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Research Article

Effect of gas flaring on physio- chemical properties of soil in Okpai, Ndukwa East Local Government area, Delta State, Nigeria

Otunkor Oliver Olisemauchei

Department of Arts and Humanities, School of General Studies, Delta State Polytechnic, Ogwashi-Uku, Delta State, Nigeria

Email: Oliseoliver4real@yahoo.com

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Abstract

The study examined the impact of gas flaring on the physio-chemical properties of the soil at Okpai in Ndukwa East Local Government Area, Delta State, Nigeria. The study used a systematic sampling technique to collect soil samples on a linear transit at distances away from the flare site. Soil samples were collected from five different locations at two depths of 0-15 cm and 15-30 cm. A total of 10 samples were collected and analyzed for basic soil physio-chemical parameters. The laboratory analysis of these samples revealed that gas flaring affects the physio-chemical properties of the soil.

Keywords: Effect, Gas Flaring, Physio-Chemical Properties, Soil, Okpai

INTRODUCTION

Over the years, the Niger Delta Region, which includes Okpai, Ndukwa East Local Government Area of Delta State has served as the primary economic hub and source of sustenance for the country. The discovery, extraction, and production of oil and gas by oil companies, however, does not come without its negative consequences. Both the environment and the ecosystem of the oil-bearing villages in the Niger Delta Region are impacted by these operations. The oil-bearing community of Okpai in Delta State, Nigeria is facing environmental and social issues as a result of the operations of Nigeria Agip Oil Company Limited (NAOC), the only oil company operating in Okpai and its environs through the exploration, exploitation, and production of crude oil and gas (Otunkor and Ohwovorione, 2015).

Gas flaring, a process of separating crude oil from gas, has been practiced in Okpai for 24 hours a day for over three decades. This has resulted in both thermal and other pollutions that affect the soil nutrients and subsequently agricultural production (Alakpodia, 1989, Otunkor and Ohwovorione, 2015). Gas flaring causes an introduction of substances and energies that are harmful to human health, living organisms, and soil micro-organisms and nutrients into the ecosystem, particularly soil component.

Gas flaring affects soil as well as vegetation, agriculture and crop production (Alakpodia, 2000, Gogoi and Baruoh, 2002, Ogdiolu, 2003, Efe, 2003, Otunkor and Ohwovorione, 2015).Gas flaring equally affects soil fertility/nutrient. This impact/effect is on the physio-chemical properties of the soil which are physical and chemical (exchangeable cations/minerals) properties. Exchangeable cations are one of the most important chemical basis of soil fertility. According to Alegre et al., 1990, the deficiencies of these mineral elements are responsible for poor nature of tropical soil. Thus, the level of fertility of the soil of a place has direct bearing on the production or yield of crops cultivated in that place. Hence, the study looks at the effect/impact of gas flaring on the physio-chemical properties of the soil of Okpai.

The Effect of Gas Flaring on Physio- Chemical Properties of the Soil

Some studies have been carried out by scholars to examine and ascertain the impact of gas flaring on soil and soil fertility. Thus, the impact of gas flaring on soil is obvious especially when considered on the basis of the long duration of the flaring. Exchangeable cations are one of the most important chemical basis of soil fertility, deficiencies of these mineral elements are responsible for poor nature of tropical soil (Alegre et al., 1990).

However, these exchangeable cations or the cation exchange capacity (CEC) of the soils under gas flaring is very low. This reduces the fertility and nutrients of the soil. The results of studies carried out by Alakpodia (2000) and Ogidiolu (2003) show that exchangeable cation (Ca, Mg, K and Na) on the soils under gas flaring is low. According to them, the mean exchangeable base value of the soils under gas flaring is far below the values of 20 milli-equivalent/100g of soils which, Young (1976) observed as required for high soil fertility. The mean value is also lower than 4.0 milli-equivalent/100g of soils, which Sanchez (1976) suggested for retaining most nutrient cations in the soil. Thus, soils within the 100 metres radius of the site of gas flaring are mostly affected because their nutrient levels are very low. Therefore, no meaningful human activity can be carried out within the area due to excessive heat. They noted also that the low mean value of exchangeable base indicates that gas flaring is detrimental to the accumulation of these basic mineral nutrients in soils and thereby promoting the degradation of soil fertility.

