

Air Quality Assessment around a Horizontal Gas Flaring Site in Izombe, Southeastern Nigeria

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Abstract

The extent to which air quality varies around gas flaring sites in Nigeria has not received the deserved attention, especially as some of the sites are located close to residential areas, farmlands and rivers/streams. This study assessed air quality around a typical horizontal gas flaring site in Izombe, Southeastern Nigeria. Air quality readings were collected from the study area at 100 m, 200 m, 300 m and 4 km (as control point (K)) away from flare site. The air quality data were analyzed using T-test and mean concentrations of air components were compared with World Health Organization (WHO) and Federal Environmental Protection Agency (FEPA) standards. Results obtained from the t-test analysis showed that there was a significant difference between air quality around the flaring site, and air quality at the control point with mean concentrations of 3.10 ppm and 0.57 ppm respectively at 0.05 significance level. Also, the mean concentrations of air components, 2.94, 0.99, 1.92, 0.85, 1.60, and 6.52 ppm for Carbon monoxide (CO), Hydrogen sulphide (H₂S), Sulphur dioxide (SO₂), Nitrogen dioxide (NO₂), Volatile Organic Compounds (VOCs), and Suspended particulate matter (SPM) respectively were all above the WHO and FEPA standards, except for H₂S (1.10 ppm) in FEPA standard. Based on these results, it is concluded here that horizontal gas flaring in Izombe community has lowered the air quality around the flaring site. This portends great danger to residents, homes, farmlands and rivers/streams around it. Therefore, it is recommended that the Federal Government of Nigeria should, among other measures, set-up and empower industrial air quality monitoring agency to check-mate the incidence of gas flaring.

Keywords: Air quality, Gas flaring, Horizontal gas flaring, Air components, Ambient air

Introduction

Gas flaring occurs when associated natural gas, which is a by-product of petroleum production, is burned on reaching the surface (Buzcu-Guven *et al.*, 2012; Kearns *et al.*, 2000). In other words, it is the burning of natural gas that is associated with crude oil when it is pumped up from the ground (Benoit, 2009). It involves the controlled burning of the gas, as a common practice in oil/gas exploration, production and processing operations (EPA, 2014), especially in Nigeria (Oni & Oyewo, 2011). Therefore, gas flaring is the wasteful burning of natural gas during crude oil processing by the oil industry (Banerjee, 1995; Atuma & Ojeh, 2013; Abdulkadir *et al.*, 2013). This gas is burnt off either through ground (horizontal) flare (Plate 1) or vertical (elevated) (Plate 2) (Nnimmo, 2008).

In elevated system, combustion reactions are carried out at the top of a pipe or stack where the burner and igniter are located. This is the most commonly used types of flare stack in refineries and chemical plants (Nnimmo, 2008). It requires less ground area, because of its high elevation it can be located within a process area or on the periphery of plant role site, since radiation effect and ground level concentration of the pollutant can be maintained within allowable limit. The ground flare is similarly equipped as the elevated flare, except that the combustion takes place at or near ground level. The distance between the point of discharge from safety values and the flare stack in the vertical flare is less than in the case of ground flare. These gas flare stacks are often times situated close to residential areas and crop farms in villages, as it is a common sight in the oil producing areas of the Niger Delta Region of Nigeria.

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Plate 1: A Horizontal Flaring

Source: Friends of the Earth (2004)



Plate 2: A Vertical Flaring

Source: Friends of the Earth (2004)

Nigeria has been described as a “Gas Province” because among the oil producing countries, the country is listed as the tenth largest proven natural gas reserves in the world (Nnimmo, 2008). Nigeria accounted for 5.48% of global gas flare from 30 major oil producing nations and ranked the sixth major gas flaring nations in 2017 (that is, 7.7 Billion Cubic Metres out of the global total of 140.6 Billion Cubic Metres) (NOAA, GGFR, 2018). The products of the combustion of associated gas include Carbon dioxide, Carbon-monoxide, Methane, Ethane, Propane, Butane, Hydrogen, Helium, Argon, Volatile Aromatic Hydro-carbons, Nitrogen monoxide, Sulphur monoxide, Halogens, Chloro-Fluoro-Carbons (CFCs), particulate matter, photochemical oxidants, hydrocarbons, ash, hydrogen sulphide as well as sound (noise) and heat (Gabriel, 2004; Uduak, 2008). Flares have been found to contain more than 250 toxins including mercury, benzene and arsenic (World Bank, 1995; 2004 and 2008).

