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# Assessment of Some Pollutant Gases in Selected Cities in Crude Oil-Rich Delta State Nigeria

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**Abstract:** Delta state is one of the petroleum-producing states in Nigeria where upstream and downstream exploration activities tend to pollute the environment. While soil and water pollution are regularly monitored, there is a dearth of information on the impact of exploration and related industries on air quality. This study investigated the levels of pollutant gases including ozone, nitrogen dioxide, sulphur dioxide, hydrogen sulphide and ammonia in ambient air samples selected cities (Warri, Ughelli, Sapele and Ugbenu) in Delta state, Nigeria. The concentration of the gases was determined using air sampling instruments equipped with appropriate sensors for selective to each gas. Meteorological parameters were also obtained concurrently during sampling. The results obtained showed that the average concentrations of $SO_2$, $H_2S$ and $NH_3$ were all below the National ambient air quality standard (NAAQS) and Federal ministry of environment (FMEnv) regulatory limits. However, the mean concentration of $O_3$ and $NO_2$ obtained exceeded the NAAQS and FMEnv regulatory limits of 0.007 ppm, 0.05 ppm and 0.04 ppm – 0.06 ppm respectively. Ugbenu, the control station did not record any value for the pollutant gases. This is as a result of non-availability of industrial activities that emit these pollutant gases in the area. There was a clear seasonal variation, with higher values recorded mostly in the dry season. The field data agreed with global model data on the pollutant gases. The information from this study provides information on the level of these pollutant gases and how the various industrial process may impact their concentration in this region.

**Keywords:** Air Quality, Pollution, Sulphur Dioxide, Ammonia, Ozone, Nitrogen Dioxide

## 1. Introduction

Anthropogenic activities due to quest for a better standard of living and the utilization of natural resources for rapid industrialization and urbanization give rise to air pollution [1]. Air pollution could also be due to natural sources (volcanic eruption, whirlwind, earthquake, decay of vegetation, pollen dispersal and forest fire ignition by lightning [2]. These activities release some gaseous emissions and particulates that contaminate air; and when in high concentrations could cause damage to environment and human health [3, 4]. Oil exploration in the Niger Delta region of Nigeria has grossly reduced the quality of air in the region and the level of industrialization does not commensurate with environmental studies and monitoring [5]. According to the World Bank report, urban outdoor air pollution in Africa is responsible for an estimated 49,000 premature deaths annually, the main burden borne by sub-Saharan African countries [6].

Air pollutants that are of great concerns regarding adverse health effects include particulate matter (PM), nitrogen dioxide ($NO_2$), Sulphur dioxide ($SO_2$) and ozone ($O_3$) [7]. The environmental effects of $SO_2$ and $NO_2$ pollutants are associated with the acidification of precipitation, visibility reduction, and deleterious effects on human health and plants [8]. $NO_2$ is one of the main traffic-related air pollutants and long-term exposures may reduce immunity and lead to respiratory infections [9]. $SO_2$ is emitted during the combustion of fossil fuels. Long exposure to $SO_2$ can result to respiratory problems, severe headache, and reduced

productivity in plants, increase the rate of corrosion of iron, steel, zinc and chromium [10]. Ozone ($O_3$), is formed by the reaction of NOx and volatile organic compounds (VOCs), it is also a major environmental concern because of its adverse impact on human health, crops and ecosystems [11-14]. Long exposure to ozone can result to shortness of breath, nausea, lung damage and death [15]. Ammonia ($NH_3$) is the most abundant alkaline gas in the atmosphere and plays an important role in the nitrogen cycle in ecosystems, the neutralization of acids in the air and the formation of fine particulate matter ($PM_{2.5}$) [16, 17]. Hydrogen Sulphide, $H_2S$ is another toxic pollutant that is a threat to human health and environment [18]. The principal source of this gas is as a by-product in the purification of natural and refinery gases. It is also a by-product of Kraft pulp and paper manufacturing [19]. Exposure above the threshold level can result to olfactory paralysis, liver and kidney damage.

Environmental pollution arising from oil-exploration and related industrial activities is an issue of major concern in oil-producing regions of the world. Delta state, Nigeria, has not been spared from these pollution cases [20]. While water and soil pollution are prominent and have been subjects of heated debates, litigation, and enjoy more environmental monitoring campaigns, there is not sufficient information on the impact of these industrial activities on the air quality. Furthermore, the country still flares a huge amount of gas from oil exploration activities which introduces huge amount of pollutant gases into the environment [21]. There is therefore the need to monitor the air quality using some pollutant gases as indices [22].

