PRINT ISSN 1119-8362
Electronic ISSN 1119-8362

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://ww.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 24 (4) 607- 614 April 2020

# Comparative Assessment of Air Quality in Igwuruta and Aluu, Rivers State, Nigeria

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**ABSTRACT:** This study investigated the air quality of Aluu and Igwuruta communities both in Obio-Akpor Local Government Area of Rivers State, using carbon monoxide (CO), nitrogen dioxide ($NO_2$), Sulphur dioxide ($SO_2$), suspended particulate matter (SPM), Methare ($CH_4$), ammonia ($NH_3$) Ozone ($0_3$) and Volatile Organic Compound (VOCs) as indices. Sampling was done at eighteen (18) locations within Aluu and Igwuruta at graded distances from the two (2) flare points located within the study area. Ambient air temperature, relative humility and windspeed were also measured for the location. Results showed the following levels for Aluu: CO; 934.2 ± 6.5 μg/m$^3$, $NO_2$; 1451.4 ± 14.28 μg/m$^3$, $SO_2$; 243.3 ± 9.085 μg/m$^3$, $NH_3$; 2167.3 ± 8.916 μg/m$^3$, $CH_4$; 34734.5 ± 9.55 μg/m$^3$, SPM; 23.55 ± 6.05 μg/m$^3$, $O_3$; 14.795 ± 6.33 μg/m$^3$ and VOC; 4.04 ± 1.842 μg/m$^3$ while for Igwuruta, results are given as: CO; 460 ± 6.81 μg/m$^3$, SPM; 95.7 ± 3.588 μg/m$^3$, $NO_2$; 1300.75 ± 4.681 μg/m$^3$, $SO_2$; 1191.72 ± 13.127 μg/m$^3$, $SO_2$; 1191.72 ± 13.127 μg/m$^3$, $NH_3$; 554.05 ± 9.241 μg/m$^3$, $CH_4$; 15078.8 ± 10.74 μg/m$^3$, $O_3$; 17.464 ± 1.696 and VOC; 4.659 ± 1.059 μg/m$^3$. The dominant pollutants were $NO_2$, $SO_2$, $NH_3$ and $CH_4$. These results raises concern on possible health risk on community dwellers while Igwuruta had higher levels than Aluu in $NO_2$ and $SO_2$ levels. It is therefore recommended among others, that gas to energy conversion approach is a readily available technology that can be used to curb the menance of environmental pollution due to gas flaring at the same time harnessing the commodity value of the associated gases currently being flared.

**DOI: https://dx.doi.org/10.4314/jasem.v24i4.10**



**Dates:** Received: 13 February 2020; Revised: 17 March 2020; Accepted: 28 March 2020

**Key words:** criteria pollutants, reinforcement, Igwuruta, Aluu, health effects

The flaring of gas by oil and gas producing nations has become a global epidemic. Nigeria being amongst the world's leading oil and gas producing nations flare a significant amount of natural gases into the environment through vertical and horizontal flaring stacks. Globally, an estimated amount of 110 billion cubic meters of associate gas is flared per annum (Ismail and Umukoro, 2012). Ogbe (2010) in his research drew a conclusion that Nigeria accounted for an estimated 12.5% of flared gases globally per annum. In Nigeria, the Niger Delta region holds this natural resource and therefore has been subject to all forms of oil and gas exploration activities over time. The Niger Delta is made up of Ondo, Edo, Delta, Abia, Imo, Bayesa, Rivers, Akwa-Ibom, and Cross Rivers State. These states holds the nation's crude oil and gas reserve until the recent addition of Lagos state as an oil producing state. Also, these named states suffer the worst impacts of gas flaring, due to the fact that they possess either onshore or offshore gas flaring facilities in their regions (Aigberua *et al*, 2017). According to Donwa *et al*. (2015), in their studies identified several impacts gas flaring poses on the environment. These impacts affect both human and environmental components. Also, the resultant occurrence and impact of acid rain due to the residual activities of some of the flared pollutants. On the list of identified impacts are vegetation and physical infrastructure (such as roofing sheets, building structures, artifacts, monuments and paints), pathological and psychological health impact (such as excessive heat and discomfort, gastrointestinal problems, skin diseases, cancer, neurological, reproductive and developmental effects, hematological and respiratory ailments, heart (cardiovascular) related illness including atherosclerosis, bronchitis, asthma, , hypertension and ischaemic heart disease (Amadi,2014). Gas flaring impacts the quality of water air and vegetation. It leads to the release of 3 major components into the environment which includes noxious gases, heat and noise. Therefore, there is a possibility that the presence of this gas flaring may have upset some environmental balance. Some notable vegetation such as Water leaf, Pumpkin 9leaf, Okra, Cassava, Cucumber, Plantain, Palm tree, and Coco yam are cultivated around the location of the facility. According to Achi (2003), gas flaring has the tendency to affect several plants species especially in terms of productivity and growth. Lawanso (2016) reported that gas flaring decreases the length and weight of Cassava and increases its amino acid and total sugar contents as the distance from the flare decreases. Such decrease as observed were also correlated with decrease in the content of starch and ascorbic acid (Vitamin C) in the tubers. In a survey

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done on the natives of Ebedei community located in Delta state regarding the impact of gas flaring on agricultural activates; 94.6, 90, 98.75, 50.4, and 5% had the opinion that gas flaring affects food crops such as Yam, Cassava, Okra, plantain and Potatoes respectively (Ozabor and Obisesan,2015).

