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The impact of gas flaring and venting in Nigeria and management options: a case study of oil producing areas

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Abstract

This study assesses gas flaring and venting impacts in some oil producing areas in the Niger-Delta of Nigeria. The research instrument adopted for this study was the questionnaire survey and laboratory analysis, both microbiological and physico-chemical. The analysis of the data was done using simple descriptive analysis of frequency distribution of the relevant statistical information, supplemented by Chi-Square (X2) statistical method. Soil samples obtained from selected flare sites were analyzed and they indicated a negative impact on the microbial content of the soil. Rain water samples collected from different locations at different times and analyzed revealed a significant level of acidity (4.5-6.9) which causes damage to property and affect crops yield. Nitrates produced by the gas flare which varied from 0.12 to 0.47 mg/L result in the production of dilute nitric acid which is also corrosive. A survey carried out in this study revealed that the majority of Nigerians believe that gas flaring and venting has negatively impacted human health and the environment mainly in the oil producing areas.

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Introduction

Nigeria is the sixth largest producer of crude oil in the world and has over 250 oil fields with more than 120 fields currently producing. The associated gas produced due to the extraction of crude oil is either flared or vented into the atmosphere and this stems from the notion that it is uneconomical to recover the gas. This practice over the years has caused more harm to human health and the environment, particularly those in the oil producing areas (Bassey, 2008). Gas flaring and venting are controlled burning and discharge of gas associated with oil production. These anthropogenic activities which are wasteful emission of crude oil associated gases, are also serious contributors to environmental hazards such as acid rain, the impacts of which are being felt in the Niger Delta region in terms of vegetation damage, corrosion and caving-in of roofing sheets and increase in death of aquatic lives (Osuntokun, 2002).

The environmental problems caused by flaring and venting of natural gas are mainly global, and to a larger extent also regional and local. Global environmental impact is due to the burning of associated or solution gas, which produces carbon dioxide and methane. These emissions increase the concentration of greenhouse gases in the atmosphere, which in turn contribute to global warming (Agho and Etiosa, 2007). These activities are also a major source of carcinogenic benzene, lung irritants such as NO_x, SO_x, H_2S (Tawari and Abowei, 2012). Flaring may furthermore contribute to regional and local environmental problems. Other environmental problems worthy of note is noise pollution, high temperature and reduction in visibility caused by soot from the smoky flares. It has been reported from surveys around local communities in the Niger-Delta region of Nigeria that the unpleasant odour, roaring noise and intense heat emanating from the gas flaring and venting are dehumanizing as many of the local community indigenes now suffer from skin diseases, cancer, hearing problems, respiratory difficult and reddening of the eyes (Efe, 2003, Nkwocha and Pat-Mbano, 2010). A study in Bayelsa State, Nigeria in 2005 found that gas flaring caused 49 pre-mature deaths, 120,000 asthma attacks and 8 additional cases of cancer (ERA and CPJ, 2005).

On the other hand, flaring of gas in Nigeria is a problem with two key dimensions; environmental and resource management. Gas flaring is a waste of a resource with potentially high economic value. As such, it represents a resource management problem. The environmental and resource management problems are inextricably coupled. Ameliorating one of the problems may thus facilitate the reduction of the other, whilst also bringing ancillary economic and social benefits. For example, reducing flaring is an important measure to curb emissions of greenhouse gases, whereas recovering and distributing the associated gas currently being flared may contribute to solving domestic and regional energy requirement problems. Enhancing local and regional utilization of the gas may furthermore improve resource management, provide access to modern and clean energy, and also halt desertification and deforestation by substituting gas for traditional fuel woods and other bio-fuels. The impact of gas flaring on the environment and health of the host communities in Niger Delta of Nigeria is of great concern. Despite all efforts, studies on the impact of gas flaring on built environment are limited thereby increasing concerns about long-term effects due to residential proximity to gas flaring points. In view of identified gaps, this research study seeks to assess and document the awareness and responses of residents of the Niger Delta region where gas flaring and venting activities of oil exploration and production have been ongoing without abatement measures. Also, provide data on the contamination status of the built environment by the physicochemical analyses of environmental samples to evaluate the potential environmental impacts and effects of gas flaring and venting, using the Ebocha-Egbema community in the Niger-Delta region of Nigeria as a case study.

