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SPATIAL DISTRIBUTION OF AIR QUALITY ACROSS OKRIKA ISLAND, RIVERS STATE, NIGERIA.

[1]George-Harry, D., [1]Gobo, A.E., and [1]Eze, C.L.

[1]Institute of Geosciences and Environmental Management, Rivers State University Port Harcourt, Nigeria.

Abstract

The study examined the spatial distribution of air quality across Okrika Island and the effect on our environment, survey research design was adopted for this study. The gas contaminant monitor used was Aeroqual Series 500 Gas Monitoring meter and the particulate matter monitor employed was MET One Aerocet 531 Particle Counter. The key findings in this study includes the determination of the ambient air quality in Okrika, Rivers State. Despite most of the pollutants not exceeding the guideline values set out by the World Health Organization and National Environmental Standards and Regulations Enforcement Agency, the pollutants were substantially present in the environs across the study area. Although, the concentrations of SO_2 and H_2S were relatively low, ranging from 0.00-0.05mg/m³. Air Quality Index revealed that the air quality across all nine (9) stations in the study area descriptively ranged from 262.5 - 459.2 % unhealthy to hazardous, especially for sensitive groups of residents. The situation of air quality in the study area is significant to the health and environment of the residents. Actions need to be taken to curb activities that impair the air quality of the study area.

Introduction

Human exposure to air pollution is a reality of today's globe, especially in the urban areas of the majority of developing nations. Despite the fact that man's desire for a higher quality of life and the exploitation of natural resources for rapid industrialization and urbanization are key human causes of air pollution, these activities also contribute to the problem. Carbon monoxide is a major air pollutant emitted by incomplete combustion of fossil fuels and waste incineration, sulphur oxides are emitted by sulphur-containing coal and oil in houses, businesses, and power plants, nitrogen oxides are emitted by high-temperature fuel combustion in motor vehicles and industries, and hydrocarbons are emitted by incomplete combustion of fossil fuels in automobiles and furnaces, and photochemical oxidants are emitted by sunlight acting on the hydrocarbons and nitrogen oxides (Ideriah et al., 2008).

According to epidemiological studies, exposure to air pollutants over an extended period of time causes a variety of health issues, which in turn raises medical expenses for individuals and causes the government to lose money due to decreased productivity (Brunekreef & Holgate, 2002). Globally, outdoor air pollution causes almost 3.7 million premature deaths each year (WHO, 2014).

Air pollution in Nigeria is not new and several scholars (Ede 1990; Ossai *et al.* 1999; Okecha 2000; Efe 2005, 2006 and 2008 etc.) have attempted to examine the concentration of pollutants and their effect on our environment. Nigeria flares more gas than any other nation in the world, according to the Niger Delta News (2004). Approximately 75 percent of total gas production in Nigeria is flared, and about 95 percent of the associated gas, which is produced as by-product of crude oil extraction, is also flared. Gas flaring in Nigeria contributes a measurable percentage of the world's total emissions of greenhouse gases (Gobo, 2002).

Okrika Kingdom in Rivers State is a place where air pollution from mobile, stationary, and interior sources has effect on the environment. Statistics on both outdoor and indoor air quality represent a person's overall exposure (Ideriah *et al*., 2001). Air pollution is serious around Okrika and its environs as a result of major air pollutants, particulates, dust and soot constantly emitted from the Port Harcourt Refinery, Eleme Petrochemical Company limited and the National Fertilizer Company (NAFCON), Port Harcourt Refinery Company (PHRC) and Pipeline Products Marketing Company (PPMC). Thus, this study focuses on the spatial distribution of air quality across various sections of Okrika Island, Rivers State, in order to determine the air quality and put forward recommendations on how to reduce its impact on human health and the environment.

Materials and Methods

Research Design

Survey research design was adopted for this study, the Aeroqual Series 500 Gas Monitoring meter and MET One Aerocet 531 particulate Counter was used for primary data collection in August 2022 spanning 3days. The ambient air quality across the study area was assessed using American Standard for Testing and Materials, ASTM. Investigation was focused on specific pollutants across the study area, these pollutants include Carbon monoxide CO, Nitrogen dioxide NO_2, Sulfur dioxide SO_2, Hydrogen Sulfide H_2S, Methane CH_4, Volatile Organic Compounds VOC, Particulate Matter (PM 1, 2.5, 7, 10) and Total Suspended Particles TSP. Assessment points in different sections of the study area were determined and geo-referenced using a study map.

Data Analysis

The adaptation of a comprehensive air pollution index was used for interpretation of air pollution quality of any city or area, so that the chances of uncertainty regarding air quality may be reduced. Thus, a modified Oak Ridge National Air Quality Index (ORNAQI), which is a nonlinear index having exponential function with coefficient with other nonlinear relationship was selected for estimation of AQI.

In this method, coefficient may be constant or may vary but the relationship contains at least one variable raised to a power and this index may be taken in several forms for assessment of air quality. The Modified Oak Ridge National Air Quality Index also has advantage for the relative ranking of overall air quality status at different locations of the study area with different air pollutants parameter.

AQI in the study area was estimated with the help of a modified mathematical equation developed by the Oak Ridge National Laboratory (ORNL), USA (Panwar, 2014) as given below:

$$Air\ Quality\ Index, AQI = \left[5.7 \sum Q_i\right]^{1.37}$$

Where Q_i = Quality rating for air quality parameters while 5.7 and 1.37 are constants

To reflect the status of air quality and its effects on human health, ranges of the AQI values were categorized as shown in Table 1

Table 1

Air Quality Index Chart

Category	**AQI**	**Description of Ambient Air**
I	0-50	Good
II	51-100	Moderate
III	101- 150	Unhealthy for sensitive groups
IV	151-200	Unhealthy
V	201 - 300	Very Unhealthy
VI	301+	Hazardous

$$Quality\ rating, Q_i = \frac{C_i}{C_s}$$

Where C_i = value of air quality parameters PM10, PM2.5, NO_2, SO_2, H_2S and CO

C_s = standard or prescribed limit for air quality parameters

If $Qi<100$, it is to be noted that the given parameter is within the prescribed limit. On the other hand, If $Qi>100$, it implies that the *i*th parameter exceeds the prescribed standard and the ambient air is harmful for breathing by human beings. Thus, the quality ratings were categorized as clean air, **0-25**; light air pollution, **26-50**; moderate air pollution, **51-75**; substantial air pollution, **75-100**; severe air pollution, **>100**.