The problems associated with air pollution abound. The presence of a gas flaring plant in Aluu and Igwuruta communities is an obvious fact that the air quality must have been impacted. Gaseous pollutants such as NOX, SOX, CO, O3, SPM, VOC, $NH_3$ and $CH_4$ are emitted from gas flaring facilities and can affect physico-chemical characteristics of various environmental components. This is a strong indication that the quality of the environment will be altered. Therefore, it is important to know the worst impacted out of the two communities so as to make appropriate recommendations on a basis of comparison on abatement techniques to adopt. This paper was aimed at conducting a comparative air quality study in Aluu and Igwuruta, which are hosts to oil exploration activities in Rivers State, Nigeria.

## MATERIALS AND METHODS

*Description of Study Area:* The study area is in the Greater Port Harcourt Municipality comprising of Port Harcourt City Local Government Area, Okrika Local Government Area along with Obio/Akpor LGA, and parts of Eleme, Ikwerre, Oyigbo, Ogu/Bolo and Etche Local Government Areas are known as Greater Port Harcourt Metropolis. Port Harcourt Metropolis being the hub of oil and gas industry in the country has attracted various people to the area leading to a burgeoning population. However, the particular area of interest for this ambient air quality study is the area encompassing the two flow stations known as Agbada I (in Mgbodo -Aluu, Ikwerre LGA) geo-referenced as N4O55'55.303", E6O58'28.58'' and Agbada II (between Rukpokwu/Rumuejime and Eneka Obio/Akpor LGA) with geographical coordinate as N4O55'54.142", E7O0'55.951" the flow stations are about 4.66km apart by crow fly. Agbada field was the first land-based oil-field in the Eastern Division of SPDC. The two flow stations, Agbada I and II were commissioned in 1960 and 1965 respectively with a combined capacity of 90,000 bbl/d. Agbada I is a single bank flow station with a nominal capacity of 30,000 bbl/d having 30 flow lines laid to the station while Agbada II is a double bank flow station with a nominal capacity of 60,000 bbl/d and having 57 flow lines. The field is located on the same mega structural trend as the Obigbo North field in the Eastern Land Area operation of Shell Petroleum Development Company (SPDC) in OML 17 situated approximately 16 km North-East of Port Harcourt in Rivers State (SPDC, 2009). The study area is within the humid tropical belt of the Niger-Delta. The climate of the area is profoundly influenced by its proximity to the Atlantic Ocean and the Orashi River. Rainfall is experienced throughout the year with peaks in June and September. The mean annual rainfall is, above 2200 and lower amounts of rainfall from November to February mm. The southwest trade winds bring moisture into the area from the coastal area. Two seasons namely, wet and dry, characterized the area. The wet season spread from April to October while the dry season was from November to March (Ayaode, 2004). In the dry season, the high daily relative humidity values ranged from 86.5 to 92.0% and occurred between 2100 and 2400h and later from 0100 to 0800 hours. The lower relative humidity values of 45.5 – 66.0% were obtained between 1300 and 1600 hours (SPDC, 2009).

Southwesterly winds were prevalent in the rainy season in the node, the prevalent wind direction within the study area is generally the South-West (210 –240°) for 8 months (Ayaode, 2008). Wind speed in the study area for dry season ranged from 0.5m/s to 1.8m/s while the wet season wind speed ranged from 0.2 to 1.00m/s. The wind is predominantly in the South Western direction accounting for about 75% of the annual winds. The North Easterly winds predominate during the dry season (November – March); this makes up about 25 % of the annual winds within the study area. Its penetration into the Niger Delta region between December and February is characterized by dry and low humidity with dusty haze. The highest temperature (°C) values ranged from 34.0 – 36.3 and they occurred between 1300 and 1800 h while the lowest temperature values ranged from 25.3 – 26.0 between 0400 and 0800 h in the dry season. Temperatures ranged between 24.5 and 29.0 °C in the early hours (0400 – 0600 h) in the rainy season. Higher temperatures (from 29 – 32 °C) occurred between 0900 and 1800 hours. The vegetation in this location comprised farmlands (cassava) and forest re-growth of approximately 3 years. Oil palms were the main growing canopy species, with a frequency of 38.1%. The secondary nature of the vegetation was further indicated by the occurrence of forest species such as Anthocleista vogelii and Ceiba pentandra. The mean height of the five tallest trees (excluding palms) was 13m, further signifying that trees of timber stature were lacking. Species composition and species diversity index were low. The dominant ground cover species included Aspilia africana, Chromolaena odorata, Sida acuta, Costus afer and Panicum maximum (SPDC, 2009; Gobe *et al*., 2009).

