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Variations in bacterial spectrum and physicochemistry of top soils exposed to gas flaring in Ologbo community, Edo state.

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Abstract

Nigeria is a major exporter of petroleum and natural gas and a majority of the petroleum exploratory activities takes place in the Niger Delta area, where high rates of gas flaring associated with exploration and production of these products occur. The study investigated changes in bacterial flora and physicochemistry of soils within the Oredo flow station facility. Seven soil samples were collected in triplicates at radial distances of 40m, 80m, 120m, 160m, 200m, 1km from the flare stack and the control sample was collected from a farmland far from the flow-station but within the community. Standard methods were employed in evaluating the physicochemical parameters and bacteriological analysis was conducted using serial dilution and pour plate methods. The results revealed that gas flaring had significant effects on some soil physicochemical parameters. The impact of gas flare was found to lower the moisture content at 4.44 % for soils collected at 40m whilst for the control soil, it was 12.83%. The nitrate and total nitrogen content of the soil varied from 9.96±1.44 to 12.21±0.13mg/kg and 0.01±0.00 to 0.2±0.01%. The total heterotrophic bacteria count varied from 0.4 ± 0.33 to 14.67±3.77 ×10^6 cfu/g. Identified bacterial species were; Streptococci sp., Corynebacterium sp., Stenotrophomonas sp., Staphylococcus sp., Micrococcus sp., Bacillus sp., Acinetobacter sp., Burkholderia sp. and Bacillus sp. The results revealed that gas flaring had a negative effect on soil bacteria population and physicochemical properties.

KeyWords: Gas Flaring , Physicochemistry , Bacterial Spectrum, Top Soil, Ologbo Community

INTRODUCTION

Crude oil is a complex mixture of liquids and gases that occurs naturally and is primarily composed of hydrocarbons. This complex mixture is discovered several kilometres underneath the surface of the earth and drilling is the process employed in bringing it to the surface (Ifeadi and Nwankwo, 1989). Gas flaring is a method of releasing unused hydrocarbon gases into the atmosphere by burning them with the use of flare stack. A gas flare stack is an elevated vertical or horizontal stack used to burn off gases from oil wells or oil platforms, as well as refineries, chemical plants, and landfills. The combustion of these gases facilitates the release of large amounts of greenhouses such as CO_2, CH_4, and oxides of nitrogen to the environment which contributes to global warming. Furthermore, gas flare materials often include wasted energies, poisonous emissions, and hazardous particulate matter (Uyigue and Enujekwu, 2017) and the emission of SO_2 into the atmosphere leading to acid rain formation.

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Nigerian oil deposits are known to include a large amount of gas, and that these gases are regularly discharged during oil production by flaring (Atumah and Ojeh, 2013). This is a standard method of operation in the process of oil production and it is not unique to Nigeria alone. For example, in Saudi Arabia, about 20% of its natural gas is flared, whereas Libya, Canada, and Algeria flare approximately 21%, 8%, and 5% respectively (Atevure, 2004). Despite the fact that there has been a ban on gas flaring in Nigeria as far back as 1984, the country has remained a top gas flaring nation.

Gas flaring is ranked among the most contentious environmental issues across the world, especially in the Niger Delta region of Nigeria which produces oil (Amadi, 2014). Oil production within the Niger Delta began more than fifty years ago, as did gas flaring, and studies have shown that it has negative social, health, and economic repercussions for Nigeria and the entire world in general. This is because it has undesirable environmental consequences and climate change contributions (Leahey *et al.,* 2001; Ishisone, 2004; Abdulkareem, 2005; and Oseji, 2007). Gas flaring has an effect on soils in gas flare areas, thereby severely impairing agricultural productivity. Ogodo (2003) reported that acid deposition from gas flare have deleterious effects on the fertility, pH and microbial spectrum of the surrounding soils. It impoverishes soils (Wild, 1993; Schnabel, 1993, and Grant *et al*., 1995), and flaring also generates tremendous heat which has direct heating and increased water loss (by transpiration) effects on nearby plants, with severe wilting and death ensuing (Mauseth, 1998).