Results of the parameters measured was statistically analysed using frequency tables, graphs, percentages and Microsoft Excel computer package, and compared with relevant regulatory standards.

Result and Discussion

The sampling stations were georeferenced with the use of Garmin *etrex* Global Positioning System (GPS) receiver as presented in Table 2 and represented in Figure 1.

Table 2 Station Codes and Coordinates

Sample Station	Station ID	Coordinates	
		Latitude (N)	Longitude €
ATC	AQ 1	4° 44' 32.3484"	7° 4' 38.9280"
Ogoloma Public Tank	AQ 2	4° 44' 23.2008"	7° 4' 57.6012"
Market Square	AQ 3	4° 44' 06.8136"	7° 4' 58.1880"
St. Peter Square	AQ 4	4° 44' 34.1592"	7° 5' 03.4152"
Anyungu Biri Health Centre	AQ 5	4° 44' 23.0964"	7° 5' 16.6704"
Foot Bridge	AQ 6	4° 44' 35.8476"	7° 5' 25.4544"
Ogbogbo Community School	AQ 7	4° 44' 43.1818"	7° 4' 55.7220"
Fienemika Drive	AQ 8	4° 43' 52.6332"	7° 4' 55.1172"
Ogoloma Health Centre	AQ 9	4° 44' 10.4028"	7° 4' 43.3909"

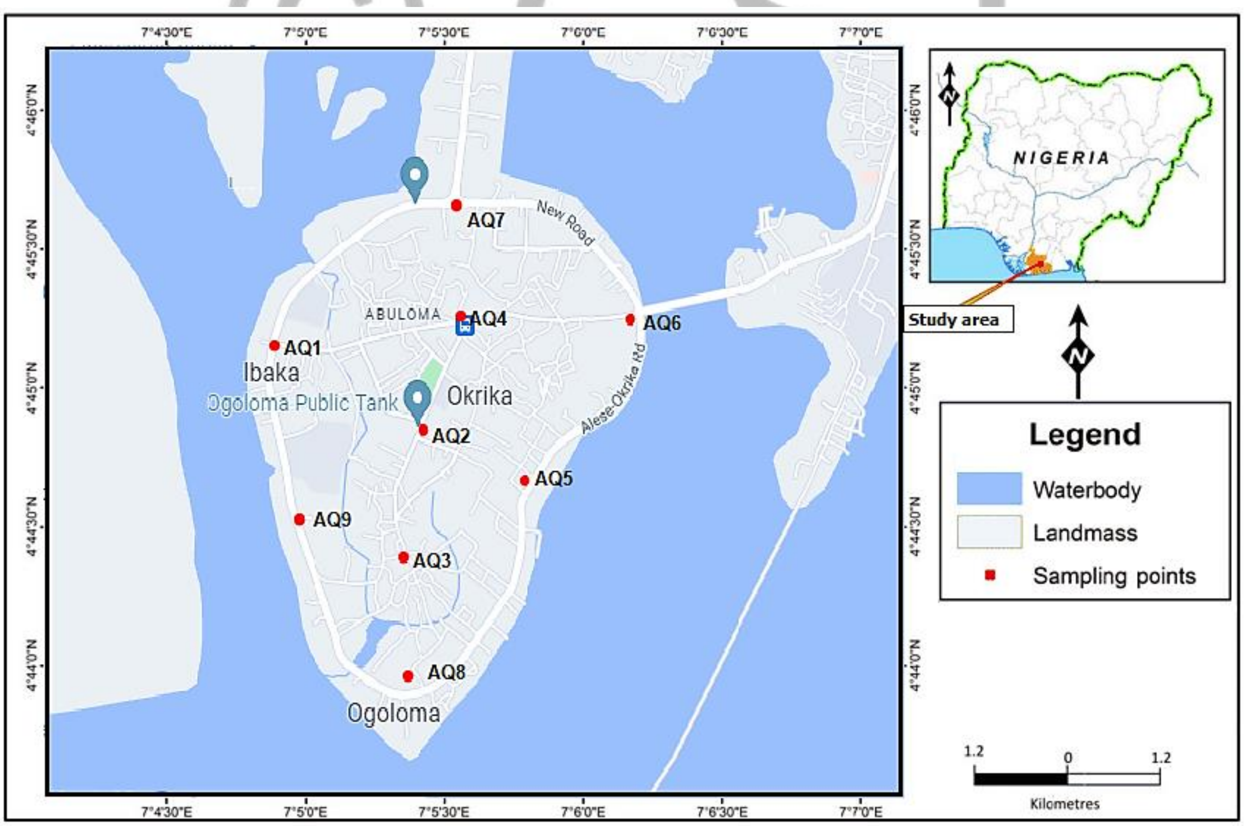

Figure 1: Sampling Map of the Study Area *(Source: Google)*

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Table 3

Air Quality Results of Okirika Island

Station	**Concentration, mg/m^3**											
	PM 1	**PM 2.5**	**PM 7**	**PM 10**	**TSP**	**NO_2**	**SO_2**	**H_2S**	**CO**	**CH_4**	**CO_2**	**VOC**
ATC	0.004	0.017	0.053	0.061	0.068	0.042	0.00	0.00	7.7	50.4	982	81
Ogoloma Public Tank	0.005	0.015	0.048	0.062	0.085	0.099	0.00	0.00	8.8	15.1	1126	39
Market Square	0.070	0.101	0.115	0.137	**0.169**	0.109	0.00	0.05	9.5	23.8	1001	56
St. Peter Square	0.029	0.094	**0.151**	0.122	**0.186**	0.070	0.00	0.00	5.5	21.9	1550	70
Anyungu Biri Health Centre	0.013	0.053	0.101	0.119	0.148	0.050	0.00	0.01	6.9	22.6	998	41
Foot Bridge	0.002	0.006	0.020	0.046	0.033	0.120	0.00	0.01	7.1	20.1	1529	78
Ogbogbo Community School	0.017	0.056	0.119	0.123	0.132	0.054	0.00	0.00	9.4	15.8	924	48
Fienemika Drive	0.005	0.005	0.011	0.092	0.117	0.106	0.00	0.00	4.9	12.1	981	35
Ogoloma Health Centre	0.012	0.016	0.127	0.098	0.124	0.095	0.00	0.02	3.4	18.9	1285	46
Range	**0.002 – 0.070**	**0.005 – 0.101**	**0.011 – 0.151**	**0.061 – 0.123**	**0.033 – 0.189**	**0.042 – 0.120**	**0.00**	**0.00 – 0.05**	**3.4 – 9.5**	**12.1 – 50.4**	**981 – 1550**	**39 – 81**
WHO	**150-230 µg/m^3 (24-hr)**					**0.320 (1hr)**	**0.350 (1hr)**	**-**	**30 (1hr)**	**-**	**-**	**-**
National Environmental (Air Quality Control) Regulations, 2014	**150 µg/m^3 (24hr)**					**0.2 (24hr)**	**0.350 (1hr)**	**0.413**	**10 (8hr)**	**-**	**-**	**-**