*Research Design*: This research was basically field survey and analysis of air quality data obtained from sampling locations. These samples were collected at eighteen (18) different locations and two (2) replications were made per sample location at a graded distance of 500m (0.5km) away from each flare point (Agbada 1 and 2) coded SP1, SP2 and SGP1, SGP2 for Agbada 1 and 2 respectively samples were collected in both, windward and leeward direction of the flare point at each flare facility for possible pollutant fallouts At a graded distant of 1km away from each flare point (Agbada 1 and 2) coded SP3, SP4, SP5 and SGP3, SGP4, SGP5 for Agbada 1 and Agbada 2 respectively(Okereke,2006;Odjugo and Osemwakhae, 2009). Also, these samples were collected while moving towards the Aluu and Igwuruta Communities respectively. Samples were collected along the Southwest prevalent wind direction moving from Agbada 1 in Aluu towards Igwuruta Community. These sampling points were coded GSP1, GSP2, GSP3, GSP4, and GSP5. Sampling was done at these locations to check for possible reinforcement of pollutant concentration from one point into another. A set of control samples were taken in Chokocho Community located in Etche Local Government Area, which is located in the same climatic zone as the study area (Aluu and Igwuruta communities). The control samples were coded SPS1, SPS2 and SPS3. Factors considered in course of the field survey and data analysis included accessibility, availability of suitable space, avoidance of obstruction from trees and buildings, reasonable distance away from traffic roads, elimination of bias, reduction of percentage of error and general safety. Ambient air quality was monitored for $NO_2$, $O_3$, $NH_3$, $SO_2$, $CH_4$, CO, and volatile organic carbons (VOCs) levels, and Air borne particulates (SPM) in accordance with standard procedures as recommended by USEPA (2016).

The following hand held air quality monitoring procedures and equipment were used for measuring the criteria pollutants in each station.

*Carbon monoxide:* **A**n Industrial Scientific Corporation ITX Multigas-Gas monitor will be used for the detection of CO. The equipment detects CO via an electrochemical sensor that generates a signal linearly proportional to the concentration of the gas. The range of detection is between 0 - 999 ppm and the limit of detection is 1ppm. Measurements were done by holding the sensor to a height of about two meters in the direction of the prevailing wind and readings recorded at stability.

*Sulphur dioxide:* A Multirae Plus (PGM - 50), a programmable Multi Gas monitor with an electrochemical sensor was used for the detection of $SO_2$. The range of detection is between 0 - 20 ppm with a resolution of 0.1ppm. The alarm set points (low/high) were at 2 and 10 ppm. Measurements will be done by holding the sensor to a height of about two meters in the direction of the prevailing wind and readings recorded at stability.

*Nitrogen dioxide:* An Industrial Scientific Corporation ITX Multigas-Gas monitor was used for the detection of $NO_2$. The range of detection is between 0 – 99.9 ppm with a resolution of 0.1ppm. Measurements were done by holding the sensor to a height of about two meters in the direction of the prevailing wind and readings recorded at stability.

*Ammonia:* An Industrial Scientific Corporation ITX Multigas-Gas monitor with a range of 0- 200 ppm and a resolution of 1 ppm was used for the detection of NH3. Measurements were done by holding the sensor to a height of about two meters in the direction of the prevailing wind and readings recorded at stability.

*Methane:* An Industrial Scientific Corporation ITX Multigas-Gas monitor with a range of 0 to 5% of volume in 0.1% increments was used for the detection of $CH_4$. Measurements were done by holding the sensor to a height of about two meters in the direction of the prevailing wind and readings recorded at stability.

*Volatile Organic Carbons*: A Multirae Plus (PGM - 50), a programmable Multi Gas monitor was used to monitor organic vapours. It has a Photo-ionisation Detector (PID) using a 10.6 eV or 11.7 eV gas discharge lamp. It includes an integrated sampling pump – a diaphragm pump providing about 250 cc per minute flow rate at high setting. It measures VOC over two ranges; 0 – 200 ppm with a resolution of 0.1 ppm, and 200 – 2,000 ppm with a resolution of 1 ppm.

