Greener Journal of Environment Management and Public Safety
ISSN: 2354-2276
Vol. 13(1), pp. 19-27, 2025

https://gjournals.org/GJEMPS
DOI: https://doi.org/10.15580/gjemps.2025.1.021325027

Health Risk Assessment of Airborne Particulate Matter Emissions from Uncontrolled Garri Processing Kilns in Bayelsa State, Nigeria

Lelei, KE; Angaye TCN

Department of Biological Sciences, Niger Delta University, Bayelsa State, Nigeria.

ABSTRACT

The air quality around Garri factories in Bayelsa State, Nigeria, was checked to see how much airborne particulate matter (PM2.5 and PM10) was being released. The use of "different kinds" of flammable materials as fuel has made these emissions a problem. We randomly selected five locations (L1, L2, L3, L4, and L5) and took meteorological measurements (temperature, wind speed, and relative humidity). Carbon monoxide (CO), oxides of nitrogen (NO_x), and oxides of sulphur (SO_x) concentrations were checked at the sites to see how they compared to the WHO and EGASPIN Guidelines for air pollution. We evaluated PM2.5 and PM10, determined the air quality index (AQI), and compared it with the guidelines. The obtained data were statistically analyzed using a one-way ANOVA ($P<0.05$). According to the results, temperature and relative humidity showed slight variations between the locations but were within normal ranges. The CO, NO_x, and SO_x concentrations showed variations between the locations but were below the recommended 24-hour levels. For PM2.5 levels, which ranged from 16.39 to 29.44 µg/m³, and PM10 from 27.98 to 68.61 µg/m³, they were above the guidelines. The AQI indicated Level 2 to Level 4 air pollution levels around the locations, with Level 1 having the highest AQI level of Level 4. Thus, the air quality around these locations is unhealthy and dangerous to Garri producers and nearby residents. Therefore, we should discourage the use of such materials as fuel sources.

ARTICLE'S INFO

Article No.: *021325027*
Type: *Research*
Full Text: *PDF, PHP, EPUB, MP3*
DOI: *10.15580/gjemps.2025.1.021325027*

Accepted: *15/02/2025*
Published: *12/03/2025*

Keywords: *Garri production, particulate matter, air quality index, hazard*

***Corresponding Author**

Dr. Angaye T.C.N.

E-mail: *tcnangaye@ ndu.edu.ng*

Phone: *+2347037889063*

Article's QR code

INTRODUCTION

Air pollution refers to the alteration of both indoor and outdoor conditions by any chemical, physical, or biological agent that alters the natural properties of the atmosphere (WHO, 2021). It is a significant risk factor for non-communicable diseases (NCDs), such as chronic obstructive pulmonary disease, asthma, lung disease, and cardiovascular diseases (WHO, 2020). Air pollution is the second biggest cause of NCD-related fatalities, after cigarette smoking (WHO, 2021). Air pollution from natural and man-made sources has health and environmental implications (WHO, 1987; Fagorite *et al*., 2021). Over two million deaths worldwide from air pollution yearly result from damage to the lungs and the respiratory tract (Shah et al., 2013). According to reports by Chuang *et al*. (2011) and Shah *et al*. (2013), fine particulate matter contributed to approximately 2.1 million of these fatalities. These health problems include people with heart or lung diseases dying too soon, asthma getting worse, heart attacks, irregular heartbeats, lungs not working as well, and breathing problems Like cough, airway irritability, or difficulty breathing (Atkinson et al., 2010; Cadelis et al., 2014).

Anthropogenic aerosols called suspended particulate matter (SPM) can be released when things are burnt openly or when dust particles react with chemicals in the air. They can pollute the air. Suspended particulate matter is mainly grouped into fine (≤2.5 µm) and coarse (>2.5 µm) particles based on their diameter (United States Environmental Protection Agency, 2017). Other subtypes of SPM include thoracic particulate matter and respirable particulate matter (Brown *et al*., 2013). SPMs can be further grouped into $PM_{1.0}$, $PM_{2.5}$ (fine particulate), and coarse SPM, which include $PM_{4.0}$, $PM_{7.0}$, and PM_{10} (Angaye, 2018). To obtain total suspended particulates (TSP), all SPM aggregates must be added.

There are some compounding factors on which the source and fate of SPM depend, but in most cases, the meteorological state of the environment is a major determinant factor (Angaye, 2018). According to the World Health Organization, $PM_{1.0}$ which is the finest particle, is carcinogenic and has been rated the most lethal among all SPM. $PM_{1.0}$ has been reported to cause infant mortality; if accumulated, it can poison the blood, reach vital organs such as the lungs, and even cause mutations (United States Environmental Protection Agency, 2010). In 2013, there were over 300,000 cases of SPM toxicity ranging from 22 to 36% of lung cancer from $PM_{1.0}$ (Ole Raaschou-Nielson *et al*., 2013). The adverse health effects of SPMs have been reported to include acute and chronic respiratory syndromes, heart diseases, lung dysfunction, cancer of the lung and infant death (Guaita *et al*., 2011; Perez *et al*., 2012; World Health Organization 2018; Oloyede *et al*., 2020).