Source: Fieldwork, 2022

Particulate Matter

The concentrations of PM 1, 2.5, 7 and 10 in the study area ranged from 0.002 – 0.070mg/m^3, 0.005 – 0.101mg/m^3, 0.011 – 0.151mg/m^3 and 0.061 – 0.123mg/m^3 respectively; while the total suspended particles ranged 0.033 – 0.189mg/m^3. The concentrations of particulate matter were all satisfactory with the National Environmental (Air Quality Control) Regulations of 0.150mg/m^3 except for Market Square and St. Peter Square, which were above the regulator limit. This is cause by the type and level of activities in these stations. Both stations are active commercially, usually busy with motorcyclist commuting coupled with the trading activities in these areas.

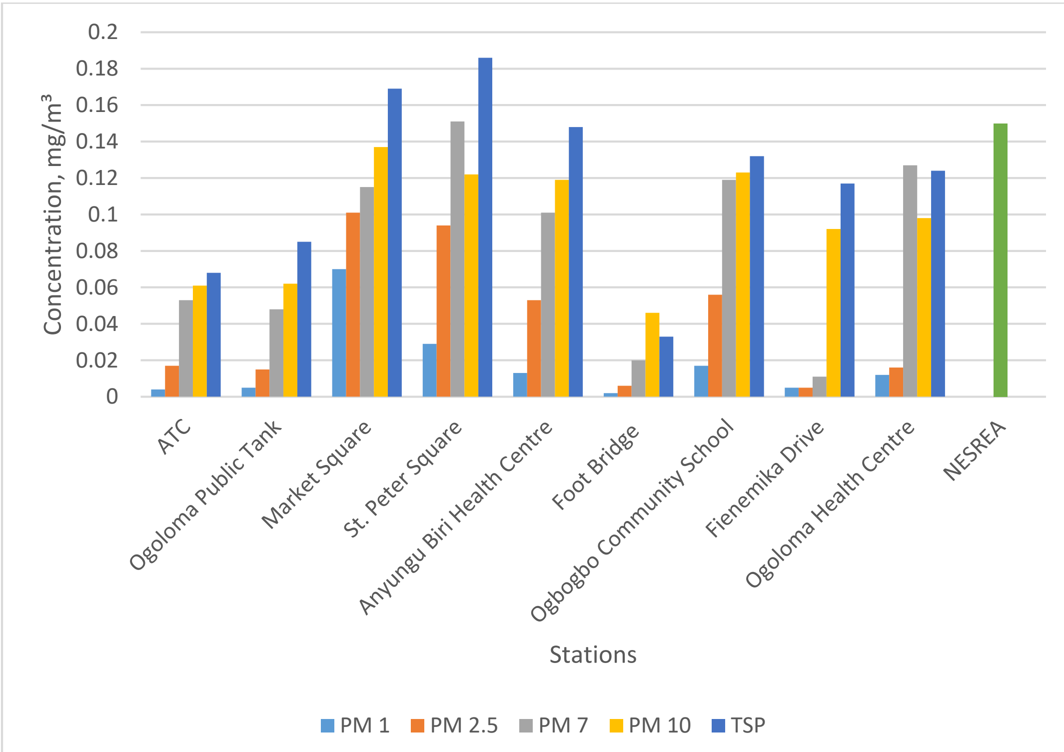

Figure 2: Particulate Matter Concentration in the study area

Nitrogen Dioxide, NO_2

Nitrogen oxide in the study area ranged from 0.042 – 0.120mg/m^3. The values obtained for NO_2 at various stations in the study area were satisfactory with regards to National Environmental (Air Quality Control) Regulations of 0.2mg/m^3. However, more recent research shows effects below 40 μg/m^3, prompting the European Union (EU) to commission a review of the evidence about a decade ago.