It was reported by Akudo. *et al*, (2012) that soil temperatures increases by between 12.6 degrees Celsius and 23.4 degrees Celsius and reduced soil moisture at 5cm by 18.6% and 2.8% from gas flaring. It is also established that changes on soil temperature and moisture contents is significant with distance away from flare sites. Gas flaring significantly affects not only the microclimate but also the soil physio-chemical properties of the flare sites. Some of the substances released alters the surface and ground water quality, aggregate nutrient deficiencies in soils, or accelerate the soiling, weathering or corrosion of engineering and cultural materials. There are also visible changes in soil characteristics close to a flare site (Alakpodia (2000). Gas flaring destroys the vegetation and destabilizes the eco-system. (Ogbonanya, 2003).

Temperature rises, as well as the discharge of soot and harmful substances into the environment, also wreak havoc on the health of the people nearest to flare sites (Nwaugo *et al*., 2006).There is also a social aspect to this negative impacts, the environment near the flare sites are perpetually illuminated by continuous flaring of gases and these has a great health implication from sleeplessness to other health challenges. There are two million people living within 4 kilometres of a gas flare stack in the oil-rich Niger Delta (Schick *et al*., 2018), and this makes them exposed to lung damage and cancer, added to these are abnormalities in children, pneumonia, bronchitis, asthma, neurologic and reproductive difficulties (CSL Stockbrokers, 2020).

In light of the above, it is evident that environments exposed to natural gas flaring are prone to environmental degradation. This research therefore focuses on the impacts of gas flaring on the changes in bacteria population and physicochemical properties of the soil at Oredo flow station located at Ologbo community, Edo State.

MATERIALS AND METHODS

Study Area

The Oredo Flow Station is located between latitudes 60 3′ 31.68′′ – 60 3′ 57.6′′North of Equator and longitudes 50 34′ 52.74′′ – 50 35′ 26.88′′East of Greenwich and in the heart of Ossiomo industrial park in Ologbo community, Ikpoba-Okha Local Government Area (LGA) of Edo State. It is about 35 km from Benin City, the capital and about 35 km from Koko, Delta State. With a rural population growth rate of 2.8%, the 2017 population projection of the community stood at 20,548 with 11,148 males and 9,400 females. Major occupation of the people is small scale farming.