Garri, processed from the tubers of cassava is a staple food source, a product of Nigeria's rich agricultural heritage. Nigeria, among the world's greatest producers of Garri (FAO, 2013), is known for its pre-gelatinized grit, abundant in fiber and carbohydrates. Garri is available in fine and coarse textures with particle sizes varying from less than 10µm to over 2000µm (Nwankpa, 2010). The production method includes peeling of the cassava tubers, grinding, fermentation, filtration, and dehydration procedures in locally built kilns to diminish moisture content, succeeded by frying (Ozigbo *et al*., 2020) and the storage for use. The selection of fuel and briquette for the local kiln utilized in the frying process is increasingly becoming a significant source of public health concern.

During garri processing, individuals involved, use 'different sorts' of inappropriate items as sources of fuel; some of which are 'hazardous fuel enhancers' in addition to the firewood used. These include used plastic containers, nylon, pet bottles, shavings, etc. The levels of SPM and other airborne contaminants bellowing around these sites are worthy of attention. In addition, the sources of fuel used in this process are not regulated and pose environmental hazards; even the processors are at risk of exposure to the hazards therein, owing to the non-use of personal safety gear. The exposure of garri processors to ambient air pollution and the associated heightened risks of respiratory symptoms have been documented (Oloyede *et al*., 2020), although, the extent of exposure and health concerns remain inadequately examined. It is crucial for researchers, public health officials, and individuals interested in food production and health to address the occupational risks linked to the emission of airborne particulate matter in Garri production. Therefore, this study focused on the health risk assessment of airborne particulate matter emissions from uncontrolled Garri processing kilns in Bayelsa State, Nigeria.

MATERIALS AND METHOD

2.1 Study Area

Bayelsa State, situated in Nigeria's southern region, is a diverse wetland rich in natural resources, notably oil reserves and agricultural activities, especially fishing. Nigeria's economy derives significant advantages from Bayelsa State's varied cultural, economic, and natural landscapes, especially the Niger Delta wetlands. The industrial characteristics of the state have drawn various business sectors, illustrating its diversity. The state serves as an industrial center due to crude oil exploration, exhibiting a diverse and rapidly increasing population driven by ongoing migration from various regions; agriculture serves as the predominant occupation. Along its southern coast, the area shows an equatorial climate marked by monthly average temperatures between 25 and 29℃ and yearly precipitation ranging between 2000 and 4000mm. From March to October the area has a unique rainy season; from November to February it has a dry season, sometimes referred to as the harmattan period. While the harmattan season is defined by the influence of tropical continental air masses originating from the desert, August usually experiences a brief dry phase linked to Southwest monsoon winds that move rainfall from the ocean (Lala et al., 2023). The study area comprised of five monitoring stations and a control station situated in the Garri processing zones of Bayelsa State. Mobile air sampling instruments were deployed at the designated stations to assess the air quality.

2.2 Sampling

Sampling was carried out thrice at 24-hours at the five different Garri processing sites randomly selected in Bayelsa State. After doing extensive site reconnaissance evaluations, and having detailed conversations with relevant parties. A variety of hand-held portable equipment were employed, including AEROQUAL-513, SPM Met-One, and KESTREL (4500NV).

2.2.1 Metrological Indicators

Meteorological indicators such as, wind speed, humidity and temperatures were measured using the KESTREL 4500NV-USA meteorological meter. The meter was powered on and positioned at a height of 1.5meters above ground level, orientated in a windward direction. The meter's screen readings were recorded in triplicates.

2.2.2 Air Quality

Air quality was measured based on; carbon monoxide (CO), oxides of nitrogen (NOx) and oxides of sulfur (SOx), as well as, Suspended Particulate Matter (SPM)-$PM_{2.5}$ (fine type) and PM_{10} (coarse type). The levels of CO, NOx and SOx were measured using AEROQUAL Meter (AEROQUAL-Series 300_Newzealand). The levels of SPM ($PM_{2.5}$ and PM_{10}) associated with the sites were measured using AEROCERT-531S (Met One _Washinton, USA). During sampling, the meters were powered on and measurements were taken in triplicates at height of 1.5meters with the probe facing the windward direction.

2.2.3 Risk Assessment

Health risk evaluation was conducted by juxtaposing the mean air quality values with the acceptable limits established by the National Ambient Air Quality Standards (NAAQS) and the World Health Organization (USEPA, 2014; USEPA, 2018; WHO, 2021) as shown in Table 1. The ambient air condition was indexed across a region using an indication tool called the Air Quality Index (AQI), which also evaluated the health risk connected with particulate matter intake within particular places. Reports on daily air quality and knowledge on the hazards related to poor air intake on human health can be given via AQI. Air quality modeling was conducted utilizing the Air Quality Index-AQI (USEPA, 2014; USEPA, 2018) and the methodologies established by Wang *et al*. (2017). Calculated from the equation below, daily mean values of the measured levels of daily air quality index (AQI):

$$AQI_{PM2.5} = \underline{PM_{2.5}\ \text{Concentration}} \times 100 / \text{WHO Standard}$$

$$AQI_{PM10} = \underline{PM_{10}\ \text{Concentration}} \times 100 / \text{WHO Standard}$$