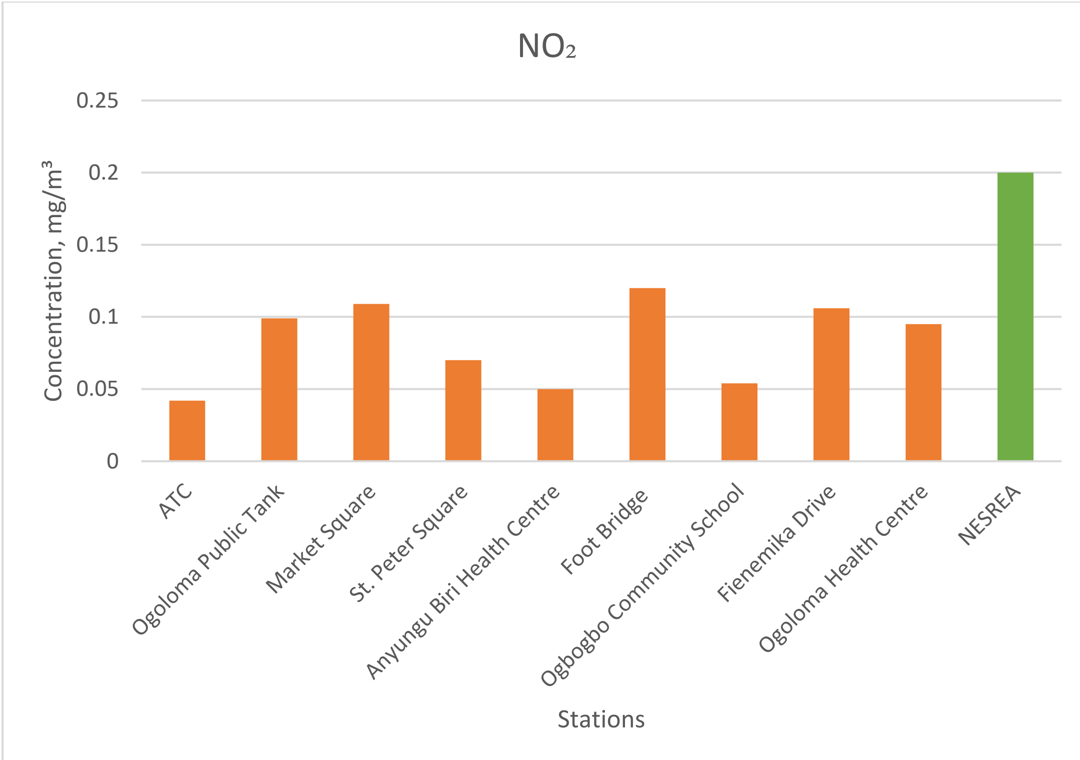

Figure 3 Nitrogen oxide Concentration in the study area

Specifically, for nitrogen dioxide, it has been observed that health effects can be regarded as confirmed above a threshold value of 20 µg/m^3 (WHO, 2013) especially for sensitive group of people, e.g. cancer and asthmatic patience (Panis, 2017). Thus, result from this study as shown in Table 3, has the lowest value of 0.042mg/m^3 at ATC, indicates that sensitive group might be susceptible to the low level of NO_2 across the study area, despite satisfying the NESREA regulatory limit.

Sulfur Dioxide, SO_2

Sulfur dioxide is a major air pollutant and has significant impacts upon human health. In addition, the concentration of sulfur dioxide in the atmosphere can influence the habitat suitability for plant communities, as well as animal life. Sulfur dioxide emissions are a precursor to acid rain and atmospheric particulates (Hogan, 2010).

Sulfur dioxide is a toxic gas responsible for the smell of burnt matches. It is released naturally by volcanic activity and is produced as a by-product of copper extraction and the burning of sulfur-bearing fossil fuels (Owen and Pickering, 1997). This toxic gas was not detected in the study area.

Hydrogen Sulfide, H_2S

Hydrogen sulphide concentration was largely undetected, however, a ranged of 0.00 – 0.05mg/m^3 was detected from four (4) stations in the study area. These value did not exceed the 0.413mg/m^3 regulatory limit specified by the National Environmental (Air Quality Control) Regulations, 2014.

It has been reported that at low levels of concentration, H_2S may be tolerated indefinitely (Ramasamy *et al.*, 2006). Thus, the level of H_2S detected in the study area may not be of any health and environmental significance.

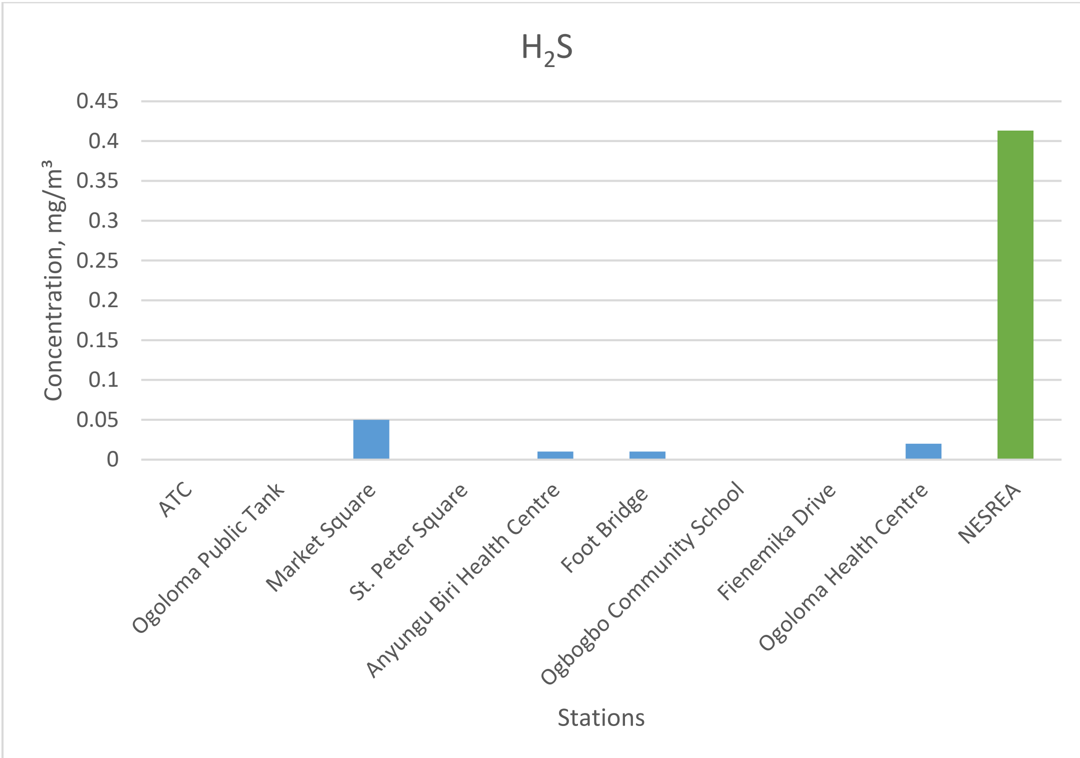

Figure 4 Hydrogen sulphide Concentration in the study area

Carbon Monoxide, CO

Results from the study area as shown in Table 3 indicates that low level of CO was detected, ranging from 3.4 to 9.5 mg/m^3 across all the stations, with the highest values at Ogbogbo Community School (9.4 mg/m^3) and Market Square (9.5 mg/m^3), and the lowest values at Ogoloma Health Centre (3.4 mg/m^3) and Fienemika Drive (4.9 mg/m^3). These values passed both the national and international regulatory requirements, however, it would be necessary to avoid exposures to 10 mg CO/m^3 (9 ppm) for 8h or 29 mg/m^3 (25 ppm) for 1h in order to protect sensitive individuals with coronary heart disease at the 3% carboxyhaemoglobin level. It was reported that at 3 – 7 ppm (3.4 – 8.0 mg/m^3), there was 6% increase in the rate of admission in hospitals of non-elderly for asthma (Sheppard *et al.*, 1999) and at 5 – 6 ppm (5.7 – 6.9 mg/m^3), there was significant risk of low birth weight if exposed during last trimester (Ritz & Yu, 1999).