*Suspended Particulate Matter:* A Met One Instrument, Inc. Aerosol Mass Monitor Model GT – 321 was used to measure total suspended particulates. This Ambient Particulate Monitor with recorder collects and records "real-time" information on airborne particulate concentration in addition to providing continuous particle monitoring. A laser optical sensor for detecting and measuring particulate concentrations up to 1 milligram per cubic meter is included. A waterproof enclosure contains the laser sensor, flow system, and digital recorder.

*Ozone:* The ultraviolet (uv) photometry method was used for ozone monitoring. The uv photometry analysis operate by using ozone's strong absorption band which coincides with the emission spectrum from low pressure mercury lamps. This radiation passes through a chamber containing ambient air and the light is absorbed by ozone pressure in the chamber. The amount of uv light depleted is determined by comparing it with that transmitted through a reference chamber with ozone free air.

*Wind Speed:* A digital hand held Cole-Parmer Combination Anemometer that measures air velocity, temperature and humidity, was used to ascertain the wind speed of the various locations. The equipment determines the wind via wind vanes that generates on revolution, signal that is directly proportional to the wind force. Wind velocity, temperature and humidity by holding the wind vane to a height of two meters, in the prevailing wind direction.

*Wind Direction:* A Compass model m-73 was used to determine the direction of wind. In addition, a wind suck in the vicinity of the Agbada II provides an alternative wind direction to serve as guide and compare results

*Data Analysis:* The data collected was subjected to descriptive statistics that employed the use of graphical illustrations to present requisite data. One-way analysis of variance (ANOVA) was used to test for significant difference in the concentration of contaminants in the air.

## RESULT AND DISCUSSION

The air quality parameters and meteorological data as obtained from this study are summarized into three locations namely; Aluu, Igwuruta and locations bordering Aluu and Igwuruta communities. Table 1 shows the mean levels of ambient air quality parameters and meteorological data for Aluu Community (which is the host community of Agbada 1). Table 2 shows the mean levels of air quality parameters for Igwuruta Community (which is the host community to Agbada 2) while Table 3 shows the mean ambient air quality parameters in the Southwest wind direction obtained from Aluu windward towards Igwuruta Community. The concentration levels of the ambient air quality parameters showed spatial variation with the levels of CO indicating least spatial spread in ambient air in both locations. The maximum levels of CO were recorded in sampling station SP3 as 1200 $\mu/m^3$ while sampling stations SP5, SGP3, SGP4, SGP5, GSP3, GSP4, GSP5 and control recorded its minimum value as 0.000 $\mu/m^3$. The maximum levels for SPM were obtained as 183.75 $\mu/m^3$ at sampling station SGP5 with its minimum value recorded at SP5. $NO_2$ highest concentrations in ambient air were gotten at SGP4 as 2805.000 $\mu g/m^3$ and its least concentration recorded at SP5, GSP5, SGP5 and control. Sampling station SGP2 recorded the maximum levels for SO2 as 1702.50 $\mu g/m^3$ while SP5 and control yielded its minimum values. Also, the maximum concentration for $NH_3$ was obtained in SP3 as 6503.250 $\mu g/m^3$ while GSP5 gave its minimum concentration as 0.000 $\mu g/m^3$.

$CH_4$ was highest at SP4 with a concentration of 58667.5 $\mu g/m^3$ in Aluu community with its minimum value at control as 2564.000 $\mu g/m^3$ in SPS1. The maximum levels of $O_3$ was obtained as 25.393 $\mu g/m^3$ in GSP1 and its minimum levels at SGP5, GSP5 and Control. Similarly, the VOCs maximum ambient level was obtained from SP1 and its minimum levels at SP3 and Control. In this study, it was observed that most of the pollutants indicated a significant decrease in concentration levels along the graded distances with an exception to SP3 and SP4 which showed a significant increase in CO, SPM, $SO_2$, $NH_3$, $CH_4$ and $O_3$ levels. This negation to the decrease can be attributed to the massive open dump situated within this location currently being utilized by the Rivers state Waste Management authorities for disposal of all kinds of wastes. Also there is the presence of an Asphalt processing plant along this path of survey which could be responsible for the almost localized elevated levels of $SO_2$ and SPM. Methane ($CH_4$) had the highest concentration levels in Aluu community far exceeding permissible limits by Federal Ministry of Environment (FME) Standards. Ammonia levels in this region were also elevated with the presence of a very offensive odor fouling breathable air. Some of the criteria pollutants showed reinforcement in concentration levels between sampling stations GSP2 and GSP4 with a consequent increase in certain criteria pollutants concentration levels recorded in Igwuruta community at SGP3 and SGP4 excluding ambient levels in methane and ammonia. SGP4, SGP5, GSP3, GSP4 and GSP5 showed a relative increase between SPM, $NO_2$, $SO_2$, $O_3$ and VOCs levels. This reinforcement in ambient pollutants levels can be attributed to atmospheric dispersion effect most especially by the prevailing wind and traffic volume. Figures 1-3 shows the histogram plots comparing pollutant concentration at different sampling stations in relative to the Nigerian Federal Ministry of Environment (FME) emission standards. Also, the Department of Petroleum Resources (DPR) and World Health Organization (WHO) daily emission permissible limits for certain criteria pollutants as identified by both regulatory bodies were employed in the histogram plots as shown in Figures 1, 2 and 3.