Table 1: Air Quality Index (USEPA, 2014; USEPA, 2018**)**

AQI	Health Concern Level	AQI Daily Colour Code	Air pollution Level
0 – 50	Good		Level 1
51 – 100	Moderate		Level 2
101-150	Unhealthy for Sensitive people		Level 3
151-200	Unhealthy		Level 4
201-300	Very Unhealthy		Level 5
>301	Hazardous		Level 6

Using colour codes to classify the degree of air pollution, the six main AQI categories define level of health risk. Level 1 using a green colour code denotes good air quality with either little or no risk for health problems. Level 2 refers to a moderate or tolerable air pollution level; yellow is the representative colour code. For a tiny number of very sensitive to air pollution, this category denotes a modest health issue. Level 3 with orange colour code represents poor air quality for sensitive and fragile population group. While susceptible groups include elderly and younger—that is, children—sensitive groups are those of people with underlying diseases including lung and heart disease. Level 4 with a red colour code denotes poor (unhealthy) air quality. The general populace will suffer unfavourable health consequences from this; more major health consequences will affect sensitive and vulnerable groups of people. Level 5 with purple colour code indicates more severe health repercussions (very unhealthy) for the sensitive groups and a major public health alert overall. Finally, level 6 with maroon colour code denotes hazardous air quality level and will cause an emergency notice of health issues thereby influencing the whole exposed population (USEPA, 2014; USEPA, 2018).

2.3 Statistical Analysis

Data obtained were expressed as mean ± standard deviation using Version 23 of SPSS for the statistical analysis. One-way Analysis of variance (ANOVA) was used for the separation of the variations in the means at $P < 0.05$ while Duncan's Post-hoc test was used to establish the degree of significance.

3.1 RESULTS

The mean (± SD) meteorological values of temperature, relative humidity, and wind speed measured at the selected sampling locations (Table 2) where Garri is processed showed that, temperature ranged from 27.96±0.033 to 31.05±0.059 ^{O}C with L5 having the highest value while L4 had the least temperature value. Temperature, relative humility and wind speed had values that were significantly different ($P < 0.05$) between the sampling locations. The relative humidity had values that ranged from 62.41±9.33 to 79.73±7.33%; L4 had the highest relative humidity level amongst the sampling locations while L5 had the lowest value. For wind speed, the mean values were from 0.51±0.00 - 1.31±0.33m/s with L1 having the highest mean level of 1.31±0.33m/s.

Table 2: Mean (± SD) values of the Temperature, Relative Humidity and Wind Speed at the Selected Sampling Locations where Garri is processed in Bayelsa State

Sampling Location	GPS Coordinates		Temperature (^{O}C)	Relative Humidity (%)	Wind speed (m/s)
L1	4°58'39''N	6°6'30''E	28.37±0.09^{b}	76.41±2.71^{e}	1.31±0.33^{d}
L2	4°32'28''N	6°24'33''E	29.53±0.043^{c}	69.81±4.11^{c}	0.55±0.04^{a}
L3	5°9'31''N	6°11'37''E	30.01±0.07^{d}	66.31±5.53^{b}	0.51±0.00^{a}
L4	4°42'27''N	6°19'35''E	27.96±0.033^{a}	79.73±7.33^{a}	0.71±0.03^{b}
L5	4°41'33''N	6°19'38''E	31.05±0.059^{e}	62.41±9.33^{d}	0.93±0.41^{c}

Key: Means with the same superscripts down the columns are not statistically different at P<0.05

The mean values of the air pollutants- carbon monoxide (CO), oxides of nitrogen (NOx) and oxides of sulphur (SOx) measured at the sampling locations L1, L2, L3, L4 and L5 (Table 3) indicated slight differences ($P < 0.05$) in the variations in the concentrations of these gases across the locations with respect to CO and NOx, The CO concentrations ranged from 0.010±0.000 - 0.057±0.003ppm with L1 having the highest CO level. NOx concentration with range of 0.010±0.000 - 0.079±0.000ppm had the highest concentration level at L2. While SOx concentration ranged from <0.010±0.000 to 0.025±0.000ppm. These values were compared with International Guidelines (WHO, 2021); and National Standards of FEPA (1991) and EGASPIN (2002) as shown in the table and were observed to be lower for all the sampling locations. These values were also lower than the SO_2 - 0.1ppm, CO – 10ppm Guidelines of the Federal Ministry of Environment (1991).