This research work focuses on assessment of pollutant gases in selected cities, Warri, Sapele and Ughelli, in oil- rich Delta state. The aim of this work is to asses and quantify ambient levels of gaseous pollutants ($NO_2$, $SO_2$, $NH_3$, $H_2S$ and $O_3$) at ten different locations in these cities. Samples were obtained during the two main seasons in Nigeria; wet and dry seasons. The results obtained will serve as database for air quality monitoring, modeling and future research.

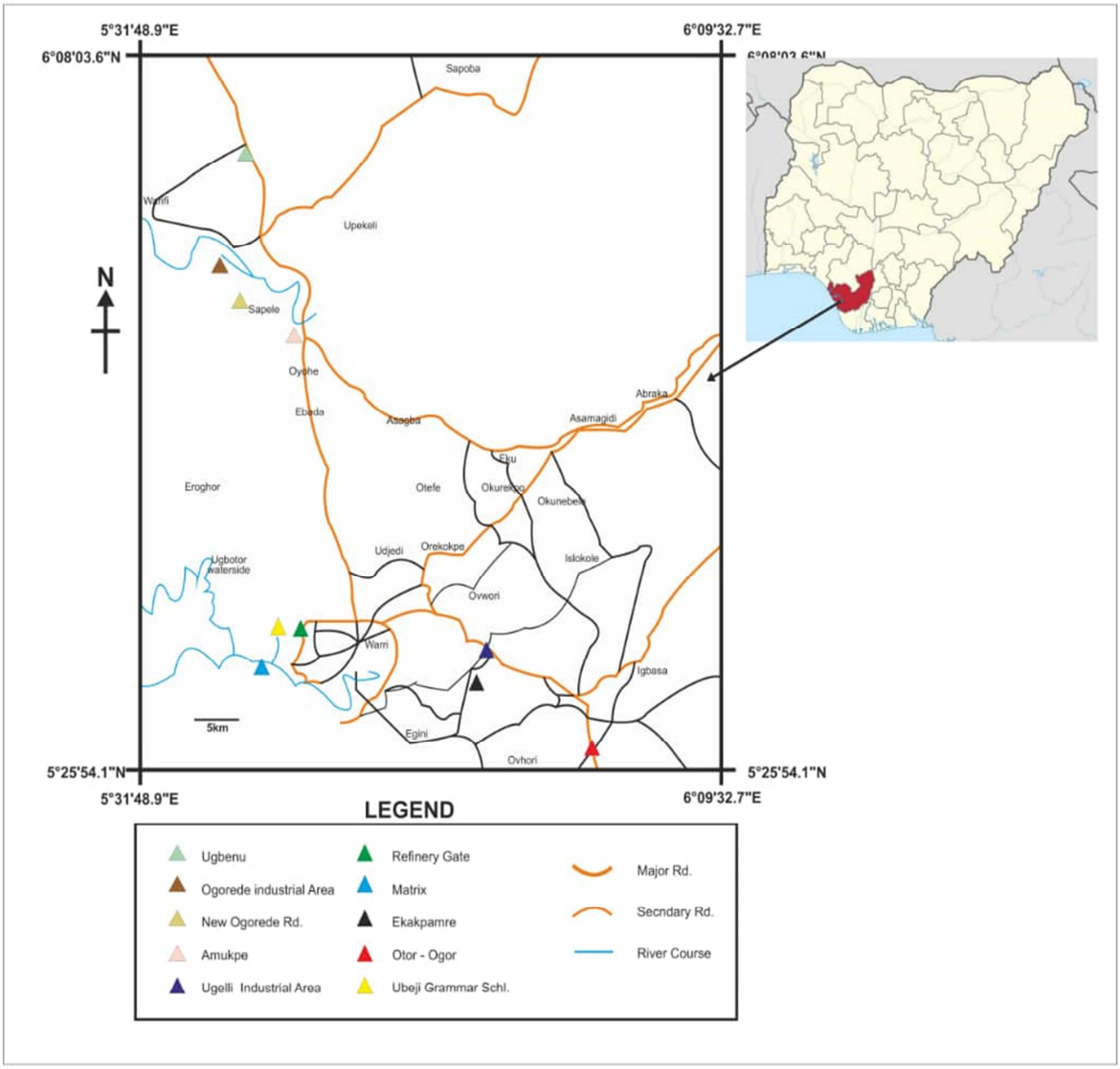


***Figure 1.*** *Map of the study area showing sampling locations.*

# 2. Materials and Method

### *2.1. Study Area*

The map of the study area showing the sampling locations is presented in Figure 1. Three cities (Warri, Ughelli and Sapele) selected for this study are in Delta state, which is one out of nine states that make up the Niger delta area in Nigeria. The Niger delta area is situated in the Gulf of Guinea between longitudes $5^0$E to $8^0$E and latitudes $4^0$N to $6^0$N. It is the largest wetland in Africa and the third largest in the world. The floodplain makes up to 7.5% of Nigeria's total land mass. More than 70% of Nigeria's crude oil and gas production is from the area. The region produces over 90% of Nigeria's foreign earnings through oil exploration activities. It plays host to most of the upstream and downstream oil related industries that release tons of pollutants into the ecosystems. Warri is one of the major cities of petroleum activities and businesses in the southern part of Nigeria. It shares boundaries with Ughelli, Sapele, Okpe, Udu and Uvwie. It is a commercial city of Delta State with a population of over 311,970 people from the national population census figures for 2006. Ughelli is a town in Delta state, Nigeria. The town was originally an agricultural center, but now, oil industries, petroleum extraction and also glass bottle factory are functional in the area. Ughelli has a population of 82,994 people from 2006 census. Sapele is a city in Delta state, Nigeria. Sapele was established in the mid - 19th century as a trading village, which was occasionally visited by Europeans. Presently, the city has one of Nigerian's major ports. There are many industries in Sapele, which include the processing of timber, rubber, palm oil, furniture, tamarind balm, footwear, flour mill and petroleum industries. The population is 142,652 people from 2006 census.

The study area recorded a temperature range of 22°C – 34°C (avg. 27°C), dew point of 22°C, pressure of 1010 mbar, visibility of 12 km. Annual rainfall of 2135 mm, 2312 mm and 2605 mm were recorded for Sapele, Ughelli and Warri respectively. Ugbenu, the control location, is situated in Delta State at the boundary between Delta State and Edo State. Graph of the sampling points is shown below:

### *2.2. Sampling*

Ten sampling points were monitored for ozone, ammonia, hydrogen Sulphide, nitrogen dioxide and Sulphur dioxide in ambient air. Three points were monitored in each city and one point was monitored in the control location. Also meteorological study of the areas was done at each sampling location. The sampling was done from December 2016 to September 2017 covering the two main seasons in Nigeria; wet and dry seasons. At each sampling site, 8 h sampling, from 8 am to 4 pm, was done for the pollutant gases while meteorological parameters including air temperature, relative humidity, wind speed and light were measured simultaneously during the sampling.

### *2.3. Methods*

All the equipment used for the analysis were pre-calibrated before usage for quality assurance purposes. Garmin Etrex 10 Gps device was used to track the coordinates of the points sampled. Environmental sensor (Gasman air monitor, Crowcon instruments Ltd, England) was used to monitor $NO_2$, $SO_2$, ozone, ammonia and hydrogen Sulphide. Windmeter TFA was used to measure wind speed and temperature. PeakTech multifunction Environment meter was used to measure light and humidity. Data generated were subjected to statistical analysis using SPSS version 16.0.

# 3. Results and Discussion

### *3.1. Annual Concentration of Pollutant Gases*

The description of sampling locations and metrological parameters is shown in Table 1. The annual concentration of the pollutant gases studied is shown in Table 1. The annual concentration of $NO_2$ measured within the sampling sites range from 0.010 ppm – 0.460 ppm. The least value was recorded at Sapele (S3) while the highest value was recorded at Warri (W1). It can be seen from Table 1 that W2, U3, S3, U2 and S2 area were within the purview of the regulatory limits of National ambient air quality standard (NAAQS) of 0.05 ppm and Federal ministry of environment (FMEnv) standard of 0.04 ppm – 0.06 ppm. This could be attributed to the fact that these locations are mainly residential and business areas devoid of industrial presence as described in Table 1. In other hand, W1, W3, S1 and U1 exceeded the limits. These locations are characterized with heavy duty vehicles and industrial activities related to dockyards, chimneys, power generating systems, tank farm activities, glass production, plastic production, flour production and thermal power station. These industrial activities are well known to be the main source of anthropogenic nitrogen oxide emissions into the atmosphere [23, 24].