**Table 1:** Variation Data of Air Quality Parameters in Aluu Community

| S/N | Description | Parameters/Parameters' Concentration | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CO ($\mu g/m^3$) | SPM ($\mu g/m^3$) | $NO_2$ ($\mu g/m^3$) | $SO_2$ ($\mu g/m^3$) | $NH_3$ ($\mu g/m^3$) | $CH_4$ ($\mu g/m^3$) | $O_3$ ($\mu g/m^3$) | VOC ($\mu g/m^3$) | Temp (°C) | Wind Speed (m/s) | R.H (%) |
| SP1 | 0.5km (Leeward) | 1141.25 | 25.25 | 939.750 | 305.25 | 1387.25 | 46115.00 | 20.28 | 10.08 | 31.15 | 1.553 | 72.58 |
| SP2 | 0.5km Windward) | 1154.75 | 33.25 | 2730.00 | 360.00 | 950.500 | 38392.50 | 20.13 | 8.540 | 33.68 | 1.398 | 72.08 |
| SP3 | 1km | 1200.0 | 31.50 | 1837.00 | 376.25 | 6503.25 | 58667.50 | 16.35 | 0.465 | 32.80 | 1.350 | 58.38 |
| SP4 | 2km | 1175.0 | 27.75 | 1750.25 | 143.75 | 1295.00 | 22630.00 | 12.00 | 0.563 | 32.48 | 3.378 | 56.05 |
| SP5 | 3km | 0.000 | 0.00 | 0.000 | 31.250 | 700.500 | 7867.500 | 5.225 | 0.553 | 31.50 | 3.305 | 57.98 |

***R.H** = Relative Humility; **Temp:** Ambient Temperature*

**Table 2:** Variation Data of Air Quality Parameters in Igwuruta Community

| S/N | Description | Parameters/Parameters' Concentration | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CO ($\mu g/m^3$) | SPM ($\mu g/m^3$) | $NO_2$ ($\mu g/m^3$) | $SO_2$ ($\mu g/m^3$) | $NH_3$ ($\mu g/m^3$) | $CH_4$ ($\mu g/m^3$) | $O_3$ ($\mu g/m^3$) | VOC ($\mu g/m^3$) | Temp (°C) | Wind Speed (m/s) | R.H (%) |
| SGP1 | 0.5km (Leeward) | 1140 | 14.00 | 1825.00 | 1562.50 | 2000.0 | 6005.50 | 12.00 | 0.480 | 33.07 | 2.210 | 53.02 |
| SGP2 | 0.5km (Windward) | 1150 | 17.50 | 2022.50 | 1702.50 | 2950.3 | 7485.00 | 13.75 | 0.540 | 36.05 | 2.100 | 53.35 |
| SGP3 | 1km (Windward) | 0.000 | 50.75 | 2605.50 | 1446.25 | 1228.8 | 11750.0 | 17.75 | 6.403 | 31.75 | 2.400 | 52.70 |
| SGP4 | 2km (Windward) | 0.000 | 143.0 | 2805.50 | 1544.25 | 1350.5 | 8500.00 | 18.38 | 3.505 | 34.00 | 1.650 | 54.00 |
| SGP5 | 3km (Windward) | 0.000 | 183.8 | 0.000 | 1210.00 | 991.25 | 2875.00 | 0.000 | 2.470 | 35.40 | 1.200 | 50.05 |