Materials and methods

Study Areas

The Niger Delta, as now defined officially by the Nigerian government, extends over about 70,000 km² and makes up 7.5% of Nigeria's land mass. Oil companies which operate there include Shell Petroleum (SPDC), TOTAL and Nigeria Agip Oil Company (NAOC) etc. Ebocha-Egbema in Ogba/Egbema/Ndoni local government area of Rivers state, Nigeria, with geographical coordinate; 5°20'30"N and 6°39'20"E is a community of small villages. Many parts of this region where crude oil is pumped are maze of winding mangroves, swamps, creeks and waterways. Leafy, green and humid, Ebocha-Egbema is an unremarkable collection of small villages with tin-roof houses and shops, located in the heart of the Rivers State in Nigeria. Huge flames billow in the air over Ebocha, and above them, black clouds leap into the sky, with a strange smell and an audible hiss in the air. Satellite image of the Niger Delta with halos of light is shown in Fig.1. The geographical map of Ebocha-Egbema community is shown in Fig. 2.

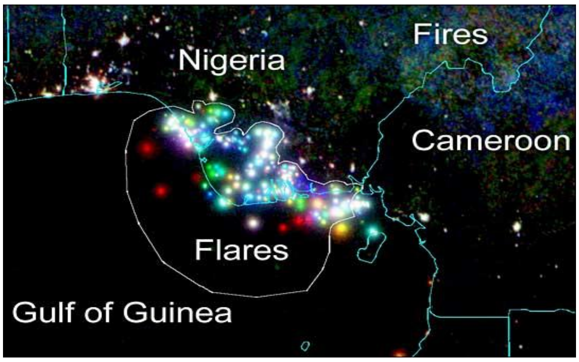

Fig. 1. Satellite Map Image showing Balls of light in the Niger-Delta region of Nigeria; Source: NOAA.

Fig. 2. Map showing Study Areas - Ebocha¬, Ogba/Egbema?Ndoni.

Sampling

Sample size

A total of 152 respondents were given questionnaires and the data were collected. Samples of rainwater were collected from different villages within the district of Egbema-Ebocha. Soil samples from the flare sites, varying the distance of the collection points.

Questionnaire

The questionnaire was drafted into structures, namely respondent's bio-data and gas flaring/venting related questions. The sample comprised people of different status, educational background in the public and corporate organizations. The sampling procedure was the simple random technique, which involved the selection of sample size that was a representative of the target population.

Rain water analysis

Sample collection

Rain water samples were collected from ten (10) different locations by plastic basins located at least one metre above ground level in the different locations. The collection of rain water was on an event basis. Samples collected were transferred into 2 litre plastic containers and 200 cm³ reagent bottles properly cleansed with distilled/deionized water prior to usage. Collection was carried out by careful immersion of the sample containers deep inside the water and sealing with tight fitting corks and stoppers after collection, in order to avoid air bubbles. Samples were transferred to a refrigerator (4°C) prior to analysis.

Electrical conductivity (EC), pH, Total Dissolved Solids (TDS) and Nitrates were determined following the procedures of the Standard methods of APHA-AWWA-WPCA for the examination of water and waste water (APHA, 1998).

The pH was measured with a corning glass electrode pH meter Model 7. Conductivity and TDS were measured with a Lovibond S/ppm/TDS metre type

CM-21. Nitrate-nitrogen was measured by the Brucine method (Ademoroti, 1996b).

Soil analysis

Sample collection

Soil samples were collected from four different gas flaring sites; Oshie flow station (owned by NAOC Ltd), Egbema West flow station (SPDC), Ebocha flow station (NAOC) and Obagi flow station (Elf Nigeria Ltd). All the stations lie within the Niger-Delta area of Nigeria. Soil samples were collected from three spots of each station. These were 10, 100 and 200 metres away from each flare site and control taken much outside the flow stations areas.