***Table 1.*** *Sampling Locations, Site Descriptions and Metrological Parameters.*

| City | Sampling location (no.) | Latitude | Longitude | Temp. (°C) | Wind speed (m/h) | Humidity (% RH) | Light (lux) | Site Description |
|---|---|---|---|---|---|---|---|---|
| Warri | Refinery Entrance (W1) | N05°34'10" | E05°42'13.8" | 32.24±0.506 | 0.490±0.185 | 74.54±3.338 | 4,964.1±2182.41 | This location is close to warri refinery. |
| | Ubeji Gr. School (W2) | N05°34'19.6" | E05°42'13.8" | 34.17±1.048 | 0.51±0.247 | 66.81±6.710 | 5,516.9±954.73 | This is School Environment |
| | Matrix (W3) | N05°32'11.6" | E05°41'11.3" | 33.49±0.448 | 0.37±0.126 | 70.01±5.013 | 1,136.15±154.95 | Concentration of Tank Farms |
| Ughelli | Ughelli Ind. Area (U1) | N05°32'28.1" | E05°55'10.2" | 30.98±0.603 | 0.48±0.106 | 70.24±3.649 | 1,169.8±1106.91 | Highly industrialized area. |
| | Ekakpamre (U2) | N05°31'15.9" | E05°54'20.3" | 33.81±0.459 | 0.72±0.218 | 61.05±1.615 | 7,697.9±1317.33 | Residential and business area. |

| City | Sampling location (no.) | Latitude | Longitude | Temp. (°C) | Wind speed (m/h) | Humidity (% RH) | Light (lux) | Site Description |
|---|---|---|---|---|---|---|---|---|
| | Otorgor (U3) | N05°27'31.8" | E06°01'21.0" | 35.11±0.457 | 0.19±0.086 | 67.42±4.620 | 6,147.2±565.34 | Outskirt of Ughelli |
| | Ogorode Ind. Area (S1) | N05°55'17.3" | E05°38'47.8" | 31.62±0.427 | 0.36±0.126 | 70.24±4.859 | 1,119±647.03 | Highly Industrialized area. |
| Sapele | New Ogorode Area (S2) | N05°53'14.3" | E05°40'00.5" | 33.1±0.711 | 0.36±0.170 | 53.86±5.593 | 1,036.3±62.89 | Residential and business area. |
| | Amukpe (S3) | N05°51'16" | E05°43'13" | 33.18±0.691 | 0.74±0.167 | 50.6±3.393 | 1,182.4±684.30 | Market area with heavy traffic. |
| Ugbenu | Ugbenu (C1) | N06°01'50. " | E05°40'22.6" | 33.76±0.608 | 0.47±0.169 | 59.08±4.176 | 3,545.5±97.59 | Residential area, devoid of industrial activity. |

***Table 2.*** *Annual average concentration of pollutant gases.*

| City | Stations | $NO_2$ (ppm) | $SO_2$ (ppm) | $NH_3$ (ppm) | $H_2S$ (ppm) | $O_3$ (ppm) |
|---|---|---|---|---|---|---|
| | W1 | 0.460±0.386 | 0.033±0.015 | 0.006±0.002 | 0.062±0.198 | 0.081±0.057 |
| Warri | W2 | 0.014±0.087 | 0.019±0.013 | 0.002±0.002 | 0.028±0.020 | 0.009±0.007 |
| | W3 | 0.106±0.065 | 0.059±0.032 | 0.039±0.051 | 0.121±0.039 | 0.297±0.239 |
| | U1 | 0.036±0.014 | 0.019±0.007 | 0.022±0.041 | 0.031±0.015 | 0.084±0.041 |
| Ughelli | U2 | 0.022±0.009 | 0.008±0.005 | 0.025±0.013 | 0.035±0.024 | 0.064±0.025 |
| | U3 | 0.014±0.006 | 0.019±0.005 | 0.006±0.004 | 0.021±0.005 | 0.035±0.006 |
| | S1 | 0.185±0.079 | 0.064±0.032 | 0.024±0.010 | 0.181±0.071 | 0.185±0.081 |
| Sapele | S2 | 0.013±0.005 | 0.009±0.004 | 0.010±0.006 | 0.164±0.059 | 0.047±0.018 |
| | S3 | 0.010±0.004 | 0.007±0.003 | 0.004±0.002 | 0.090±0.007 | 0.173±0.096 |
| Ugbenu | C1 | 0.000±0.000 | 0.000±0.000 | 0.000±0.000 | 0.000±000 | 0.000±0.000 |