These flared gases, depending on their amounts in the atmosphere (in particular the ambient air), have various effects. Some of them can cause damage to the nerves in the brain and cancer (Egbuna, 1987; Yakubu, 2008). Flared gases trapped in the upper atmosphere may cause among others re-radiation to take place within the immediate environment of the flare site, thereby increasing the mean daily temperature beyond tolerance range (Nwakire, 2014). The greenhouse gases emitted through the flaring are known to be principal contributors to air pollution and acid rain (FOE, 2004; Medilinkz, 2010 and Orimoogunje *et al.*, 2010). Soot emitted during gas flaring has dark and tiny physical characteristics. Its dark characteristic makes it a good absorber of terrestrial radiation that is escaping from the earth’s surface to the atmosphere. In absorbing this radiation, the soot becomes a radiator thus heating up the atmosphere, and by extension increasing the temperature around flaring sites. Sometimes, this soot and the gases it contains are deposited on the roofs of homes of flare site host communities and are washed down to earth by rain. Such washed down gases could poison water bodies, soils, crops, and corrode surfaces, such as corrugated roofs (Hassan and Konhy, 2013).

Soils and sediments are the ultimate sink for most petroleum contaminants, such as benzene, toluene, ethyl benzene, and xylenes (BTEX), aliphatic and polycyclic aromatic hydrocarbons (PAHs) (Ite and Semple, 2012), thus impacting adversely on soil fertility and biogeochemical nutrient cycles (Akpojiri, 2005; Nwaugo, Onyeagba & Nwachukwu, 2006).

Basically, these adverse impacts of gas flaring on the environment, especially air quality, vary with geography and geology. For example, different geographies present different climates, topographies, vegetations, soils etc. Also, different geologies or geological formations will present natural gases with different contents. Furthermore, vertical gas flaring is more common than horizontal gas flaring which is attributable to vertical type having less ground area when compared with the horizontal type (Nnimmo, 2008). The implication of this is that a horizontal gas flaring site would likely impact the environment more than a vertical gas flaring site as ground level concentration of air component gases from vertical flaring can be maintained within allowable limit. Therefore, this paper assessed the air quality (an aspect of the environment) around a typical horizontal gas flaring site in Izombe, Southeastern Nigeria.

Materials and Methods

Izombe is a community located at the intercept of latitude $5^{\circ}38'35''$ North and longitude $6^{\circ}52'16''$ East in Oguta Local Government Area of Imo State, Nigeria. It is bounded to the north by Ossu Obodo, Egwe and Oguta, to the east by Awomama, to the south by Amafor and to the west by Ohaji/Egbema Local Government Area (<http://www.maplandia.com/nigeria/imo/oru/izombe>).

The study area falls under the tropical rainforest zone with an annual rainfall of about 2,800mm. The climate is extremely influenced by its closeness to the Atlantic Ocean which creates a relative humidity of 85% in the rainy season and decreases to 45% in the dry season with ambient temperature ranging from 24.5°C to 35°C in the wet season and 25.5°C to 37°C in dry season (NIMET, 2016; Imo State Ministry of Aviation, 2016.).

The people of Izombe community are predominantly farmers, and hunters, though these activities have been hindered in the area due to activities of oil companies. The area hosts many oil companies such as Agip, Addax, Chevron and NNPC (Ubuoh *et al.*, 2010).

