to the problems of deforestation. The demand for charcoal production will continue to rise due to the demand and cost of energy in urban areas. Most people who engage in charcoal production activities do it not for the viability but for the purpose of survival. Charcoal production processes release high quantity of air pollutants into the air. The inhabitants of the vicinity of the charcoal production site are likely to suffer severe threatening health challenges in the future due to charcoal production in the community Jialong, et. al., (2023).

Among the implication of the high concentration of CO it can dramatically reduce hemoglobin's ability to transport oxygen. Other effects of exposure of CO at Ogwanja Sapele charcoal production includes headache, nausea, rapid breathing, weakness, exhaustion, dizziness, and confusion when these are prolong as also observed by TzeMing, Ware, Janaki and Scott (2007).

This in view of the findings of TzeMing, Ware, Janaki and Scott (2007) who affirmed that sulfur dioxide (SO_2) contributes to respiratory symptoms in both healthy patients and those with underlying pulmonary disease, the observed that human exposure to SO_2 exposure causes changes in airway physiology, including increased airways resistance. Both acute and chronic exposures to carbon monoxide are associated with increased risk for adverse cardiopulmonary events, including death.

Jialong, et. al., (2023) and Eniola and Odebode (2018) noted that $PM_{2.5}$, PM_{10} and SO_2 are associated with increased prevalence of pain/discomfort and anxiety/depression. The findings of Jialong, et. al., (2023) depicts that health status of infants and older Chinese adults was not only associated with demographic, socioeconomic, and health-related factors, but also negatively correlated with air pollution, especially through increased pain/discomfort and anxiety/depression it is a pointer to the implications of the observations of this study meaning that the infants and the aged health will seriously be jeopardize.

Based on the findings it is recommended that

1. Charcoal production site should be sited far from residential areas or charcoal can be produced with sustainable cleaner methods by the introduction of improved technology with noxious emission reduction features.
2. The federal, state and local government should organize and launch an enlightenment campaign on the importance of routine air quality assessment in our environment and industries/companies should not be placed or located in residential areas.
3. There should be proper environmental monitoring in the urban and rural areas of Imo State to control the atmospheric pollution and anthropogenic emissions in these areas.
4. Government should subsidise cooking gas to reduce the demand for charcoal.

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