*R.H: Relative Humility, Temp: Ambient Temperature*

**Table 3:** Variation Data of Air Quality Parameters for the bordering location between Aluu and Igwuruta Communities

| S/N | Description | Parameters/Parameters' Concentration | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CO ($\mu g/m^3$) | SPM ($\mu g/m^3$) | $NO_2$ ($\mu g/m^3$) | $SO_2$ ($\mu g/m^3$) | $NH_3$ ($\mu g/m^3$) | $CH_4$ ($\mu g/m^3$) | $O_3$ ($\mu g/m^3$) | VOC ($\mu g/m^3$) | Temp (°C) | Wind Speed (m/s) | R.H (%) |
| GSP1 | From Agbada 1 1km (Windward towards Igwuruta) | 1150.0 | 28.2 | 1840.0 | 1264.0 | 700.000 | 15045.000 | 25.395 | 5.628 | 35.025 | 1.300 | 56.325 |
| GSP2 | From Agbada 1 2km (Windward towards Igwuruta) | 1150.2 | 46.7 | 1843.0 | 1358.5 | 708.000 | 14242.750 | 25.130 | 3.560 | 35.225 | 1.500 | 52.600 |
| GSP3 | From Agbada 1 3km (Windward towards Igwuruta) | 0.0 | 59.2 | 2505.2 | 1517.7 | 748.500 | 20472.500 | 20.910 | 8.333 | 36.050 | 1.100 | 51.750 |
| GSP4 | From Agbada 1 4km (Windward Igwuruta) | 0.0 | 172.7 | 315.5 | 768.3 | 613.750 | 18522.500 | 15.885 | 3.308 | 36.400 | 1.350 | 52.575 |
| GSP5 | From Agbada 1 5km (Windward Igwuruta) | 0.0 | 171.5 | 0.0 | 1050.0 | 0.000 | 7111.250 | 0.000 | 2.465 | 36.150 | 1.355 | 52.525 |

***R.H:** Relative Humility; **Temp:** Ambient Temperature*

In comparing the mean values for each air quality parameter (CO, $NO_2$, $SO_2$, $CH_4$ SPM, $O_3$, $NH_3$ and VOCs) for all the sampling points in both communities, the results obtained showed a corresponding significant difference in ambient concentration. The following values; 5.088319, 0.003392 and 2.658197 were obtained for the "f", "p" and "f-crit" respectively as shown in Table 4.

From the descriptive statistics data presented in Table 5, a vivid comparative study on the ambient; levels of air quality parameters can be done on data obtained from Aluu and Igwuruta the communities. CO levels is higher for Aluu with a recorded value of 934.2 ± 13.76 μg/m$^3$ than Igwuruta which recorded CO levels of 458.05 ± 4.501 μg/m$^3$. SPM levels were higher in Igwuruta (81.8 ± 1.567 μg/m$^3$) than Aluu which only recorded 23.55 ± 6.05 μg/m$^3$. $SO_2$ recorded higher ambient concentrations in Igwuruta (1493.1 ± 7.738 μg/m$^3$) than Aluu with just 243.3 ± 9.085 μg/m$^3$.

$NH_3$ concentration obtained from Aluu ($NH_3$: 2167.3 ± 8.916) was more elevated than that recorded in Igwuruta ($NH_3$:1704.15± 7.625 μg/m$^3$. $NO_2$ levels in Igwuruta (1851.7 ± 8.113 μg/m$^3$) was higher than that obtained for Aluu (1451.4 ± 14.28 μg/m$^3$). The $CH_4$ concentration obtained in Aluu (34734.5 ± 9.55) was almost five (5) times higher than that recorded in Igwuruta (7323.2 ± 12.259 μg/m$^3$). $O_3$ levels obtained from Aluu ($O_3$:14.795 ± 6.33 μg/m$^3$) was just slightly higher than that recorded for Igwuruta (12.375 ± 3.317 μg/m$^3$). Lastly, the VOCs level in ALuu (4.04 ± 1.842 μg/m$^3$) was only slightly elevated than that obtained from Igwuruta Community (2.68 ± 1.096 μg/m$^3$).