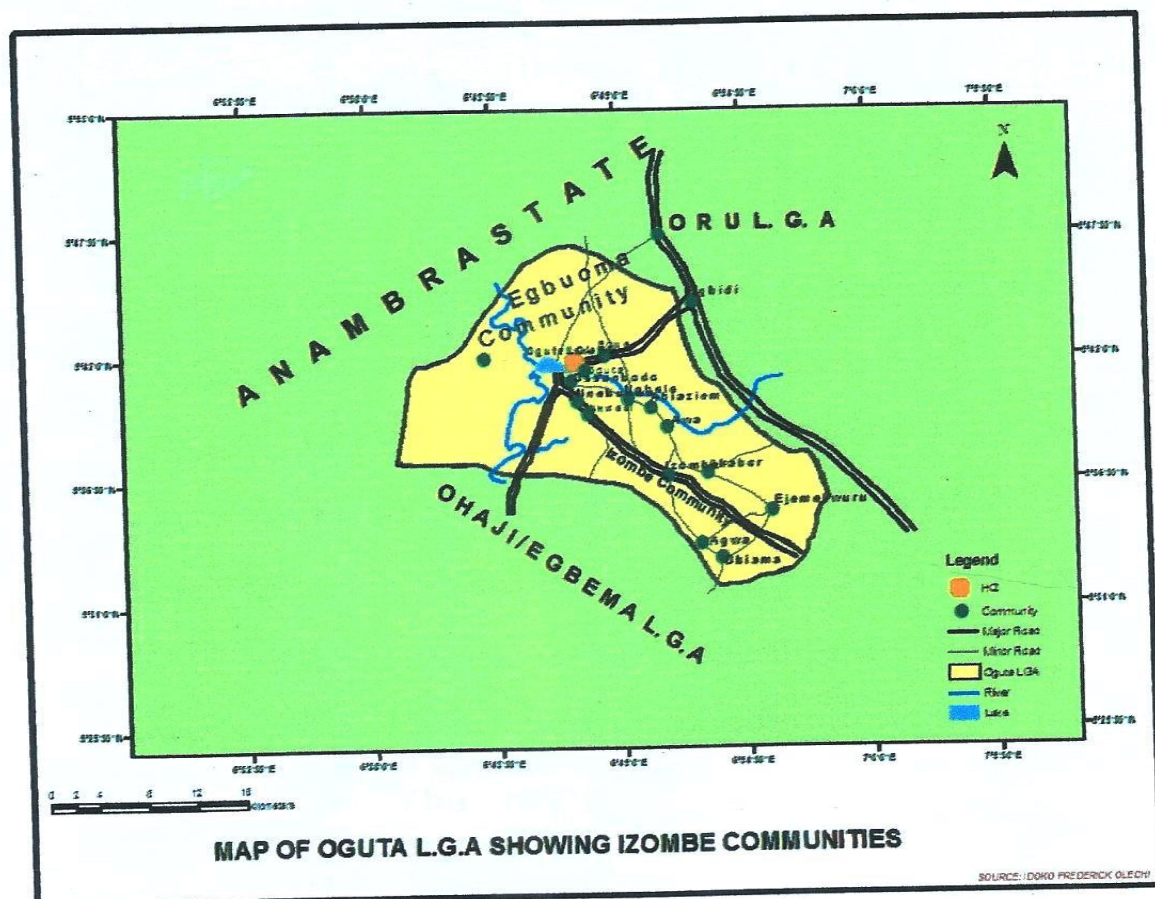


Figure 1: Map of Study Area: Izombe

Izombe gas flaring site is located at latitude 05°37'073" North and longitude 06°48'075" East. The gases sampled are namely Carbon monoxide (CO), Hydrogen sulphide (H₂S), Sulphur dioxide (SO₂), Nitrogen dioxide (NO₂), Volatile Organic Compounds (VOCs), and particulate matter and is Suspended particulate matter. The concentration levels of these air components were measured and recorded from three (3) equidistant points, at intervals of 100, 200 and 300 m away from the gas flaring point, and a control point (k) 4 km outside the flaring point.

Multiple Gas Monitor was used to determine the concentration level of gaseous samples, and Suspended Particulate Matter (SPM) meter was used to determine the concentration level of suspended particulate matters in the atmosphere. The instruments were exposed to the atmosphere at a height of 2 m above the ground in the direction of the prevailing wind; and the readings were taken and recorded at stability. Three readings were taken at each sampling point at a time interval of 4 – 10 minutes, as soon as the readings on the Liquid Crystal Display (LCD) screen normalize. Readings of the samples were recorded and instruments were switched off. At each point, three samples were taken and the mean-values were determined to eliminate bias. The readings were compared with FEPA (Federal Environmental Protection Agency) and WHO (World Health Organization) standards for air quality. T-test statistic was used to establish the difference between air quality around the flaring site and that outwards at 0.05 significance level.

Results

In Table 1, the concentration level of CO gas varied with distance away from the gas flaring point. At 100m, the concentration level CO was highest (5.29 ppm) whereas at K (control point) it was lowest, that is 0.63 ppm.