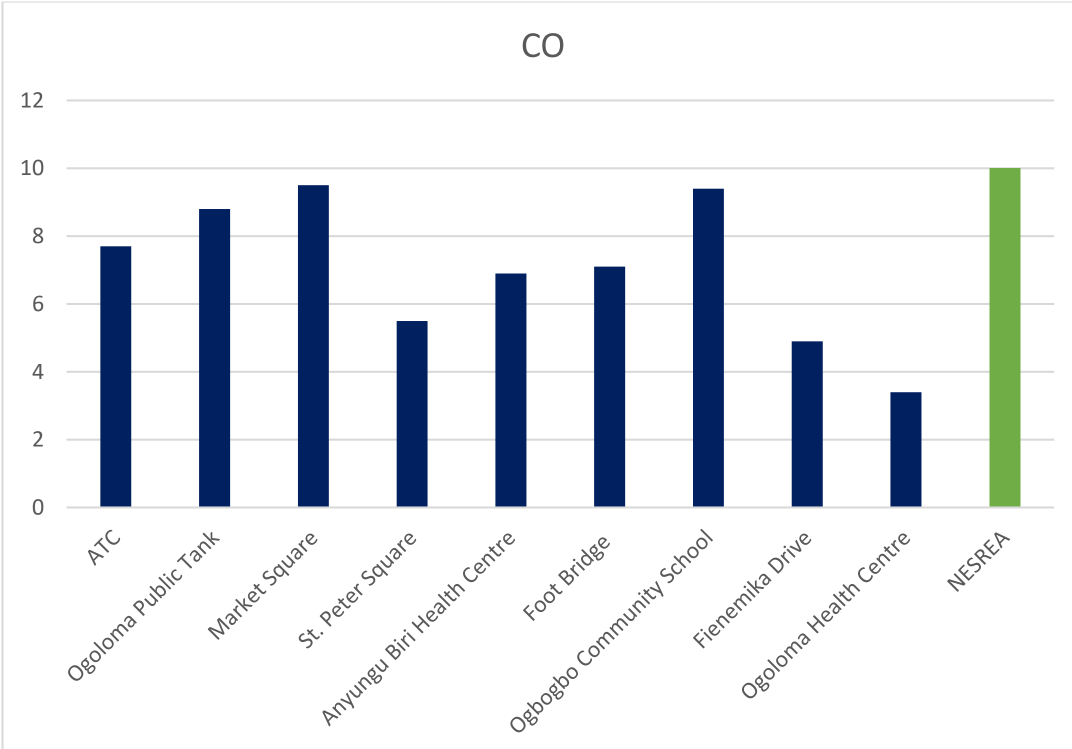

Figure 5 Carbon Monoxide Concentration in the study area

Methane, CH_4

Methane is a greenhouse gas that is emitted from a variety of anthropogenic (human-influenced) and natural sources. The concentration of methane in the study area ranged from 12.1 – 50.4mg/m^3 as shown in Figure 6. During the course of this study, there was no know regulatory limit set by either WHO or NESREA for methane outdoor concentration. However, this does not underplay its health and environmental significance. Methane is known to be nontoxic, yet it is extremely flammable and may form explosive mixtures with air. It is also an asphyxiant if the oxygen concentration is reduced to below about 16% by displacement, as most people can tolerate a reduction from 21% to 16% without ill effects.

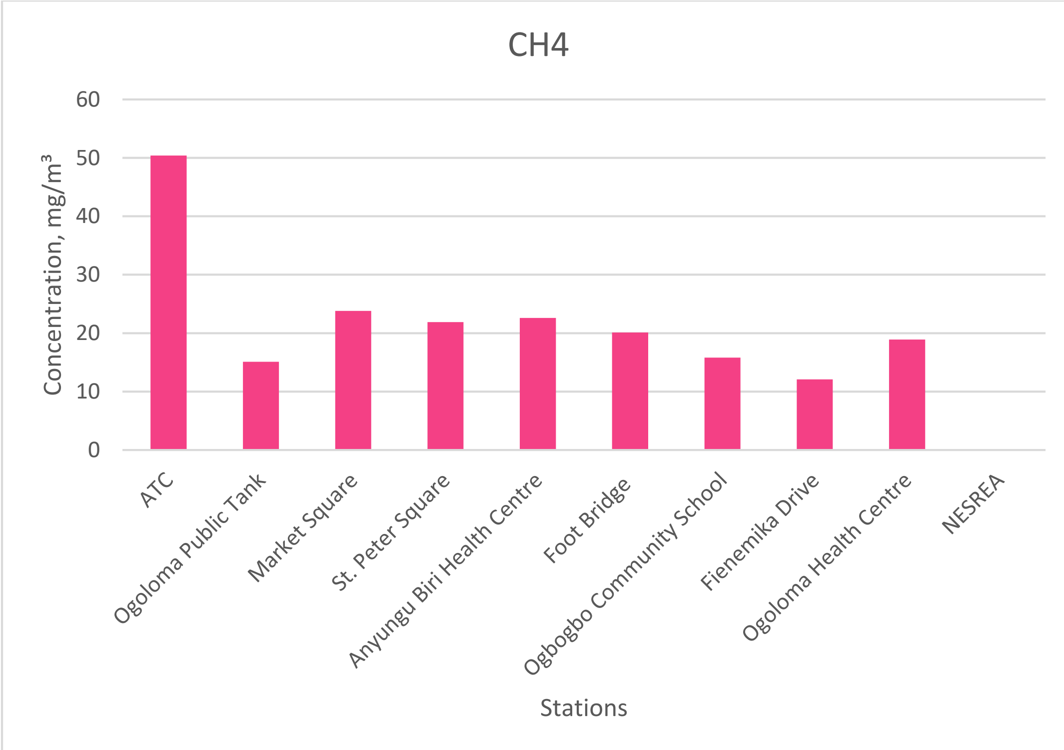

Figure 6 Methane Concentration in the study area

Carbon Dioxide, CO_2

Carbon dioxide, whose main sources are known to be from two sources, which are aerobic respiration and fossil fuel emissions (Gougoulias *et al*., 2014), was substantially detected in the study area. The CO_2 measured values ranged 981 – 1550mg/m^3 as shown in figure 7. During the course of this study, there was no know regulatory limit set by either WHO or NESREA for outdoor concentration of CO_2. The gas varies across all the stations in the study area as shown in Table 3, ranging from 981 mg/m^3 at Fienemika Drive to 1550 mg/m^3 at St. Peter Square.