Table 3: Mean (±SD) Concentrations of the Carbon monoxide (CO), oxides of nitrogen (NOx) are pollutants of air, and Oxides of Sulphur around the Selected Sampling Locations in Bayelsa State and Guidelines of WHO (2021), EGASPIN (2002) and FEPA (1991)

Sampling Location	GPS Coordinates		Levels of Air Polluting Gases at 24-Hour		
			Carbon monoxide (CO) in ppm	Oxides of Nitrogen (NOx) in ppm	Oxides of Sulphur (SOx) in ppm
L1	4°58'39''N	6°6'30''E	0.057±0.003^{b}	<0.010±0.000^{a}	0.011±0.000^{a}
L2	4°32'28''N	6°24'33''E	0.050±0.021^{b}	0.079±0.000^{b}	0.025±0.000^{a}
L3	5°9'31''N	6°11'37''E	0.023±0.000^{a}	<0.019±0.000^{a}	<0.010±0.000^{a}
L4	4°42'27''N	6°19'35''E	0.010±0.000^{a}	<0.010±0.000^{a}	<0.010±0.000^{a}
L5	4°41'33''N	6°19'38''E	0.031±0.000^{a}	<0.010±0.000^{a}	<0.010±0.000^{a}
WHO (2021) 24-Hr Limits			4.0ug/m^{3}	25.0ug/m^{3}	40.0ug/m^{3}
EGASPIN (2002) 24-Hr Limits			10ug/m^{3} (0.01 mg/m^{3})	150ug/m^{3} (0.15 mg/m^{3})	100–150ug/m^{3} (0.1–0.15mg/m^{3})
FEPA (1991) 24-Hr Limits			10mg/m^{3}	350–1000mg/m^{3}	30–3000mg/m^{3}

Key: *Values with same superscripts in the columns are not significantly different at P 0.05; FEPA (1991) - Federal Environmental Protection Agency; EGASPIN (2002) - Environmental Guidelines and Standards for the Petroleum Industry in Nigeria; WHO (2021)- World Health Organisation regarding Ambient Air Quality Standards*

From the results on the particulate matter for $PM_{2.5}$ and PM_{10} (Figure 1), $PM_{2.5}$ levels at the selected sampling locations ranged from 16.39 – 22.44µg/m^{3} with L1 having the highest $PM_{2.5}$ level while PM_{10} levels ranged from 27.98 to 68.61µg/m^{3} with L1 also having the highest PM_{10} level.

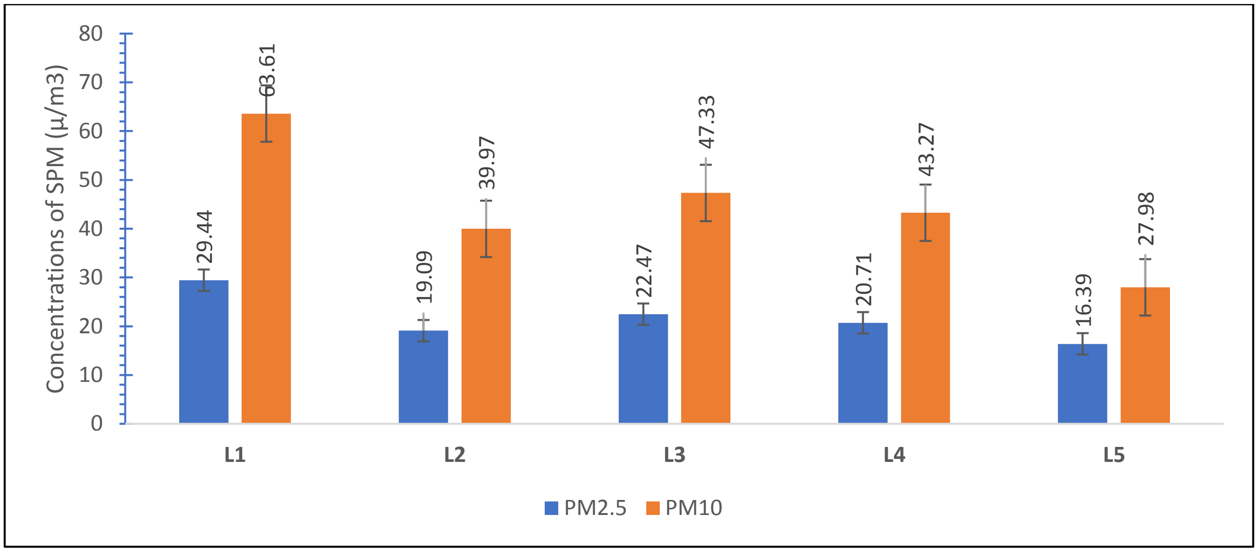

Figure 1: Showing 24-hour $PM_{2.5}$ and PM_{10} levels at the selected Garri Processing locations in Bayelsa State

The PM values at the sampling locations were compared with the WHO (2021) recommended 24-hour average time limit presented in Table 4. The values determined from the selected Garri processing locations (L1, L2, L3, L4 and L5) indicated that, for PM $_{2.5}$ which ranged from 16.39 -29.44µg/m^3 were at levels higher than the recommended 15ug/m^3 while for PM_{10} which ranged from 27.98 - 68.61µg/m^3, L1 and L3 had levels higher than the recommended 45ug/m^3. L1 had the highest particulate matter levels with $PM_{2.5}$ at 29.44µg/m^3 and PM_{10} at 68.61µg/m^3. Interestingly, L5 had the lowest PM levels ($PM_{2.5}$ at 16.39µg/m^3 and PM_{10} at 27.98µg/m^3), as well as, the lowest humidity (62.41±9.33%) but highest temperature (31.05±0.059℃).