Ogidiolu (2003) observed a decline in organic matter and total nitrogen contents/status of soils under gas flares. However, it also exhibits increasing pattern with increasing distance from the flares. According to him, this decline is brought about by intense heat, which affects the process of the formation of organic matter and total nitrogen formation. In the same vein, Dosunmu and Amadi (1996) noted a decline in organic matter formation and total nitrogen in soils under gas flaring. According to them, heat from gas flares affects the microbial populations, which participate in organic matter decomposition and nitrogen formation process. They also noted that with decline in organic matter and total nitrogen as well as microbial populations, humid (top soil) formation, nutrient availability and soil fertility are affected.

Alakpodia (2000) observed that there is a very low mean value of organic matter (1.83%) and total nitrogen (0.08%) of soils under gas flaring. According to him, heat affects the process of organic matter and total nitrogen formation. The process of mineralisation which concerns the biochemical break-down of dead plant tissue by micro-organisms, to produce simple — structured soluble organic matter (Knapp, 1979) is disturbed. The micro-organisms are rendered somehow inactive under the perennial heat from the gas flaring. He also noted that the regrouping of the soluble organic substances into larger molecule polymerization), which then become poorly soluble and stabilized as a major part of soil humus, is not effective as a result of constant heat especially near the gas flares.

Gas flaring activities of the oil companies result in soil acidity with mean pH values between 4.3 and 5.8 (Alakpodia, 2000 and Ogidiolu, 2003). Ogidiolu (2003) noted that one major effect of gas flaring on the chemistry of the soil is the increase in acidity. That gas flaring leads to increase in soil acidity means that, it renders soils unproductive agriculturally (NNPC, 1981; 1985) because solubility and hence the uptake of nutrients from soil is reduced (Ogidiolu, 2003).

Althaus (2004) reported that flaring or deliberate burning of natural gas has been cited as a leading cause of global warming and a contributing factor to acid rain, which damage not only vegetation but soil also. Okizie (1989) noted that gas flaring has affected the soil through the process of acid rain, which percolates through the soil and constantly alters the nitrogen, phosphorus and potassium contents in the soil and other nutrient elements. Charles Brandt, a scientist who studies oil production's tropical impact at the U.S. Department of Energy's Pacific Northwest National Laboratory observed that all flaring, regardless of how efficient or what petroleum by products are burned, leaves residue in the air and the soil. He noted that some compounds in that residue are known carcinogens (Houston Chronicle, 2004). This residue has detrimental effect on soil and soil fertility.

Ukoima et al. (2016) in their study on Changes in Fungal Population and Soil Physio-Chemical Properties Following Gas Flare in Oloma Community, Bonny Local Government Area observed that gas flaring has negative effects on the soil physio-chemical properties thereby affecting soil fertility.Their findings on soil chemical properties indicated that total nitrogen (0.001%) was the least nutrient that occurred at 50metres and the highest was phosphorous (6.44mg/kg). At 100metres the least nutrient was total nitrogen (0.006%) and the highest sodium (5.22cmol/kg). Phosphorus was highest (2.76 mg/kg) (2.76 mg/kg) at 150m and 1km respectively. Similarly, total nitrogen was lowest (0.006%) at 150m and 1km respectively. Potassium, Sodium and total Carbon were all significant ($P< 0.05$) in all distances. Their study also shows that gas flare has effect on fungal population. This in turn will affect the formation of soil organic matters and minerals/ nutrients.