The annual concentration of $SO_2$ measured range from 0.007 ppm – 0.064 ppm. The least value was recorded at S3 while the highest value was recorded at S1. It can be seen from table 1 that all the figures obtained were within the purview of the regulatory limits of NAAQS of 0.5 ppm and FMEnv limit of 0.14 ppm. This implies that the Sulphur content of the fuel and diesel produced and marketed in the area is quite low. It also shows that biomass burning that generates charcoal production is minimal at the sampling locations. In Singapore, China, lower average of $SO_2$was reported which was comparable with lower values of $SO_2$ found in Accra and Kampala [25].

The annual mean concentration of $NH_3$ within the sampling sites range from 0.002 ppm – 0.039 ppm. W2 recorded the least value of $NH_3$ while W3 recorded the highest value. The figures obtained in all the locations were within the purview of Occupational Safety and Health Administration (OSHA) threshold limit value of 25 ppm as seen in table 1. This implies that biomass burning at the sampling locations was minimal. This agrees with the research which said that in western African capitals, domestic fires and biomass burning are the main source of $NH_3$ emission [25, 26].

The annual mean concentration of $H_2S$ within the sampling sites range from 0.021 ppm – 0.181 ppm. U3 recorded the least value of $H_2S$ while S1 recorded the highest value of $H_2S$. The figures obtained in all the locations were within the purview of threshold limit value of 1.0 ppm as seen in table 2. This implies minimal activities related to purification of natural and refinery gases. Also, there was no production of pulp and paper at any of the sampling location that could have contributed to high level of $H_2S$. This agrees with the study carried out by Rai (4).

The annual mean concentration of $O_3$ within the sampling sites range from 0.009 ppm – 0.297 ppm. W2 recorded the least value of $O_3$; while W3 recorded the highest value of $O_3$. W2, U2, U3 and S2 were within the purview of National ambient air quality standard of 0.07 ppm. This is due to lack of industrial activities at the locations. W1, W3, U1, S1, and S3 exceeded the limit. This is as a result of industrial activities that give rise to reactions that led to pollution by this gas at the sampling locations. However, Adon reported that $O_3$ is usually the most abundant in different African ecosystems especially in dry and humid savannahs [27].

### *3.2. Seasonal Variation of Pollutant Gases*

The average concentration of $NO_2$ measured in dry season was higher than that measured in the wet season. The figures obtained exceeded the NAAQS regulatory limits of 0.05 ppm and FMEnv standard of 0.04 ppm – 0.06 ppm as seen in Figure 2a. Averagely, the mean concentration of $SO_2$ measured in dry season was lower than that measured in wet season. This could be as a result of seasonal variations, where the sampling was actually done in wet season, but it was dry on the days of sampling. All the figures obtained were within the purview of the NAAQS regulatory limits of 0.5 ppm and FMEnv limit of 0.14 ppm as seen in Figure 2b. The average mean concentration of $H_2S$ measured in dry season was higher than that measured in the wet season; though the figures obtained in all the locations were within the purview of threshold value of 1.0 ppm (Figure 2c). The average mean concentration of $NH_3$ measured in dry season was lower than that measured in wet season. This could be as a result of seasonal variations, where the sampling was actually done in wet season, but it was dry on the days of sampling. The figures obtained in all the locations were within the purview of OSHA threshold limit value of 25 ppm (Figure 2d). The average mean concentration of $O_3$ measured in dry season was more than that measured in wet season. Averagely, dry season exceeded the regulatory limit of National ambient air quality standard of 0.07 ppm; though, W1, W2 and S3 did not exceed the regulatory limit. While averagely, the wet season was within the purview of the regulatory limit; though, W1, S1, U1 and U3 exceeded the regulatory limit as seen in figure 2e. The variations could be as a result of seasonal variation, where the sampling was actually done in wet season, but it was dry on the days of sampling.