Physico-chemical analysis

pH

The pH of the various soil samples was determined using a PYE UNICAM model 291 MKZ pH meter (with a combined glass electrode) from the supernatant obtained after (1:1 w/v) mixture of the soil samples was made with sterile distilled/deionized water.

Temperature

The temperature of the soil samples were taken at the site of collection with a mercury-in-glass thermometer. The probe of the thermometer was dipped into the samples and the reading taken after 2 minutes.

Moisture

For moisture determination, 10g of each sample was placed in a hot air oven for 8-12 hours at 80°C till a constant weight was obtained.

Microbiological analysis

Ten folds serial dilution with sterile physiological saline as diluent was carried out with each soil sample collected and inoculated on nutrient agar (NA) for total heterotrophic bacterial count(THBC), and McConkey agar (MCA) for total coliforms count (TCC) using the spread plate technique (Chessbrough, 1987). Mineral salt agar (MSA) was used for the determination of the petroleum degrading bacterial count (PDBC) using vapour-phase transfer technique as described by Okpokwasili and Amanchukwu (1987). Microbial species observed were sub-cultured to obtain pure isolates. These were further subjected to macroscopy, microscopy (after stirring) and biochemical tests for characterization and identification according to Cowan and Steel (1965).

Results and discussion

The data generated from the questionnaires that were properly answered and recovered are presented in Table 1. The results show the detailed and comprehensive features of the respondents' bio and socio-demographic data with their respective frequencies and percentages.

Analysis of the respondents' responses to the gas flaring/venting related questions was done and hypothesis formulated based on their responses. The validity of the hypotheses was tested against the results obtained from the respondents in the sample population.

H_0: Represents Null hypothesis

H_1: Represents Alternative hypothesis

Chi-square test was used to test the hypothesis. It is a test of the goodness of fit and also a measure of discrepancies existing between observation and the expected frequencies.

Hypothesis I

The data used was derived from the research hypothesis formulated based on the scope of study.

H_0: Gas flaring and venting has its health and environmental impacts

H_1: Gas flaring and venting does not have its health and environmental impacts

Test of hypothesis result using the Chi-square (X^2) shows that

X^2 calculated = 0.18 and X^2 tabulated = 3.84. Since $X^2_{cal} < X^2_{Tab}$.

Table 1. Bio-data of Respondents.

	Sex		Marital Status			Age Distribution				
	Male	Female	Single	Married	Separated	16-25	26-35	36-45	46-55	≥56
FREQUENCY	102	50	100	32	20	25	45	40	30	12
PERCENTAGE (%)	67.11	32.89	65.79	21.05	13.16	16.45	29.61	26.32	19.74	7.89
	Educational Qualification					Occupation				
	FSLC	SCH. CERT	NCE, ND	B.Sc	M.Sc/MA	CS	SE	PR	U.E	
FREQUENCY	20	60	46	24	2	42	60	10	40	
PERCENTAGE (%)	13.16	39.5	30.26	15.79	1.32	27.63	39.5	6.58	26.32	

C.S- Civil Servant. S.E- Self Employed. FSLC- First School Leaving Certificate. U.E- Unemployed. PR- private.

Hence, its means the hypothesis (H_o) is accepted while the alternative hypothesis (H_1) is rejected. This agrees with the fact that flaring and venting has its health and environmental impacts.

Residents of the Niger Delta region, where Ebocha is located, say gas flaring is ruining lives and livelihoods. While many villagers may not be familiar with the concept of climate change, they complain that the air around them is hotter and foul-smelling because of the gas flares.

Hypothesis II

H_o: The improper management of the oil and gas sector has led to gas flaring and venting resulting in emission of dangerous gases.

H_1: The improper management of the oil and gas sector has not led to gas flaring and venting resulting in emission of dangerous gases.

Test of hypothesis II result using the Chi-square (X^2) shows that X^2 calculated = 0.08 and X^2 tabulated = 3.84. Since $X^2_{cal} < X^2_{Tab}$.