Table 4: $PM_{2.5}$ and PM_{10} Levels at the Sampling Locations Compared with the WHO (2021) Recommended 24-hour Air Quality Levels

Sampling Locations	GPS Coordinates		Levels of Suspended Particulate Matter (µg/m^3) at 24-hour		Air Pollution Level	
			PM $_{2.5}$	PM_{10}	PM $_{2.5}$	PM_{10}
L1	4°58'39''N	6°6'30''E	29.44	68.61		
L2	4°32'28''N	6°24'33''E	19.09	39.97		
L3	5°9'31''N	6°11'37''E	22.47	47.33		
L4	4°42'27''N	6°19'35''E	20.71	43.27		
L5	4°41'33''N	6°19'38''E	16.39	27.98		
WHO (2021) 24-hr Air Quality Level			15.0	45.0	NA	

Risk Assessment

The health risks connected with these emissions (pollutants) were assessed using an air quality index (AQI) derived from the World Health Organisation (WHO, 2021) criteria. The AQI values determined for the quantified $PM_{2.5}$ and PM $_{10}$ values for the sampling stations L_1, L_2, L_3, L_4 and L_5 as shown in Table 4 were between Levels 2 to 4 with L1 having the highest AQI levels (as indicated in the values of $PM_{2.5}$ at 29.44µg/m^3 and PM_{10} at 68.61µg/m^3). L5 had the lowest PM and AQI levels also reflected in their values ($PM_{2.5}$ of 16.39µg/m^3 and PM_{10} of 27.98µg/m^3 at Level 3 and Level 2 respectively).

4.1 DISCUSSION

The climate of the study area is tropical with alternating wet and dry seasons. The mean monthly temperature ranges from 25 to 38℃ (Obafemi and Omiunu, 2014). Angiamowei *et al*. (2019), in their study around Gbaran – Ubie Gas Processing Plant, Bayelsa State, Nigeria reported 2.80 - 3.75m/s wind speed, relative humidity values ranged between 37.15 - 98.80% with temperature between 24.80 – 31.05℃. Abulude *et al*. (2022), gave results of temperature of 24-31℃, wind speed of 3.3-12.5m/s, and relative humidity of 60-91% for Yenegoa, Nigeria. From this study, the 24- hour meteorological values for temperature, wind speed and relative humidity during the sampling time ranged from 27.96 to 31.05^{O}C, 0.51 - 1.31m/s and 62.41 to 79.73% respectively. Which except for temperature were lower than the previous findings, attributable to the specific locations, sampling time, and presence of vegetative cover. Variations observed in the meteorological values between the sampling locations were also attributable to these factors- specific locations, sampling time, and presence of vegetative cover. These implied that these values were within the expected ranges for ambient environment.

Among the most important and alarming air pollutants mentioned by Lala et al. (2023) are oxides of nitrogen (NOx), oxides of sulphur dioxide (SOx), carbon dioxide (CO2), carbon monoxide (CO), and particulates (PM1, PM2.5 and PM10), and other uncontrolled emission activities of great relevance. Angiamowei *et al*. (2019), in their report for study around Gbaran – Ubie Gas Processing Plant, Bayelsa State, Nigeria gave the values for that of SO_2 to range between 0.50 – 1.50ppm and CO at 0 .50 – 6.00ppm. Onakpohor et al. (2020) conducted a study on air pollution from artisanal refinery operations in the Niger Delta, Nigeria gave values of 3215.67–9001.07mg/m^3 for CO, 233.00–437.68mg/m^3 for NOx, and 160.25–350mg/m^3 for SO_2. Yorkor *et al.* (2023), field measurement of air pollutants (SO_2, NO_2, CO,) reported that, except for CO, exceeded permissible limits around Tombia-Edepie, Swali, Igbogene and Yenegoa which they attributed to vehicular movement. Angaye *et al*. (2024), reported carbon monoxide (0.01–0.07µg/m^3), NOx (< 0.01µg/m^3) and SOx (0.01–0.04µg/m^3) for gases related with Bayelsa State's artisans' petroleum refining. The air pollutants measured at the sampling locations L1, L2, L3, L4 and L5 in this study at 24-hour showed variations between the sampling stations especially for CO and NOx. The sampling locations had values for these gases that were lower than the recommended 24-hour limits of WHO (2021), EGASPIN (2002) and FEPA (1991). These values indicated that these air polluting gases were not at obnoxious levels as to result in environmental or/and health implications, hence, pose no threat.

The differences in the concentrations of these gases amongst the studies are attributable to the anthropogenic activities that resulted in the various gaseous emissions that are air pollutants. The temperature, humidity, wind speed, and wind direction are primary meteorological factors that correlate with airborne pollutant concentrations (Zhang et al., 2015). As observed in the findings of this study, the values for the meteorological readings and the air polluting gases- CO, NOx and SOx were relatively low.

The PM2.5 (fine particles) poses a greater risk than PM10 (coarse particles). The surface area to volume ratio of PM2.5 is significantly higher than that of PM10, which renders PM2.5 more dangerous, particularly when inhaled and gets into the bloodstream. Assessing the extent to which humans are exposed to air pollutants based on air quality monitoring is important for developing policy frame works, guidelines, regulations for their regulation to improve air quality and human health through controlled/reduced emission.