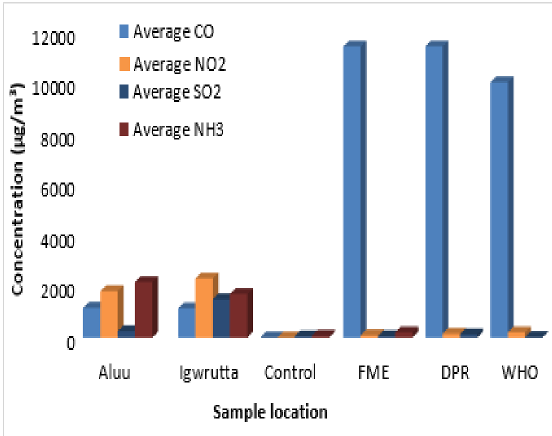


**Fig 1**. Comparing CO, $NO_2$, $SO_2$ and $NH_3$ Ambient levels from the different sampling locations

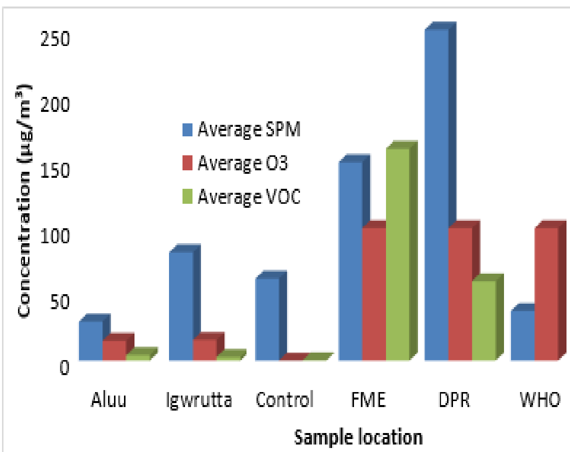


**Fig 2.** Comparing SPM, $O_3$ and VOC Ambient levels from the different sampling locations

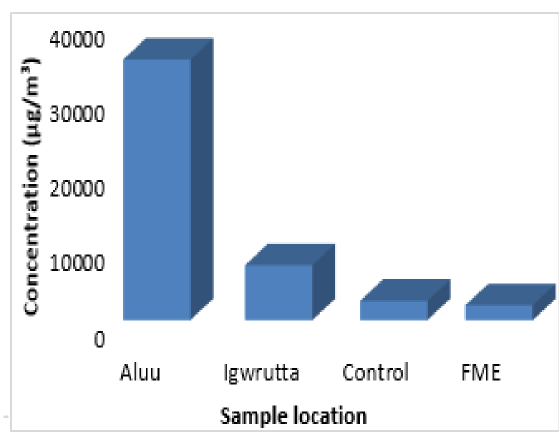


**Fig 3**. Comparing $CH_4$ Ambient levels from the different sampling locations

The CO levels obtained from both Aluu (934.2 ± 13.76 µg/m$^3$) and Igwuruta (458.054 ± 4.501 µg/m$^3$) are far below permissible limits as specified by FME (1140 µg/m$^3$) respectively. SPM levels for Aluu (23.55 ± 6.05 µg/m$^3$) and Igwuruta (81.8 ± 1.567 µg/m$^3$) satisfies both the FME and DPR Limits of 150 and 250 µg/m$^3$ respectively but violates the W.H.O daily permissible limits.

$NO_2$ levels in both communities grossly violates all three (FME, DPR and WHO) air quality standard $SO_2$ levels in Aluu was above, the FME limits by a factor of four (4) the DPR limits by a factor of two (2) and the WHO limits by a factor of eight (8) respectively. In Igwuruta Community, $SO_2$ levels grossly violates all three (FME, DPR and WHO standards) with an elevated concentration of 1493.1 ± 7.738 µg/m$^3$.

$NH_3$ levels recorded in Aluu was about ten (10) times higher than the FME regulatory standard while than the FME regulatory standard while that obtained from Igwuruta was about eight (8) times higher than the FME daily permissible limits. The methane ($CH_4$) recorded in Aluu was very high and was about seventeen (17) times higher than the FME daily permissible limits. $CH_4$ levels in Igwuruta exceed the FME limits by a factor of three (3).

$O_3$ concentrations recorded for both communities were far higher than the limit given by all three (FME, DPR and WHO) regulator bodies whose limits are 100 µg/m$^3$. VOCs obtained from both communities was also far below the DPR and FME daily maximum permissible limits of 160 µg/m$^3$.

In view of the comparative study, it is sufficient to postulate that both Aluu and Igwuruta communities are dominantly polluted by $NO_2$, $SO_2$, $NH_3$ and $CH_4$ out of the eight (8) air quality parameters investigated in the course of this study. In the same vein, Igwuruta community is more polluted by $SO_2$ and $NO_2$ therefore Igwuruta community is most likely to experience more ecological and environmental losses because of the possible residual actions of $SO_2$ and $NO_2$ in the ambient concentrations recorded (Gerret, 2007 WHO, 2013). Whereas Aluu community is dominated by $CH_4$ and $NH_3$. The $CH_4$ presence in Aluu Community is alarmingly high and therefore is a point of concern (CCOHS, 2017).

Cross-examining Levels of $NO_2$, $SO_2$, $CH_4$ and $NH_3$ for Igwuruta and Aluu with recorded effects from existing literature suggests that present ambient levels could lead to possible health effects. Such health effects include: Eye irritation, hypertension, cough, fever, Asthma, headache, dizziness, skin irritations, breathing difficulties, body weakness, chest pain, catarrh, stooling and dysentery. An observation of the data for the two communities suggest the prevalence of respiratory and skin related problems (WHO, 2013; Loftus *et al*., 2015).