Achebe and Epstein (2004) asserted in their study that there has been a deterioration of the properties of soil as a result of reduced organic matter (the structure, aeration and water holding capacity of soil), soil chemical properties and reduction of soil organisms, as a result of much heat and associated gases from gas flaring. Abiodun (2004) noted also that the environment of the oil-bearing region has borne the brunt of gas flaring. Thus, the valuable wetlands of the Niger Delta in which oil prospecting and production take place have been virtually destroyed.

MATERIALS AND METHODS

Study Area

Okpai is a settlement in Nigeria's Niger Delta. The Ndukwa East Local Government Council Area in Delta State, Nigeria, has local control over Okapi. Latitudes 5.5^0 17^1 and 5.2^0 14^1N and longitudes 4^0 40^1 E and 4^0 45^1 E of the Greenwich Meridian correspond to Okapi. According to Okpai's 2003 EIA, it is situated in the Central Delta Socio-Economic Zone's lower Niger floodplain. Its boundaries are the River Niger to the east, the Ase River to the west, the Onuabo Community to the south, and the Umuagboma and Benuku Communities to the north.

Generally dark greyish brown on the surface, Okpai's soil eventually turns yellowish brown with reddish mottling and concretion, with hints of light grey visible.

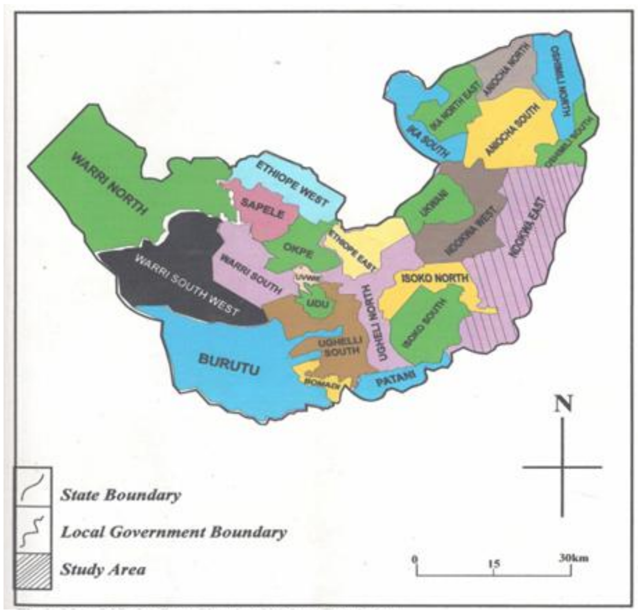

Figure 1. Map of Delta State Showing Ndokwa East L.G.A
Source: Ministry of Land and Survey, Asaba 2000

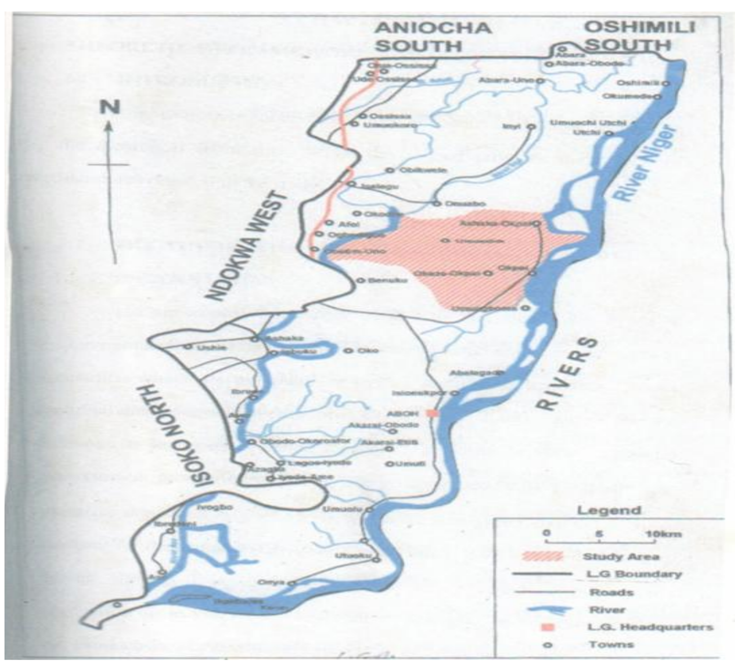

Figure 2. Ndokwa East L.G.A Showimg Study Area
Source: Ministry of Lands and Survey, Asaba 2000