Abulude *et al*. (2022), in their study on air quality index levels of $PM_{2.5}$ in Yenegoa, gave $PM_{2.5}$ result of 11.1-26.2µg/m^3**.** Yorkor *et al.* (2023), field measurement of PM_{10} and $PM_{2.5}$ had values that exceeded permissible limits around Tombia-Edepie, Swali, Igbogene and Yenegoa which they attributed to vehicular movement. Lala *et al*. (2024), in their findings in the Niger Delta Region showed that**,** majority of the dispersed particles of $PM_{2.5}$ assessed were located between 0m and 500m and ranged between 145.50µg/m^3 and 425.23µg/m^3. Angaye *et al*. (2024), reported 0.09–18.00 and 22.00–55.13µg/m^3 for $PM_{2.5}$ and PM_{10} respectively associated with artisanal refining of crude oil in Bayelsa State. In this study, the 24-hour $PM_{2.5}$ which ranged from 16.39 - 29.44µg/m^3 across the sampling locations were at levels higher than the WHO (2021) recommended 24-hour limit of 15ug/m^3 while PM_{10} which ranged from 27.98 - 68.61µg/m^3, had L1 and L3 with levels higher than the WHO (2021) recommended 24-hour limit of 45ug/m^3. These findings were similar in that, PM values were higher than the recommended levels indicating airborne emissions that pose threat to the environment and health.

The air quality index (AQI) reported by Abulude et al. (2022) indicated results ranging from 46 to 80 for PM2.5, categorizing it as Level 1 air pollution. Lala et al. (2024) found that the AQI levels during the period studied ranged from unhealthy for those who are sensitive (145.50µg/m3) to hazardous (425.23µg/m3) air quality. Their findings led to the conclusion that the residents of the Niger Delta region of Nigeria are at risk of adverse health effects due to prolonged exposure to elevated levels of PM2.5 in the area. From this study, the AQI at the selected Garri processing locations indicated Level 2 (with yellow colour code) to Level 4 (with red colour code), with L1 having the highest AQI levels at Level 4 for $PM_{2.5}$ and PM_{10} (as indicated in the values of $PM_{2.5}$ at 29.44µg/m^3 and PM_{10} at 68.61µg/m^3) while L5 had the lowest PM and AQI levels at Level 2 (with yellow colour code) reflected in their values ($PM_{2.5}$ of 16.39µg/m^3 and PM_{10} of 27.98µg/m^3 at Level 3 and Level 2 respectively).

The implications of these AQI values are that the air quality around these Garri processing locations at Level 2 indicates a moderate air pollution level, presenting an acceptable standard with some health concerns for a small subset of individuals who are particularly sensitive to air quality issues. Level 3 indicates an unhealthy air condition for sensitive and vulnerable populations. The sensitive group includes individuals with underlying health issues, such as lung and heart diseases, while the vulnerable groups consist of the elderly and children. Level 4 indicates that the air quality is unhealthy. This will lead to adverse health consequences for the general population and more severe health impacts on sensitive and vulnerable groups- which is case for L1, Confirming the allusion of Lala *et al*. (2024), that, "inhabitants of these areas are liable to hazardous health effects over a prolong exposure to the high level of PM_2"These are probably due to the use of 'different sorts' of combustible materials used in the kilns for frying of Garri in these locations that pose hazard to the environment and health of exposed persons.

The scientific basis for particle pollution mainly consists of epidemiological studies evaluating the morbidity and mortality impacts of both acute and chronic exposure to particle pollution (Abulude et al., 2022). Ephraim-Emmanuel et al. (2023) demonstrated a significant correlation between soot-containing air pollutants, such as PAHs (a component of particulate matter), and the prevalence of respiratory health issues in specific populations in Bayelsa State, Nigeria. Hence, the need to create awareness about the hazards and discourage the use of such materials as sources of fuels in such production activities; and more research in this area is encouraged.

Acknowledgement

The authors would like to express their gratitude to TETFUND for their invaluable support and funding, which facilitated the completion of this research.

CONCLUSION

Garri, processed from the tubers of cassava is a staple food source in Nigeria, with Bayelsa State not being an exception. Its production has increased with increase in population and has resulted in resorting to the use of 'different sorts' of combustible materials as sources of fuels during the frying. These materials have had resultant impacts on ambient air quality which was the thrust of this study. In which the findings showed that, at 24-hour average time, the air polluting gases- CO, NO_x and SO_x were not particularly affected since they were lower than the WHO (2021) recommended guidelines but $PM_{2.5}$ and PM_{10} were at levels higher than the recommended levels. The AQI values at Level 2 to Level 4 indicated that the PM levels were hazardous and pose threat to the environment (air quality) and health of individuals (as they inhale the polluted air) involved in the Garri production, as well as, those who live close to the sampled locations. Hence, the need to create awareness about the hazards and discourage the use of such materials as sources of fuels in such production activities.