CO_2 is an asphyxiant gas and not classified as toxic or harmful in accordance with Globally Harmonized System of Classification and Labelling of Chemicals standards of United Nations Economic Commission for Europe by using the OECD Guidelines for the Testing of Chemicals (Friedman, 2009). In concentrations up to 10,000 ppm (1800 mg/m^3), it will make some people feel drowsy and give the lungs a stuffy feeling. Concentrations of 70,000 to 100,000 ppm may cause suffocation, even in the presence of sufficient oxygen, manifesting as dizziness, headache, visual and hearing dysfunction, and unconsciousness within a few minutes to an hour (Friedman, 2009).

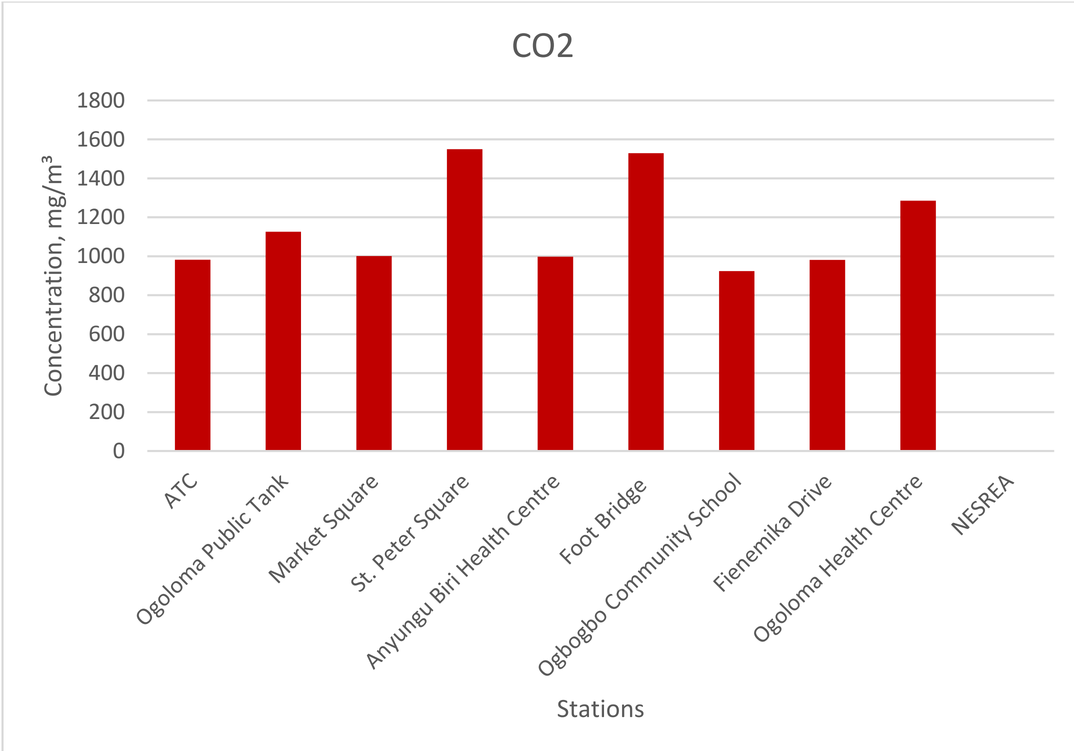

Figure 7 Carbon dioxide Concentration in the study area

Volatile Organic Compound, VOC

Volatile organic compounds (VOCs) are organic chemicals that are responsible for the odour of scents and perfumes as well as pollutants. Some VOCs are dangerous to human health or cause harm to the environment. Anthropogenic VOCs are regulated by law, especially indoors (Koppmann, 2007). VOC was detected in the study area, with the range of 39 – 81 mg/m^3 across all the station monitored. This pollutant also has no outdoor regulatory limit in Nigeria during the course of this study. However, this air pollutant is significant to human health and environment. VOCs are mostly felt in the indoor environment, where concentrations are the highest. Most VOCs are not acutely toxic, but may have long-term chronic health effects.

Health effects of indoor VOCs include eye, nose, and throat irritation; headaches, loss of coordination, nausea; and damage to the liver, kidney, and central nervous system. Some organics can cause cancer in animals; some are suspected or known to cause cancer in humans. Key signs or symptoms associated with exposure to VOCs include conjunctival irritation, nose and throat discomfort, headache, allergic skin reaction, dyspnoea, declines in serum cholinesterase levels, nausea, vomiting, nose bleeding, fatigue, dizziness (EPA, OAR, 2014).