Sample Collection

Systematic sampling technique was used in the collection of soil samples. The soil samples were collected on a linear transect in the direction of the wind. This is because wind is known to influence the direction or orientation of a burning flame and as such its associated gases. The wind direction was determined during the reconnaissance survey using a wind vane. The soil samples were collected at a determined interval of 50 meters from the embankment or bound wall (barrier built to confine the flaring site). From the bound wall, soil samples were collected from five points, which were labelled A, B, C, D and E with E being the most distant point. A total of 10 soil samples were collected at depths of 0-13cm and 15 -30cm which were referred to as top soil and subsoil respectively. At each point, four soil samples were collected around the point to form a composite sample. The linear transect method was chosen for this study to ensure that the relationship between distance from the flare site and changes in soil physio- chemical properties are properly represented and to further facilitate a proper data analysis. The control site was located at Aboh where flaring is not taking place.

The instruments that were employed for this study and laboratory test are soil, meter rule, tape, soil auger, cutlass polythene bags, recording book, soil testing kit and chemicals.

Analysis of Soil Physio-Chemical Properties

Table 1 shows the values of soil properties analysed for both the top soil and subsoil. Table 2 shows the range and mean values of soil properties analysed. While Table 3 shows the mean values of soil parameters in relation to distances away from the flare site.

Table1. Physio-chemical properties of soil in Okpai and control site

No of Points	Sample Depth (cm)	Dist From Flare Site(m)	Particle Size (%)			Soil Temp(^0C)		Soil pH $C_aC_aCl_2$	EC (Ms/cm)	Organic carbon (%)	Total Nitrogen (%)	Available Phosphorus	Total Exchangeable Cation (Meq/100g)					
			Sand	Salt	City	AM	PM						Mg^+	Ca^+	Na^+	K^+	EA	CEC
A	0-15	50	83.22	5.20	11.58	48.3	54.3	5.86	0.043	1.482	0.08	25.38	0.48	1.60	0.10	0.22	0.10	2.40
	15-30	..	83.62	2.40	13.98			5.58	0.019	0.858	0.46	29.22	0.72	1.44	0.22	0.13	0.10	2.51
B	0-15	100	79.32	9.30	11.38	48.3	53.0	6.15	0.022	1.716	0.50	28.69	1.04	4.56	0.25	0.57	0.10	2.51
	15-30	"	80.62	4.70	14.68			5.77	0.039	1.482	0.18	28.26	0.72	3.68	0.18	0.61	0.00	5.19
C	0-15	150	74.32	9.60	16.08	47.5	50.4	5.80	0.025	2.106	0.21	32.85	1.04	2.88	0.18	0.44	0.10	4.54
	15-30	"	76.02	7.90	16.08			5.89	0.024	1.248	0.15	34.02	0.72	1.84	0.22	0.31	0.60	3.09
D	0-15	200	79.22	6.70	14.08	46.2	48.0	5.49	0.019	1.716	0.15	35.62	0.80	1.60	0.16	0.29	0.80	3.49
	15-30	"	75.22	6.20	18.58			4.87	0.013	1.092	0.12	32 .96	0.32	1.28	0.22	0.16	1.50	1.98
E	0-15	250	83.62	3.80	12.58	42,0	47.3	5.80	0.030	1.560	0.16	29.65	0.48	1.68	0.24	0.26	0.50	2.66
	15-30	"	81.32	3.40	15.28			5.64	0.014	1.092	0.14	33.49	0.16	1.36	0.27	0.20	0.80	1.99
	0-15		73.31	8.74	16.95	29.0	35.0	6.50	2.80	3.94	1.45	36.30	2.51	2.69	2.10	1.85	0.90	9.15
	15-30		72.09	8.46	18.45			5.95	1.36	2.84	1.58	35.40	2.42	3.46	1.14	0.99	1.68	4.01