Hence, its means the hypothesis (H_o) is accepted while the alternative hypothesis (H_1) is rejected. Thus, the improper management of the oil and gas sector has led to gas flaring and venting, resulting in emission of dangerous gases.

The results of rain water samples analyzed from the various locations are presented in Table 2. The results show that most of the rain water samples were slightly acidic, with a pH range of 5.5-6.9 except for samples from Okansu which was found to be slightly above pH of 7.

There was no definite trend in the acidity and nitrate contents of the rainwater samples, which varied from 0.12-0.47 mg/L (Table 2). The variation of nitrate content and hence the acidity during each sample period, must have been affected by wind speed and direction, the general nature of which had been described (Botkin and Keller, 1998). However, the nitrate concentrations in the waters were apparently highest for samples collected on the first day of sampling. When the rainfall frequency and intensity had increased, the results showed ample evidence of NO_X gases generation from the flaring, and a consequent production of dilute nitric acid which is corrosive and greatly affects crop yields. The acid also accelerates the rusting of corrugated iron roofing sheets, and other environmental pollution related problems.

Location	Rain water (Day 1)				Rain water (Day 2)				Rain water (Day 3)			
	pH	Cond. (S/cm)	TDS (mg/L)	Nitrate (mg/L)	pH	Cond. (S/cm)	TDS (mg/L)	Nitrate (mg/L)	pH	Cond. (S/cm)	TDS (mg/L)	Nitrate (mg/L)
Omoku	6.9	30.0	21.0	0.39	6.4	9.0	6.0	0.43	5.9	19.0	13.0	0.14
Kreigani	6.3	20.0	13.0	0.33	6.5	52.0	20	0.34	6.1	33	15.0	0.19
Ede	6.9	41.0	29.0	0.40	6.6	40.0	28.0	0.27	6.6	38.0	27.0	0.17
Okwuzi	4.5	50.0	29.0	0.45	6.6	25.0	18.0	0.46	6.2	18	9.0	0.18
Okansu	6.0	29.0	20.0	0.32	7.1	56.0	39.0	0.39	5.5	22.0	16.0	0.20
Obrikom	6.2	23.0	16.0	0.34	6.7	67.0	47.0	0.40	6.3	20.0	14.0	0.12
Ebocha	5.8	45.0	32.0	0.40	6.2	87	42.1	0.33	5.9	19.0	14.0	0.25
Mgbede	6.8	370.0	260.0	0.47	6.8	170.0	120.0	0.29	6.4	23.1	12.2	0.14
Idu	6.8	49.0	34.0	0.35	6.4	31.0	22.0	0.15	6.8	30.0	21.0	0.15
Okposi	6.7	61.0	43.0	0.31	6.8	30.0	21.0	0.13	6.3	12.0	8.0	0.17

Table 2. Results of Rain Water Analysis.

From the results presented, it can be seen that the acidity and nitrate contents of the rainwater is a function of the frequency and intensity of the rainfall as well as the direction of the prevailing wind prior to the rainfall. Nitrate concentration in the precipitate is higher if the interval between one rainfall and the other is longer as observed by Overrein *et al.,* (2005).

The results presented in Tables 3-6 show the effects of gas flaring on soil physical parameters and bacterial spectrum in examined parts of the Niger-Delta of Southern Nigeria, using the culture techniques and some ecological factors. The gas flaring had adverse effects on all groups of bacteria examined.

Table 3. Results of soil physical parameters.

Distance from flare site	Obagi			Ebocha			Egbema			Oshie		
	pH	Temp. (°C)	Moisture (%)	pH	Temp. (°C)	Moisture (%)	pH	Temp. (°C)	Moisture (%)	pH	Temp. (°C)	Moisture (%)
10	4.2	60	18	4.0	55	15	4.2	50	18	4.3	52	15
100	5.0	46	26	5.1	41	21	5.2	41	25	5.0	40	20
200	6.1	33	35	6.3	32	35	6.3	31	34	6.3	31	31
Control	6.6	30	45	6.7	29	41	6.6	30	40	6.7	29	35

The results of the physico-chemical analysis of the soil samples are presented in Table 3. Temperature decreased away from the flare points (60-28 °C) (Fig. 5), pH values changed from acidic (4.0-4.2) to near neutral (6.4-6.6) away from the flared points (Fig. 4). Moisture content also increased away from the flare sites (Fig. 6).