REFERENCES

Abulude, F. O., K. M. Arifalo, Amoke, M. K., A. Akinnusotu, S. D. Oluwagbayide and Acha, S. (2022). Air Quality Index Levels of Particulate Matter ($PM_{2.5}$) in Yenogua, Nigeria. *Jurnal Geografi Gea*, 22 (2). ISSN 2549-7529. https://ejournal.upi.edu/index.php/gea

Angaye, T.C.N. (2018). Assessment of the fate and intensity of particulate matter associated with playgrounds in traffic-congested areas of Yenagoa metropolis, Nigeria. *MOJ Toxicology, 4*(6). https://doi.org/10.15406/mojt.2018.04.00141

Angaye, T. C. N., A. N. Ebelegi, and K. E. Lelei (2024). Levels of Toxic Emissions Associated with Artisanal Refining of Crude Oil In Bayelsa State, Nigeria. *Proceedings of the 1st Annual Faculty of Science International Conference, Niger Delta University, Amassoma, Bayelsa State, Nigeria, 14th -16th April, 2024.* Pp 191-198.

Angiamowei, S. V., G. I. Nwankwor and C. A. Ahiarakwem (2019). Assessment of Air Quality Around Gbaran -Ubie Gas Processing Plant, Yenagoa, Bayelsa State, Southern Nigeria. *Journal of Environment and Earth Science,* 9 (7): 11-18. Doi: 10.7176/JEES

Atkinson, R. W., Fuller, G. W., Anderson, H. R., Harrison, R. M., and Armstrong, B. (2010). Urban particulate matter and cardiorespiratory diseases. *Epidemiology*, 21(4): 491-501. Doi: 10.1097/EDE.0b013e3181e11ad

Brown, S. G., Frank, N. and Hafner, H. R. (2013). Source apportionment of particulate matter in the eastern United States. *Journal of the Air & Waste Management Association*, 63(9): 1119-1128. Doi: 10.1080/10962247.2013.822044

Cadelis, G., Tourres, R. and Molinie, J. (2014). Indoor air quality in schools in the French Caribbean. *Environmental Health Perspectives*, 122(11): 1249-1256. Doi: 10.1289/ehp.1306973

Chuang, K. J., Chan, C. C., Su, T. C., Lee, C. T. and Peng, C. M. (2011). Associations between particulate sulfate and organic carbon exposures and heart rate variability in patients with or at risk for cardiovascular diseases. *Journal of Occupational and Environmental Medicine*, 53(11): 1230-1236. Doi: 10.1097/JOM.0b013e318234aebe

EGASPIN (2002). Environmental Guidelines and Standards for the Petroleum Industry in Nigeria. Department of Petroleum Resources Lagos State, Nigeria.

Ephraim-Emmanuel, B.C., Enembe, O. and Ordinioha B. (2023). Respiratory Health Effects of Pollution Due to Artisanal Crude-Oil Refining in Bayelsa, Nigeria. *Annals of Global Health*, 89(1): 74, 1–11. https://doi.org/10.5334/ aogh.424

Fagorite, V. I., Anifowose, F. A. and Chiokwe, V. N. (2021). Air Pollution; Causes, Effects and Remediation in Nigeria. *International Journal of Advanced Academic Research (Sciences, Technology and Engineering),* 7 (1): 13-30. Doi: 10.46654/ij.24889849.e7114

FAO (2013). Food and Agriculture Organization of the United Nations. Statistical Database _ FAOSTAT, http://faostat.fao.org/; 2013 [Accessed 14 July 2013].

Federal Ministry of Environment, FMEnv (1991). "National Interim Guidelines and Standards for Industry Effluents, Gaseous Emissions and Hazardous Waste Management in Nigeria. Pp 91-110.

FEPA (1991). Guidelines to Standards for Environmental Pollution Control in Nigeria. Federal Environmental Protection Agency (FEPA), Lagos State, Nigeria.

Guaita, R., Pichiule, M., Mateos, V. M., Lope, V. and Moreno, T. (2011). Indoor and outdoor air pollution levels in schools in Barcelona. *Microchemical Journal*, 99(2): 289-295. Doi: 10.1016/j.microc.2011.05.008

Lala, M. A., Ajibola, E. T., H. A. Lawal, O. A. Adesina and A. I. Igbafe (2024). Particulate matter pollution over artisanal crude oil refining areas of Niger-Delta Nigeria: Spatiotemporal analysis, transport modelling and risk assessment. *Ain Shams Engineering Journal,* 15: 102654. https://doi.org/10.1016/j.asej.2024.102654

Lala, M.A., Onwunzo, C.S., Adesina, O.A. and Sonibare, J.A. (2023). Particulate matters pollution in selected areas of Nigeria: Spatial analysis and risk assessment. *Case Stud. Chem. Environ. Eng.*, 7:100288. https://doi.org/10.1016/j.cscee.2022.100288.

Nwankpa, G. U. (2010). Heat and Mass Transfer Analysis of a Gari Frying Machine. A Project Report for the award of Master of Engineering Degree in Mechanical Engineering, University of Nigeria, Nsukka.