Source: field work, 2023

Table 2. Range Mean Value of Physio-Chemical Properties of Soil in Okpai and Control Site

Soil Parameters	Affected Area		Control Site	
	Range	**Mean**	**Range**	**Mean**
Sand (%)	74.32-83.62	79.65	72.09-75.31	73.70
Silt (%)	2.40-9.60	5.92	8.46-8.74	8.60
Clay (%)	11.38-18.58	14.43	16.95-18.45	17.70
Soil Temperature (%)	42.0-54.3	48.50	29.0-35.0	32.0
Soil pH (in $CaCl_2$)	4.87-6.15	5.69	5.95-6.50	6.23
Electrical Conductivity (EC) (Ms/cm	0.013-0.043	0.025	1.36-2.80	2.08
Organic carbon (%)	0.858-2.106	1.435	2.84-3.94	3.39
Total Nitrogen (%)	0.08-0.50	0.22	1.45-1.58	1.52
Available Phosphorus (ppm)	25.38-35.62	31.01	35.40-36.30	35.85
Magnesium (Mg^+) meq/100g)	0.16-1.04	0.65	2.42-2.51	2.47
Calcium (Ca^+) ,,	1.28-4.56	2.19	2.69-3.46	3.08
Sodium (Na^+) ,,	0.10-27	0.20	1.14-2.10	1.62
Potassium (K^+) ,,	0.13-0.61	0.32	0.99-1.85	1.42
Exchange Acidity ,,	0.00-1.50	0.46	0.90-1.68	1.29
CEC ,,	1.98-6.52	3.44	4.01-915	6.58

Source: Field Work, 2023

Table 3. MEAN Values of soil parameters in distances away from flare site

No of points	Dist. From flare site(m)	Particle size (%)			Soil Temp. (^0C)	Soil $_pH$ (in $CaC1_2$)	EC (Ms/cm)	Organic carbon (%)	Total Nitrogen (%)	Available phosphorus(ppm)	Total Exchangeable cation (Meq/100 g)					
		Sand	Silt	Clay							Mg^+	Ca^+	Na^+	K^+	EA	CEC
A	50	83.42	3.80	12.78	51.3	5.72	0.031	1.17	0.27	27.30	0.60	1.52	0.16	0.18	0.10	2.46
B	100	79.97	7.00	13.03	50.5	5.96	0.031	1.60	0.34	28.48	0.88	4.12	0.22	0.59	0.05	5.86
C	150	75.17	8.75	16.08	50.0	5.85	0.025	1.68	0.18	33.44	0.88	32.36	0.20	0.38	0.35	3.82
D	200	77.22	6.45	16.33	47.1	5.18	0.016	1.40	0.14	34.29	0.56	1.44	0.19	0.23	0.15	2.74
E	250	82.47	3.60	13.94	44.7	5.72	0.022	1.33	0.15	31.57	0.32	1.52	0.23	0.23	0.65	2.33

Particle Size Distribution of the Soil

The values obtained range from 74.32 to 83.62%, 2.40 to 9.60% and 11.38 to 18.58% for sand, silt and clay respectively with mean values of 79.65%, 5.92% and 14.43% for sand, silt and clay. These values have no significant difference with that of the control site which ranges between 72.09 to 75.31%, 8.46 to 8.74% and 16.95 to 18.45% for sand, silt and clay with mean values of 73.70%, 8.60% and 17.70% for sand, silt and clay respectively.

Soil Temperature

The results show that soil temperature around the flare site is very high ranging from 42.0°C to 54.3°C for both morning and evening. The mean value is 48.50°C. This is relatively higher than that of the control site that ranges from 29.0°C to 35 .0°C with mean value of 32.0°C.