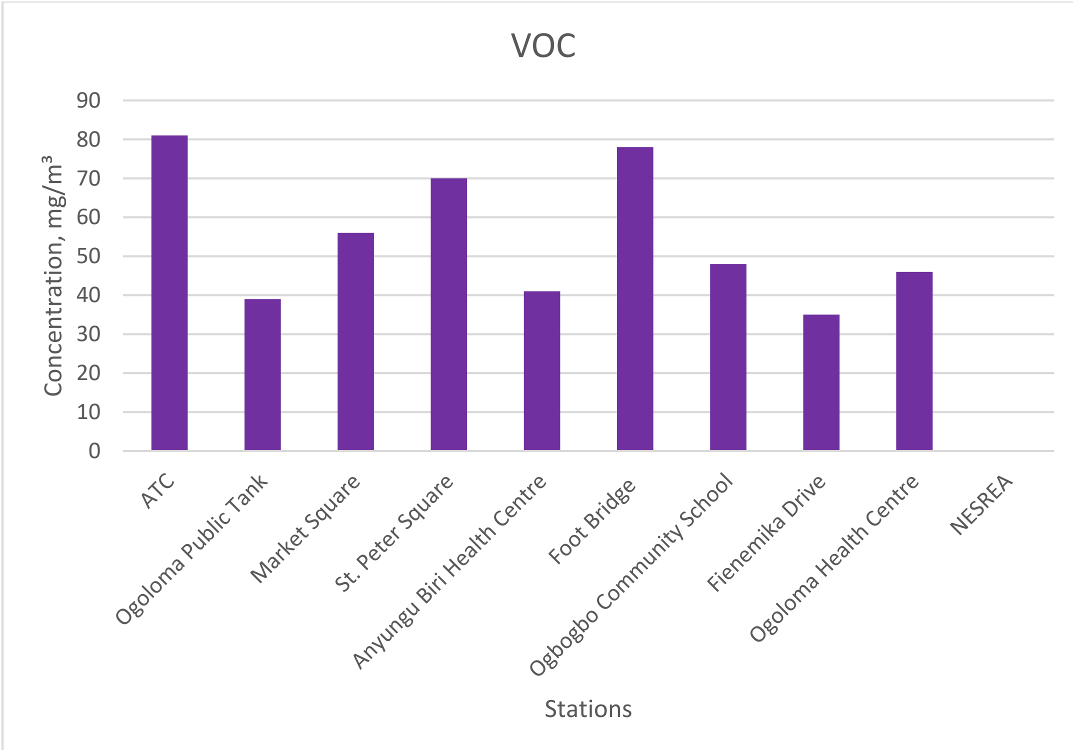

Figure 8 VOC Concentration in the study area

3. Air Quality Rating Across the Study Area

According to Nigam *et al*. (2015), Air Quality Index (AQI) is an indicator tool, which is widely used worldwide since last 2 – 3 decades. It is basically used for assessing the air pollution hot spots in a region for delineating management and concrete actions. The air quality ratings of various stations in the study area are presented in Table 4 and Table 5.

Table 4

Quality Rating of the Measure Air Quality Parameters

Station	Quality Rating, %								
	PM 1	PM 2.5	PM 7	PM 10	TSP	NO_2	SO_2	H_2S	CO
ATC	2.7	11.3	35.3	40.7	45.3	21.0	0.0	0.0	**77.0**
Ogoloma Public Tank	3.3	10.0	32.0	41.3	56.7	49.5	0.0	0.0	**88.0**
Market Square	46.7	67.3	**76.7**	**91.3**	**112.7**	54.5	0.0	12.1	**95.0**
St. Peter Square	19.3	62.7	**100.7**	**81.3**	**124.0**	35.0	0.0	0.0	55.0
Anyungu Biri Health Centre	8.7	35.3	67.3	**79.4**	**98.7**	25.0	0.0	2.4	69.0
Foot Bridge	1.3	4.0	13.3	30.7	22.0	60.0	0.0	2.4	71.0
Ogbogbo Community School	11.3	37.3	**79.3**	**82.0**	**88.0**	27.0	0.0	0.0	**94.0**
Fienemika Drive	3.3	3.3	7.3	61.3	**78.0**	53.0	0.0	0.0	49.0
Ogoloma Health Centre	8.0	10.7	**84.7**	65.3	**82.7**	47.5	0.0	4.8	34.0

Table 5

Air Quality Index of the Assessed Stations in the Study Area

Station	AQI (%)	Observation
ATC	**162.5**	Unhealthy
Ogoloma Public Tank	**222.7**	Very Unhealthy
Market Square	**459.2**	Hazardous
St. Peter Square	**298.7**	Very Unhealthy
Anyungu Biri Health Centre	**259.4**	Very Unhealthy
Foot Bridge	**189.9**	Unhealthy
Ogbogbo Community School	**309.9**	Hazardous
Fienemika Drive	**187.7**	Unhealthy
Ogoloma Health Centre	**181.0**	Unhealthy
Range	**162.5 – 459.2**	

From Table 4 particulate matter quality rating was fairly okay in the study except for some stations that have substantial particulate matter pollutions. PM 7 at the Market Square, St. Peter Square, Ogbogbo Community School and Ogoloma Health Centre was observed to be 76.7%, 100.7%, 79.3% and 84.7% respectively. While PM 10 at Market Square, St. Peter Square, Anyungu Biri Health Centre, and Ogbogbo Community School was observed to be 91.3%, 81.3, 79.4% and 82.0% respectively. Furthermore, TSP at Market Square, St. Peter Square, Anyungu Biri Health Centre, Ogbogbo Community, Fienemika Drive and Ogoloma Health Centre was observed to be 112.7%, 124.0%, 98.7%, 88.0%, 78.0% and 82.7% respectively.