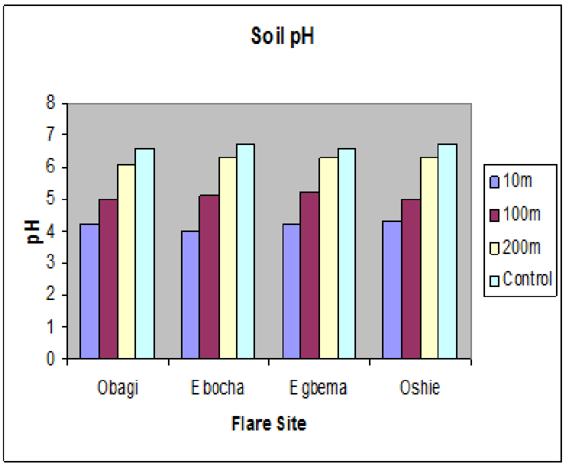

Fig. 4. Chart showing soil pH.

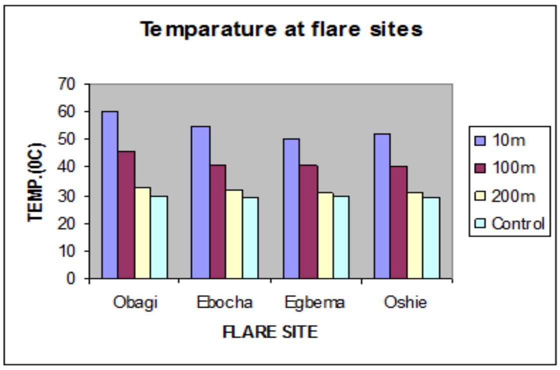

Fig. 5. Chart showing temperature at flare sites.

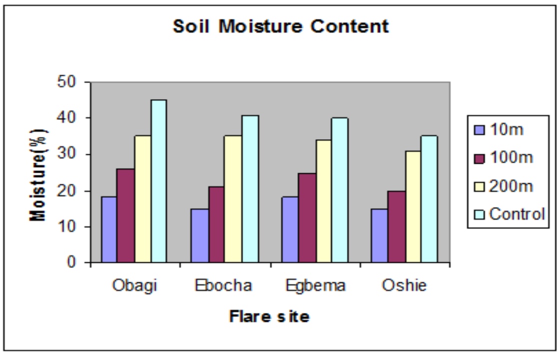

Fig. 6. Chart showing soil moisture.

In all flow stations examined, the most acidic were the samples collected at 10m away from the flare jets, followed by that collected at 100m distance. There was no much difference between the 200m samples and the control in each case (Table 3). A similar trend was also observed with the temperature and moisture contents. As expected, the hottest spot was the nearest to the flare jets and it gradually decreased away from the flare points. All the soil samples examined had the least moisture contents in each soil at 10 metres (10-12 %), followed by 100 metres (15-19%). The 200m soil samples had 23-28% and the control had 29-30 % moisture content.

The low pH values at the flare points could be attributed to the acidic oxides produced by the flaring. Atmospheric nitrogen and carbon are forced to combine with elemental oxygen forming acidic oxides which dissolve in rain water to give dilute carbonic acid and nitrous/nitric acids (Overrein *et al.,* 2005). Similarly, the heat produced from the flaring point was highest as expected. The low moisture content close to the flaring points may be attributed to the direct effect of the heat.

The results of the microbiological analysis of the soil samples collected are shown in Tables 4-6. Bacterial load of total Heterotrophic bacterial count (TBHC), petroleum degrading bacterial count (PDBC) and total coliforms count (TCC) were observed to increase away from the flare points.