Soil pH

Soil pH measures the degree of soil acidity or alkalinity. The soil pH ranges between 4.87 and 6.15 while the mean value is 5.69. These values show appreciable increase in soil acidity. Thus, the soil can be said to be acidic. The control site has a mean value of 6.23.

Electrical Conductivity (EC)

Electrical conductivity measurements are used as indication of total quantities of soluble salts in soil. The electrical conductivity values of the soil are shown in Table 2. These values range from 0.0 13 to 0.043Ms/cm with a mean value of 0.025 Ms/cm. This value is very low compared with the control site.

Organic Carbon

Organic carbon is often used as a measure of the quantity of organic matter in a soil, which in turn is taken as a crude measure of fertility. The data in Tables 2 and 3 show a low value of organic carbon, which ranges from 0.858% to 2.106% with mean value of 1.435%. This value is an indication of a very low organic matter in soil of Okpai. The control site has a higher value that ranges from 2.84 to 3.94% with mean value of 3.39%.

Total Nitrogen

Tables 2 and 3 show that the total nitrogen in the soil of Okpai is very low. The values range from 0.08 to 0.50% with a mean value of0.22%. The control site has values that range from 1.45 to 1.58% with a mean value of 1.52%.

Available Phosphorus

The result of the analysis of available phosphorus of soil in Okpai shows high values as can be seen in Table 2. These values range from 25 .38ppm to 35 .62ppm with mean value of 31.0 lppm (Table 3).
Available phosphorus in control site is also high with values ranging from 35.40 to 36.30ppm and mean value of 35.85ppm.

Total Exchangeable Cations

The exchangeable cations Mg, Ca, Na and K are the essential macronutrient ions. These ions can easily exchange for other ions, hence the name exchangeable cations.

The data presented in Table 3 show that magnesium has values ranging from 0.16 to 1.04 with mean value of 0.65 meq/100g, calcium ranges between 1.28 to 4.56 meq/100g with mean values of 2.19 meq/100g, sodium ranges between 0.10 and 0.27 meq/100g with mean value of 0.20 meq/100g and potassium 0.13 to 0.61 meq/100g with mean value of 0.32 meq/100g. These values are low with calcium having the highest value. The control site recorded higher values. The data in Table 3 show that magnesium ranges between 2.42 to 2.51 meq/100g with mean value of 2.47 meq/100g, calcium 2.69 to 3.46 meq/100g with mean value of 3.08 meq/100g, sodium 1.14 to 2.10 meq/100g with mean value of 1.62 meq/100g and potassium 0.99 to 1.85 meq/100g with mean value of 1.42 meq/100g.

Cations Exchange Capacity (CEC)

This is a measure of the number of absorption sites per unit weight of soil at a particular pH. It is often defined as the sum of exchangeable cations absorbed per unit weight of soil.
The data from Tables 2 and 3 reveal that cation exchange capacity of soil in Okpai is low. Table 3 shows that the value ranges between 1.98 to 6.52 meq/100g with mean value of 3.44 meq/100g.
This value is rated low. The value of CEC for control site is higher than that of gas flaring site, which ranges from 4.01 to 9.15 meq/100g with mean value of 6.58meq/100g.

CONCLUSION

The study shows that gas flaring affects the physio-chemical properties of the soil of Okpai. The results show high soil acidity and very low electrical conductivity (EC). This impact negatively on both plants and crops production. Organic Carbon which is a measure of the quantity of organic matter in the soil that shows crude measure of fertility in the soil is very low. The total nitrogen, total exchangeable cations as well as cations exchangeable capacity are also low in Okpai soil. These are as a result of consequential effect of gas flaring in Okpai which in turn affects the soil and farming activities/ agricultural productivities of the people. To this end, flaring activity of the oil producing companies should be properly regulated by legislation if not stopped and the people adequately compensated.

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