Table 1: Result for Ambient Air Concentration of Carbon Monoxide (CO)

Distance (m)	Reading (ppm)
100	5.29
200	3.17
300	2.68
K	0.63

The values for the concentration level of Hydrogen Sulphide (H₂S) decreased with increasing distance away from the gas flare point as seen in Table 2. The 100 m distance has the highest value of 2.32 ppm while the control point is the least in value (0.01 ppm) (Table 2).

Table 2: Result for Ambient Air Concentration of Hydrogen Sulphide (H₂S)

Distance (m)	Reading (ppm)
100	2.32
200	1.21
300	0.43
K	0.01

Similarly, the concentration level of SO₂ gas decreased with increase in distance away from the gas flaring point (Table 3). The control point recorded the least value of 0.59 ppm which is slightly above FEPA and WHO standard, that is 0.10 ppm and 0.35 ppm respectively (see Table 7).

Table 3: Result for Ambient Air Concentration of Sulphur Dioxide (SO₂)

Distance (m)	Reading (ppm)
100	3.49
200	2.33
300	1.27
K	0.59

In Table 4, the values for the concentration level of NO₂ gas decreased with increasing distance away from the gas flare point. The highest value of NO₂ gas concentration of 1.39 ppm was recorded at 100 m distance while the control point had the least value of is 0.03 ppm (Table 4). The control point value is far below the FEPA (0.06 ppm) and WHO (0.10 ppm) standards for air quality.

Table 4: Result for Ambient Air Concentration of Nitrogen Dioxide (NO₂)

Distance (m)	Reading (ppm)
100	1.39
200	1.04
300	0.92
K	0.03

Equally, the values for the concentration level of VOCs decreased as distance increased away from the gas flaring point (Table 5). At the control point, the concentration level of VOCs was 0.00 ppm, which indicates that there was absent of VOCs at that point.

Table 5: Result for Ambient Air Concentration of Volatile Organic Compounds (VOCs)

Distance (m)	Reading (ppm)
100	3.00
200	2.19
300	1.22
K	0.00

As in the other components of the air around the gas flaring site, the value for the concentration level of SPM (see Table 6) decreased with increase in distance away from the gas flaring point. At the control point the concentration was lowest at 2.17ppm.

Table 6: Result for Ambient Air Concentration of Suspended Particulate Matter (SPM)

Distance (m)	Reading (ppm)
100	10.71
200	8.51
300	4.69
K	2.17

This result is in agreement with Leachey *et al.* (2008). They found out that Suspended Particulate Matter (SPM) was highest at the gas flaring point, and decreased away from the flare point.

Table 7 shows the comparison between the mean concentration of the air components in the study area in relation to FEPA and WHO standards for air quality. It also presents at a glance the differences that exist in the concentration values of the various air components in the study area.

Table 7: Result of the Mean Concentration of the Air Components Gases in ppm in relation to FEPA and WHO standards for Air Quality

Distance (m)	CO (ppm)	H ₂ S (ppm)	SO ₂ (ppm)	NO ₂ (ppm)	VOC _s (ppm)	SPM (ppm)
100	5.29	2.32	3.49	1.39	3.00	10.71
200	3.17	1.21	2.33	1.04	2.19	8.51
300	2.68	0.43	1.27	0.92	1.22	4.69
K	0.63	0.01	0.59	0.03	0.00	2.17
\bar{x}	2.94	0.99	1.92	0.85	1.60	6.52
FEPA	0.50	1.10	0.10	0.06	1.00	0.25
WHO	0.50	0.05	0.35	0.10	1.00	0.25

Furthermore, in Table 7 the mean concentration level of each of the gas measured is conspicuously higher than the stipulated standards by FEPA and WHO.

Table 8 presents a comparison between the mean air components within the flow station and outside the flow station. And there is a significant clear-cut difference in the concentration value of the gas in these areas, which reveal the effect of gas flaring on the concentration of the gases within the flow station.

Table 8: Comparing the Mean Air Components quality within the Flare Station and Control (K) Area outside the Flare Station.

GASES	\bar{X}	K
Co	3.71	0.63
H ₂ S	1.32	0.01
SO ₂	2.36	0.59
NO ₂	1.12	0.03
VOC _s	2.14	0.00
SPM	7.97	2.17

The T-test analysis to determine if there was a significant difference between air quality around the flare site and air quality outwards with a degree of freedom of 22 at 0.05 level of significance is shown in Table 9.