**Table 4:** ANOVA Statistics Significance check of Pollutant Concentration and Flare Location

| Anova: Single Factor | | | | | | |
|---|---|---|---|---|---|---|
| **SUMMARY** | | | | | | |
| ***Groups*** | ***Count*** | ***Sum*** | ***Average*** | ***Variance*** | | |
| CO | 3 | 1852.3 | 617.4333 | 75256.84 | | |
| SPM | 3 | 201.05 | 67.01667 | 1465.316 | | |
| NO2 | 3 | 4603.85 | 1534.617 | 81080.24 | | |
| SO2 | 3 | 2928.12 | 976.04 | 425388.4 | | |
| NH3 | 3 | 4425.5 | 1475.167 | 689968.9 | | |
| CH4 | 3 | 57136.4 | 19045.47 | 2E+08 | | |
| O3 | 3 | 44.634 | 14.878 | 6.479647 | | |
| VOC | 3 | 11.378 | 3.792667 | 1.024669 | | |
| **ANOVA** | | | | | | |
| ***Source of Variation*** | ***SS*** | ***df*** | ***MS*** | ***F*** | ***P-value*** | ***F crit*** |
| Between Groups | 894552868 | 7 | 1.28E+08 | 5.088319 | 0.003392 | 2.657197 |
| Within Groups | 401840426 | 16 | 25115027 | | | |
| **Total** | **1296393294** | **23** | | | | |

**Table 5:** Descriptive Statistics for Air Quality Parameters in Ambient Air in the Study Area

| | | **Aluu** | | | |
|---|---|---|---|---|---|
| **Parameters** | **Minimum** | **Maximum** | **Range** | **Mean** | **SE** |
| CO | 0 | 1200 | 1200 | 934.2 | 13.76 |
| SPM | 0 | 33.25 | 33.25 | 23.55 | 6.05 |
| $NO_2$ | 0 | 2730 | 2730 | 1451.4 | 14.28 |
| $SO_2$ | 31.25 | 376.25 | 345 | 243.3 | 9.085 |
| $NH_3$ | 700.5 | 6503.25 | 5802.75 | 2167.3 | 8.916 |
| $CH_4$ | 7867.5 | 58667.5 | 50800 | 34734.5 | 9.55 |
| $O_3$ | 5.225 | 20.275 | 15.05 | 14.795 | 6.33 |
| VOC | 0.465 | 10.08 | 9.615 | 4.04 | 1.842 |
| | | **Igwuruta** | | | |
| CO | 0 | 1150.25 | 1150.25 | 458.05 | 4.501 |
| SPM | 14 | 183.75 | 169.75 | 81.8 | 1.567 |
| $NO_2$ | 0 | 2805.5 | 2805.5 | 1851.7 | 8.113 |
| $SO_2$ | 1210 | 1702.5 | 492.5 | 1493.1 | 7.738 |
| $NH_3$ | 991.25 | 2950.25 | 1959 | 1704.15 | 7.625 |
| $CH_4$ | 2875 | 11750 | 8875 | 7323.2 | 12.259 |
| $O_3$ | 0 | 18.375 | 18.375 | 12.375 | 3.317 |
| VOC | 0.48 | 6.403 | 5.923 | 2.68 | 1.096 |
| | | **Location Bordering Aluu And Igwuruta** | | | |
| CO | 0 | 1150.25 | 1150.25 | 460.05 | 6.581 |
| SPM | 28.25 | 172.75 | 144.5 | 95.7 | 3.588 |
| $NO_2$ | 0 | 2505.25 | 2505.25 | 1300.75 | 4.681 |
| $SO_2$ | 768.35 | 1517.75 | 749.4 | 1191.72 | 13.127 |
| $NH_3$ | 0 | 748.5 | 748.5 | 554.05 | 9.241 |
| $CH_4$ | 7111.25 | 20472.5 | 13361.3 | 15078.8 | 10.74 |
| $O_3$ | 0 | 25.395 | 25.395 | 17.464 | 1.696 |
| *VOC* | *2.465* | *8.333* | *5.868* | *4.659* | *1.056* |

***SE:*** *Standard Error*

Therefore, a list of possible health effects corresponding to elevated levels of $NO_2$, $SO_2$, $CH_4$ and $NH_3$ are drawn for both communities below views of existing literature health effects which are identifiable with SPM are also included for Igwuruta in this study.

Considering the criteria pollutants mentioned above in levels as recorded, the residents exposed to such fouled air quality could be predisposed to the following health conditions if left unchecked: Eye irritation, hypertension, cough, fever, Asthmas, Headache; dizziness, skin irritations, breathing difficulties, body weakness chest pain, catarrh, stooling and dysentery (WHO, 2013; Lofus *et al*., 2015; Gobo *et al*., 2009).

*Conclusion:* This study was designed to investigate the extent of gas flaring effects on the air quality of Aluu and Igwuruta communities respectively. The results obtained indicated that the ambient air quality of Igwuruta and Aluu communities have been compromised by the presence of gas flaring facilities in both communities. Results obtained postulates that the study area is susceptible to acidic precipitation due to elevated levels of sulphur dioxide and nitrogen dioxide. Igwuruta and Aluu communities can notably contribute to the environmental issue of global warming with spiked methane levels recorded in this study. Furthermore this paper has provided an evidence into the cumulative aspect of adjacent point sources of pollution.

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