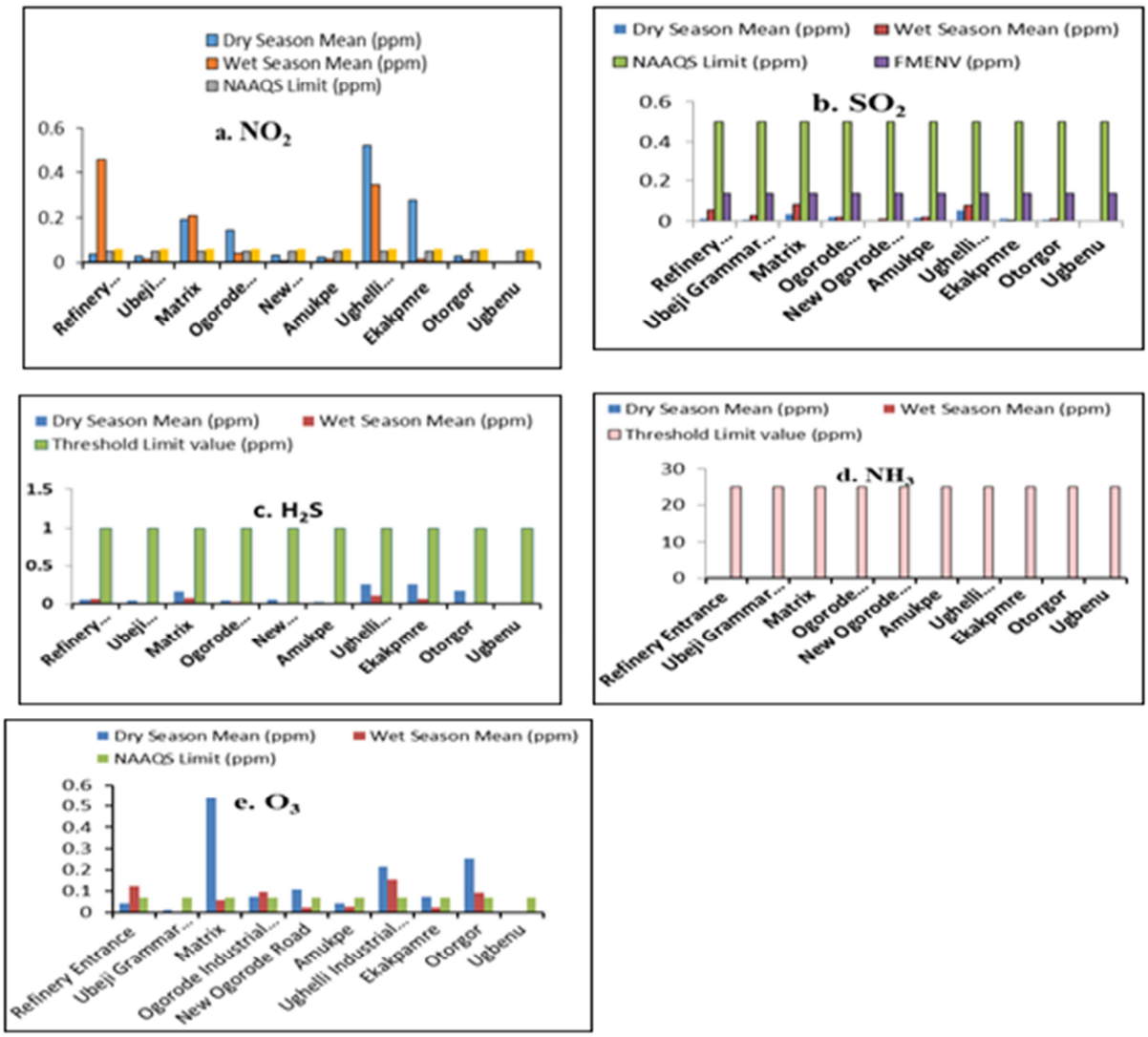


***Figure 2.*** *Comparison of (a) $NO_2$ (b) $SO_2$ (c) $H_2S$ (d) $NH_3$ (e) $O_3$ levels (ppm) with recommended standards.*

Analyzing the data using a paired t- test, there was significant difference for $NO_2$, $SO_2$ and $H_2S$ ($P<0.001$) and no significant difference ($P > 0.05$) for $O_3$ among the sampling locations in dry season. In wet season, there was no significant difference ($P > 0.05$) for all the pollutant gases among the sampling locations. Meteorology parameters studied showed significant difference among the sampling locations in the dry season except wind speed which showed no significant difference ($P > 0.05$). In wet season, only light and humidity showed significant difference among the sampling locations.