Table 9: Summary of t-test analysis between air quality around the flaring site and air quality outwards

Variables	N	\bar{x}	SD	df	P.value	t.cal	t.cri	Remarks
Air quality around the Flare Site	18	3.10	2.73	22	0.038	2.21	2.074	H ₀ Rejected
Air quality outside	6	0.57	0.84					

P<0.05 at 0.05 level of significance

The result in Table 9 showed that the t-test calculated value of 2.21 is greater than the t critical value of 2.074. Therefore, the null hypothesis thereby failed to be accepted implying that there was a significant difference between air quality around the flare site, and air quality outwards.

Discussion

The results obtained from the study as shown in Tables 1-9, indicate that the concentration level of all the air component gases sampled far exceeded the legal stipulated FEPA and WHO air quality standards. Table 1 shows that gas flaring contributes to the amount of carbon in the atmospheres. This is in line with the studies of Marland *et al.* (2003) and Caseiro *et al.* (2019). They stated that anthropogenic carbon emissions result from among others gas flaring. At a distance of 100m away from the gas flare point, 5.29ppm of carbon monoxide was emitted, this concentration level decreased as distance increased away from the gas flare point. At distance of 200m (3.17ppm) of CO was recorded, and at distance of 300m (2.68ppm). The variation between the sample collected at distance 300m away from the gas flaring point and the control was significant. Similar trends were also observed in the concentration level of hydrogen sulphide emitted at a distance of 100m was highest followed by 200m and the 300m (2.32, 1.21 and 0.43 ppm respectively (see Table 2)). The difference in ppm between the sample collected at a distance of 300m from the gas flaring point and the one at the control was large, that is 0.43 ppm and 0.01 ppm respectively, as shown in Table 2.

The highest concentration of SO₂ (sulphur Dioxide) was observed at a distance of 100m away from the gas flare point. It then gradually decreased away from the gas flare point. The variation between the samples collected at a distance of 300m away from the gas flare point and the control was significant (i.e. 1.27 ppm and 0.59 ppm respectively). In Table 4, the highest concentration of Nitrogen Dioxide was sampled at a distance of 100m away from the gas flare point, followed by 200m and the 300m as shown in Table 4. Similarly, there was much variation between the samples collected at 300m away from the gas flare point and the control point (0.92 ppm at 300 m and 0.03 ppm at the control). In Table 5, gas flaring contributes to the amount of volatile Organic Compounds (VOCs) in the atmosphere, as the concentration values obtained from a distance of 100m away from the gas flare point was the highest at 3.00ppm. At a distance of 200m, a concentration of 2.19 ppm of VOCs was detected. The value was reduced to 1.22ppm at a distance of 300m away from the gas flare point. And at the control the concentration was 0.00 ppm. Table 6 shows that Suspended Particulate Matter (SPM) in Izombe flow station is above the FEPA and WHO standards for air quality. At a distance of 100m from the gas flare point, the value of 10.71 ppm of SPM was emitted as against 0.25 ppm of FEPA and WHO stipulated standard for SPM.

Conclusion

Gas flaring in Izombe, Imo State, Nigeria has direct effect on the gaseous components of the host environment. This is revealed in the analysis of the air quality samples collected around the gas flare site. The results obtained from the work showed a distinct trend in the concentration of all the air quality components considered from the gas flare station outward. They all decreased away from the station beginning from 100m away to 4km. Also, the components of air quality within the flare site are above FEPA/WHO standard for air quality. Therefore, gas flaring in Izombe is not only a threat to the health of human beings, animals and plants, but also to non-living things such as metal roofing sheets and painted walls of buildings.

Recommendations

In view of the gas flaring situation in Izombe, with respect to air quality, it is therefore recommended that:

- 1) Government should catalyze and implement the Nigerian Gas Flare Commercialization Programme (NGFCP) contained in the newly gazetted flare Gas Prevention of waste and pollution Regulation 2018, which introduces new payment regimes or penalties for gas flaring;
- 2) Government should set-up and empowers industrial air quality monitoring agency to check-mate the incidence of gas flaring;
- 3) Government should pass and enforce laws that will strictly put an end to gas flaring, where fines failed.
- 4) More gas turbines electricity generation should be built;

- 5) Residential areas should be situated at a minimum of 4km away from the flare station.
- 6) Oil companies should develop better and take more seriously re-injection strategies of the associated gas.

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