Bacterial species were affected as only three, Pseudomonas and Bacillus species were found 10m away from the flare points. The number increased to seven with the addition of E-coli, Enterbacter, Flavobacterium and Micrococcus species at 100m away and finally at 200m with Citrobacter, Staphylococcus and Lactobacillus species. This trend was observed in the various types of bacteria cultured. The bioload from 10m samples were the least, followed by the 100m and the 200m sample points. The difference between the 200m and the control was not significant (Table 4).

Table 4. Total Heterotrophic Bacteria.

Distance (m)	Bacteria Counts (cfu/g)			
	Obagi	Ebocha	Egbema West	Oshie
10	0.11 x 10^3	1.2 x 10^2	1.4 x 10^2	1.2 x 10^2
100	5.1 x 10^3	6.0 x 10^3	5.3 x 10^3	1.7 x 10^3
200	5.1 x 10^3	4.3 x 10^5	2.2 x 10^5	2.2 x 10^4
Control	3.30 x 10^3	4.8 x 10^5	2.6 x 10^5	3.0 x 10^5

The most affected by the gas flaring was the coliforms. Total coliforms counts were consistently low for the 10 m (0.1 x 10^2 – 0.4 x 10^2 cfu/g) and 100m (1.6 x 10^3 – 2.1 x 10^3 cfu/g) samples, However, there was a sharp increase at 200 m samples (3.3 x 10^4 – 1.1 x 10^5 cfu/g) which was not much different from the values obtained in the controls (3.9 x 104 – 2.3 x 105 cfu/g) (Table 5).

Table 5. Total Coliform Counts.

Distance (m)	Bacteria Counts (cfu/g)			
	Obagi	Ebocha	Egbema West	Oshie
10	0.04 x 10^3	0.2 x 10^2	0.5 x 10^2	0.4 x 10^2
100	1.6 x 10^3	1.7 x 10^3	2.1 x 10^3	1.8 x 10^3
200	3.6 x 10^3	3.3 x 10^4	1.1 x 10^5	4.9 x 10^4
Control	4.1 x 10^3	3.9 x 10^4	2.1 x 10^5	6.1 x 10^5

Table 6.0 Shows that the gas flaring affected the oil degrading bacterial species isolated and bacillus and pseudomonas were found at 10m in each sample. At a distance of 200m away from the flare point, more bacterial species were isolated. Bacilli are good spore formers hence can survive very harsh environmental conditions like that observed in 10m samples. Similarly, pseudomonas has been implicated as the major crude oil degrader (Gibson and Subramariam, 1997). The micro-organisms isolated have been variously observed in different soil samples (Amund *et al.,* 1987).

Table 6. The Petroleum Degrading Bacterial Counts.

Distance (m)	Bacteria Counts (cfu/g)			
	Obagi	Ebocha	Egbema West	Oshie
10	1.1 x 10^2	1.0 x 10^2	0.8 x 10^2	0.7 x 10^2
100	2.1 x 10^2	2.4 x 10^3	2.0 x 10^3	1.3 x 10^3
200	3.9	4.3 x 10^4	3.4 x 10^4	6.2 x 10^4
Control	4.2	4.6 x 10^4	3.6 x 10^4	6.6 x 10^4

The results obtained in this study show a trend in all parameters considered, a gradient away from the flare points in all the flow stations. The results indicated adverse ecological and bacterial spectrum modification by the gas flaring. This picture indicates that crude oil, though is of high economic value to

Nigeria, has adverse effect accompanying it exploration (Amund *et al.,* 1987).

Conclusion

The results obtained in this study showed some definite trends as all physicochemical and microbiological parameters showed a gradient away from the flare points in all the flow stations. The survey carried out in this study revealed that the majority of respondents believe that gas flaring and venting has negative impacts on human health and the environment and that the improper management of the oil and gas sector has led to the continuous routine gas flaring and venting, resulting in the emission of dangerous gases. The study recommends that government should effectively implement the gas flare-out policy and empower regulators to deal with violators appropriately. Also, the development of clear, operational procedures for gas flaring and venting should be introduced and the authorities saddled with the responsibility of managing the oil and gas industry should finalize all outstanding legal and regulatory framework initiatives for the gas sector.

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