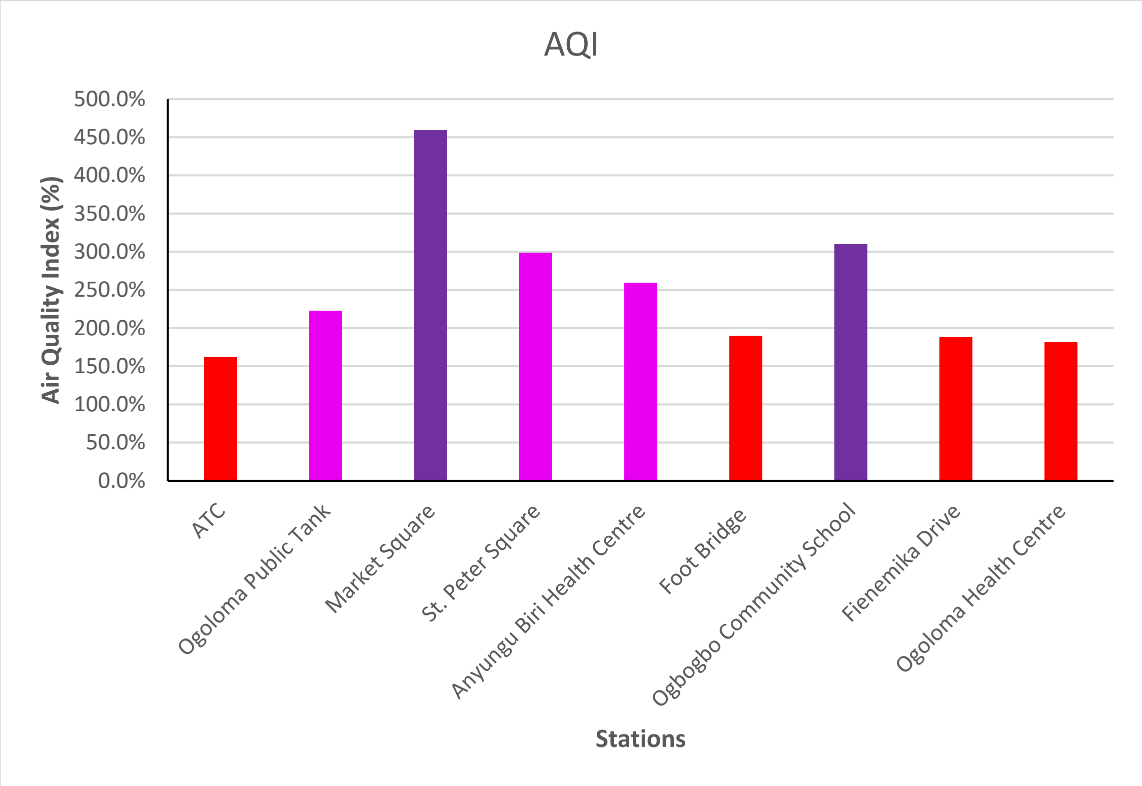

Figure 8 Air Quality Index Across all Stations in the Study Area

The quality rating of most air pollutants – Nitrogen dioxide, Sulfur dioxide and Hydrogen sulphide – in the study area were below 75%, indicating that they were fair to moderately present in the ambient air in all the stations. However, this is different for carbon monoxide in four (4) locations in the study area, which were substantially polluted with CO, above 75% quality rating. These locations with their CO rating are as follows, ATC (77.0%), Ogoloma Public Tank (88.0%), Market Square (95.0%) and Ogbogbo Community School (94.0%).

The result of the modified Oak Ridge National Air Quality Index (ORNAQI) used in the study is shown in Table 5. The AQI highlights areas of overall concern despite the fact that most of the air quality parameter were within regulatory limits. The combine quality ratings for all the air parameters in all the stations reveals serious truth was hidden in the quality ratings for each of the parameters. Table 5 and Figure 8 have shown that all the stations have unpleasant air quality indices from 162.5% to 459.2%, which range from unhealthy to hazardous ambient air quality in the study area. The situation will be especially felt by sensitive and non-sensitive group in Okirika island community.

In ATC, the AQI was 162.5% indicating an unhealthy air quality. This is because of substantial amount of CO (77.0%) detected in the environment. ATC is an area known for transportation business, the island jetty is located in this area, as such, commuting and petty trading activities is regularly high in this environment. The poor air quality observed in the area will, most probably be felt by the sensitive groups.

AQI around Ogoloma Public Tank was computed to be 222.7%, which indicate a very unhealthy air quality in the area. This also is caused by the elevated and substantial amount of CO (88.0%) detected in the environment, 10% higher than the value detected at ATC. This area has might not have as much as commuting and trading activities but has a more compact structures probably due to the presence of a public tank. Human have been known from history to be naturally drawn to areas where there is access to water as a basic need for living.

Market Square have the highest CO detected in the study area (95% quality area). This also made the air quality in the area hazardous to residents especially the sensitive groups. The area has the air quality index of 495.2%. However, other pollutants that contributed to this figure are PM 7 (76.7%), PM 10 (91.3%) and TSP (112.7), which are all substantially present in that environment. As the name implies, this station has the highest commuting and trading activities in the study area. Dusts and smokes are significantly present in the area, making it very unhealthy for residents around the Market Square. This is a similar situation observed in Ogbogbo Community School, where there is significant human activities, arising to a hazardous air quality with the AQI of 309.9%, which is 149.3% less than Market Square AQI.

St. Peter Square might not have as much trading activities but have a significant commuting activities in the area. The air quality in this station is computed to be 298.7%, which is very unhealthy. The particulate matter presence is significant, with PM 7 and TSP discovered to be above the regulatory requirement of $0.150mg/m^3$.

In Anyungu Biri Health Centre, the AQI is also very unhealthy (259.4%), though 39.3% lower than that of St. Peter Square. This is due to the substantial pollution by PM 10 (79.4%) and TSP (98.7%) coupled with the moderate detection of CO (69.0%) in the area. Similarly, at Foot Bridge, where NO_2 (60.0%) and CO (69.0%) are moderately detected. These detections made this unhealthy with the AQI of 189.0%. Other stations with unhealthy air quality are Fienemika Drive and Ogoloma Health Centre.

Other factors indirectly contributing to the air quality situation in the study area is the constant emission/diffusion of air pollutants, particulates, dust and sooth from the Port Harcourt Refinery Company (PHRC), Eleme Petrochemical Company limited, National fertilizer Company (NAFCON), and Pipeline Products Marketing Company (PPMC) at the adjacent Okirika communities in close proximity with Okirika island. The situation of air quality in the study area is significant to the health and environment of the residents. Actions need to be taken to curb activities that impair the air quality of the study area.

Conclusion

The key findings in this study includes the determination of the ambient air quality in Okrika, Rivers State. As observed, despite most of the pollutants not exceeding the guideline values set out by the World Health Organization and National Environmental Standards and Regulations Enforcement Agency, the pollutants were substantially present in the environs across the study area. Although, the concentrations of SO_2 and H_2S were relatively low.

The Air Quality Index revealed that the air quality across all nine (9) stations in the study descriptively ranged from unhealthy to hazardous, especially to sensitive groups of residents. It was also observed that the major causes of this air quality situation in the study area are the commercial/commuting activities coupled with the proximity of the area to Port Harcourt Refinery Company (PHRC), Eleme Petrochemical Company limited, National fertilizer Company (NAFCON), and Pipeline Products Marketing Company (PPMC).

Recommendations

Most sources of outdoor air pollution are well beyond the control of individuals and thus, demands combined action by local, national and regional level policy-makers working in sectors like transport, energy, waste management, urban planning, and agriculture to provide adequate environmental policies and regulations to curb the pollution of ambient air in Okrika Island.

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