Obafemi, A.A. and Omiunu, P. (2014) Analysis of Immigrations' Residential Preference and Ethnic Segregation in Yenagoa Metropolis: *Research on Humanities and Social Sciences*. 4(19): 24-35

Ole Raaschou-Nielsen, A. V., Andersen, Z. J., Hvidberg, M., Jensen, S. S., Ketzel, M., and Sørensen, M. (2013). Air pollution and lung cancer incidence in 17 European cohorts: Prospective analyses from the European Study of Cohorts for Air Pollution Effects (ESCAPE). *The Lancet Oncology*, 14(9): 813-822. Doi: 10.1016/S1470-2045(13)70279-1

Oloyede, T., Akintunde, A. A., Oloyede, T. W., Adeniran, J. A., Desalu, O. O., Tanimowo, M. O. and Salami, A. K. (2020). Air Quality Index and Respiratory Symptoms among Garri Processing Workers in Ogbomoso, Nigeria. *West African Journal of Medicine*, 37(2): 152–158.

Onakpohor, A., B. S. Fakinle, J. A. Sonibare, M. A. Oke and F. A. Akeredolu (2020). Investigation of air emissions from artisanal petroleum refineries in the Niger-Delta Nigeria. *Heliyon*, 6 (2020): e05608

Ozigbo E. S., Bamgboye A. I., Adunoye F. O. and Murphy K. M. (2020). Review of Gari Processing Technologies: The Challenges and Prospects. *International Journal of Innovative Science and Research Technology*, 5(5): 1309 – 1316.

Perez, L., Lüthi-Carter, R., Tainio, M. and Prüss-Üstün, A. (2012). Transport-related air pollution and deaths in Europe: Results from the APHENA study. *American Journal of Respiratory and Critical Care Medicine*, 186(10): 964-971. Doi: 10.1164/rccm.201202-0259OC

Shah, A. S., Lee, K. K., McAllister, D. A., Hunter, A., Nair, H., W. N. Whiteley, J. Langrish and Mills, N. L. (2013). Short term exposure to air pollution and stroke: Systematic review and meta-analysis. *British Medical Journal*, 346: f653. Doi: 10.1136/bmj.f653

United States Environmental Protection Agency, USEPA (2016). National Ambient Air Quality Standards for Particulate Matter. Federal Register, 81(206), 61113-61216.

United States Environmental Protection Agency, USEPA, (2014). A Guide to Air Quality and Your Health; Brochure; EPA-456/F-14-002; U.S. EPA: Washington, D.C., USA, https://www3.epa.gov/airnow/aqi_brochure_02_14.pdf (accessed on 18 October 2018).

United States Environmental Protection Agency, USEPA (2018). Inventory of U.S. Greenhouse Gas Emissions and Sinks, (430-P-17-001), https://www.epa.gov/ghge missions/inventory-us-greenhouse-gasemissions-and-sinks-1990-2016.

United States Environmental Protection Agency, USEPA (2017). National emissions inventory, https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-documentation.

Wang, M., Aaron, H. H. and Zimmerman, J. (2017). Particulate matter and cardiovascular disease: A review of the epidemiological evidence. *Environmental Health Perspectives*, 125(10): 105001. Doi: 10.1289/EHP1063

World Health Organization, WHO (2020). Regional Office for Europe (http://www.euro.who.int/en/health-topics/health-policy/health-2020-the-european-policy-forhealth-and-well-being, accessed 2 April 2020).

World Health Organization, WHO (1987). Air quality guidelines for Europe. Copenhagen, WHO Regional Office for Europe (WHO Regional Publications, European Series, No. 23.

World Health Organization, WHO (2018). Air pollution: ambient air pollution: health impacts, WHO: Geneva, Switzerland. https://www.who.int/airpollution/ambient/health-impacts/en/,2018. (Accessed 4 October 2018).

World Health Organization, WHO (2018). Factsheet on Ambient Air Quality and Health, WHO: Geneva, Switzerland, http://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health (accessed on 4 October 2018).

World Health Organization, WHO (2021). Global air quality guidelines, Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization, Licence: CC BY-NC-SA 3.0IGO

Yorkor, B., Degi, E.M. and Ogbonna, C. E. (2023). Dry Season Concentration of Selected Air Pollutants in Yenagoa, Bayelsa State, Nigeria. *Uniport Journal of Engineering and Scientific Research (UJESR),* 8 (1): 81-91. ISSN: 2616-1192.

Zhang, F., Zu Wu Wang, Hai Rong Cheng, Xiao Pu Lv, Wei Gong, Xin ming Wang and Gan Zhang (2015). Seasonal variations and chemical characteristics of $PM_{2.5}$ in Wuhan, Central China. *Sci. Total Environ*., 518–519: 97-105 https://doi.org/10.1016/j.scitotenv. 2015. 02.054.

Cite this Article: Lelei, KE; Angaye, TCN (2025). Health Risk Assessment of Airborne Particulate Matter Emissions from Uncontrolled Garri Processing Kilns in Bayelsa State, Nigeria. *Greener Journal of Environmental Management and Public Safety*, 13(1): 19-27, **https://doi.org/10.15580/gjemps.2025.1.021325027.**