However, comparing the two seasons, higher concentrations of the pollutant gases were observed in the dry season than in the wet season except $SO_2$ and $NH_3$ which showed no significant difference in both seasons. This could be attributed to insignificant emission of these two gases as a result of the activities in the study areas. There was significant difference for all the meteorology parameters studied among the sampling locations. Higher values were recorded in the dry season than the wet season except humidity, which recorded higher value in the wet season than the dry season; this is because there is an increase in water vapour during the wet season.

### *3.3. Comparison with Global Atmospheric Model*

The data used for the modeling was derived from the Copernicus Atmospheric Monitoring Service (CAMS) for $NO_2$, $SO_2$ and $O_3$ to compare with the field results. CAMS provides daily analyses and forecasts of worldwide long-range transport of atmospheric pollutants as well as the background air quality. This is shown in animation 1, animation 2 and animation 3. The spatial resolution of the model is $0.75^o$ X $0.75^o$ (~83km) grid. The model supported the field observations of this research. Though there was discrepancy between the model and the actual field result which could be attributed to slight difference in parameters and instructions used to construct the model. The model predicted $NO_2$ to be higher than the limits which also agrees with the results obtained in this study. $SO_2$ is below the limits for both the model and actual result and the model predicted highest concentration of $O_3$ at Matrix location and lowest concentration at Ugbenu location which agrees with the study of this research. Comparisons of the model with the actual

results are shown in Table 3.

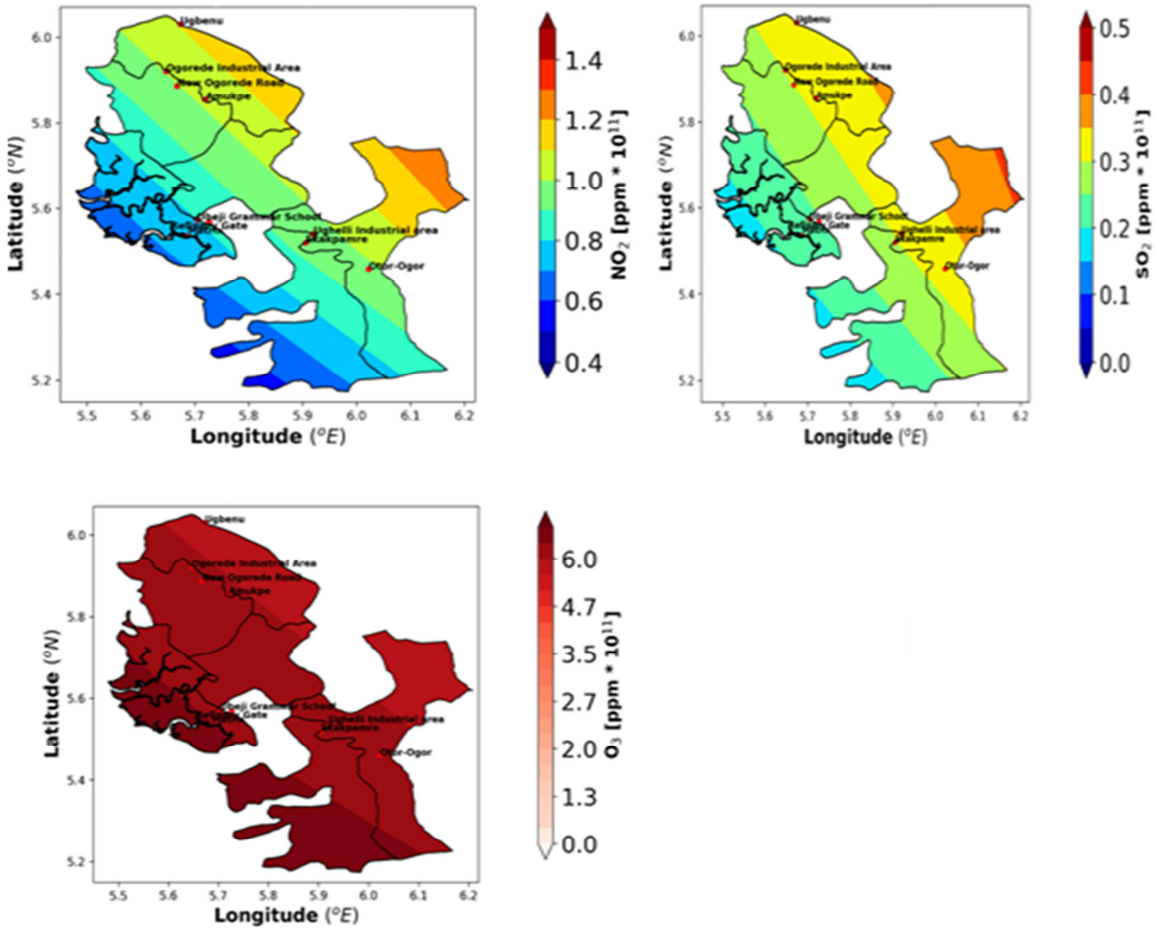


***Figure 3.*** *a-c: Global model of the level of $NO_2$ (a), $SO_2$ (b) and $O_3$ (c) at the sampling sites during the sampling period.*

***Table 3.*** *Comparison of Actual Data with Global Model.*

| Sampling Sites | Expected $NO_2$ | Actual $NO_2$ | Expected $SO_2$ | Actual $SO_2$ | Expected $O_3$ | Actual $O_3$ |
|---|---|---|---|---|---|---|
| W1 | 0.6 | 0.25 | 0.2 | 0.03 | 3.5 | 0.08 |
| W2 | 0.5 | 0.02 | 0.1 | 0.02 | 2.7 | 0.01 |
| W3 | 0.5 | 0.20 | 0.15 | 0.06 | 4.7 | 0.30 |
| S1 | 1.0 | 0.09 | 0.3 | 0.019 | 3.5 | 0.08 |
| S2 | 1.0 | 0.02 | 0.3 | 0.008 | 3.5 | 0.06 |
| S3 | 1.02 | 0.02 | 0.32 | 0.02 | 2.7 | 0.04 |
| U1 | 1.0 | 0.44 | 0.3 | 0.06 | 3.5 | 0.18 |
| U2 | 0.9 | 0.15 | 0.3 | 0.01 | 3.5 | 0.05 |
| U3 | 1.0 | 0.02 | 0.35 | 0.01 | 2.7 | 0.17 |
| C1 | 1.1 | BDL | 0.35 | BDL | 1.3 | BDL |

## 4. Conclusion

Results obtained from the assessment of pollutant gases studied ($NO_2$, $SO_2$, $NH_3$, $H_2S$, $O_3$) strongly indicated emission of these pollutant gases from facilities characterized with heavy duty vehicles and industrial activities related to dockyards, chimneys, power generating systems, tank farm activities, glass production, plastic production, flour production and thermal power stations. The control location was below detection limit as a result of non-availability of industrial activities at the area. Emission of $NO_2$ and $O_3$ at the sampling locations constitutes a serious threat to health and environment. Among the pollutant gases studied, $SO_2$, $H_2S$ and $NH_3$ were within the purview of the regulatory limit. This is as a result of low Sulphur content of the fuel and diesel produced and marketed in the area and minimal burning of biomass at the sampling locations. Also, pulp and paper production facilities were absent at all the sampling locations. Comparing the three cities studied annually, it can be seen that the highest concentration of $NO_2$ and $H_2S$ were recorded at Ughelli, highest concentration of $SO_2$ and $O_3$ were recorded at Warri while Sapele recorded the highest concentration of $NH_3$. Hence, Ozone recorded the highest value of the pollutant

gases at W3; exposing the inhabitants to danger of lung damage and death. Data generated from this study also indicated seasonal variation with higher concentrations in the dry season than the wet season. This is as a result of increased wind movement of gases and burning of substances in the dry season. But in the wet season, gaseous pollutants are dissolved due to rainfall. There is an agreeable trend between the global model and the actual data generated from this research; hence, the global model supported the field observations of this research.

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