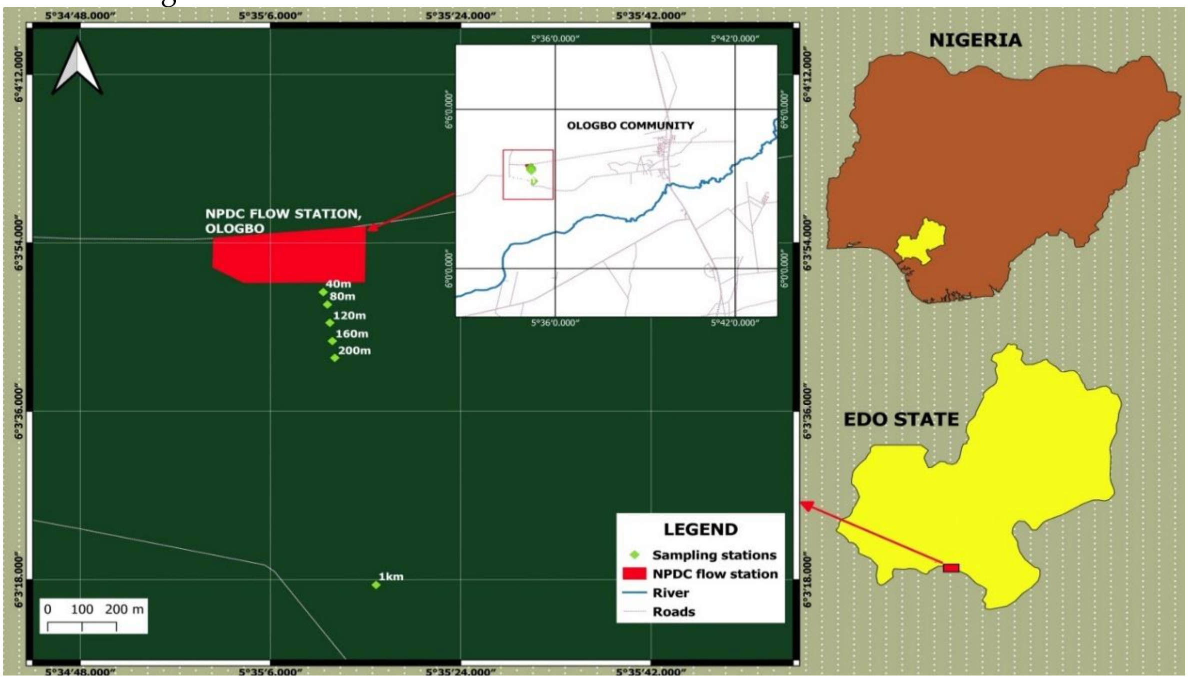

Figure 1: Map of the study Area

Sample Collection and Preparation

A soil auger was used in the collection of soil samples from the vicinity of the gas flare stack of the Flow Station. A total of seven (7) soils were randomly collected at radial distances in triplicates at the depth of 0-15cm at 40m, 80m , 120m , 160m , 200m and at 1km . A soil sample was also collected outside the facility but within the community which served as the control. All the soil samples were collected in clean polythene bags and appropriately labelled. Samples collected were transferred to the laboratory for analysis.

Determination of Physicochemical Properties

Some physicochemical parameters of the soil samples were determined. Soil pH was determined by dipping the glass electrode of an EIL model 7055 pH meter into a 3:6 soil: water suspension. The core sampling method as described by Blake and Hartge (1990) was used to determine soil bulk density. Soil conductivity of samples was determined with the aid of a chandos conductivity bridge (Model A 19). The soil moisture was determined by employing the APHA (1998) standard procedure as described by Ayotamuno *et al.* (2011). The amount of nitrate and nitrite was determined using UV-Visible Spectrophotometry. The Walkley and Black method was applied in the determination of the amount of organic carbon present. To determine the THC of the samples, the method modified by Benka-Coker and Ekundayo (1995) was employed. Water holding capacity was measured by calculating the percentage of moisture retained by soil (Arias *et al.*,2005).

Isolation and Identification of Bacteria

For each soil samples, total viable aerobic bacteria present in the soil samples were isolated on nutrient agar into which sterile nystatin (50g/ml) had been added for the inhibition of fungal growth. About1g of the soil sample was taken from each of the soil samples contaminated with the different hydrocarbons and suspended in 10ml of sterile water. The suspension was serially diluted and 0.1ml of appropriate diluents was evenly spread on the surface of the already prepared Nutrient Agar. Triplicate plates were incubated for 24 hours at 37^0 C and morphologically distinct colonies were sub-cultured onto fresh plates. Pure colonies of each isolated bacteria strains were stored on Nutrient agar slants at 4^0 C for further study (Olutiola *et al* ., 2000).

Pure cultures of isolates were determined based on colonial morphology, cultural characteristics, micro morphological and biochemical characteristics using standard procedures. The bacterial identifications were carried out in accordance with the methods described by Gerhardt *et al*. (1981).

RESULTS

Physicochemical parameters of soil . From the results it was observed that with the exception of Total Hydrocarbon Content, all other soil physicochemical parameters analysed such as : Electrical conductivity, pH ,Nitrate, Nitrite, Moisture content , Water Holding Capacity, Bulk Density , Total Organic Carbon and Total Nitrogen showed an ascent with increasing distance from the flare point.

Table 1: Physicochemical properties of gas flare-impacted soil

PARAMETER	Distance from flare site (m)						CONTROL	
	40	80	120	160	200	1000		p-value
pH	5.89±0.01	6.01±0.01	6.02±0.04	6.21±0.08	6.74±0.02	6.81±0.16	7.06±0.01	p>0.05
EC (µS/cm)	7.36±0.56	18.63±0.76	17.09±0.13	24.75±0.64	52.35±7.71	123.2±22.63	175.1±6.36	p<0.01
Nitrate (mg/kg)	9.96±1.44	10.91±0.02	10.94±0.07	10.99±0.04	11.03±0.04	11.98±0.06	12.21±0.13	p>0.05
Nitrite (mg/kg)	0.47±0.00	0.48±0.01	0.62±0.00	0.70±0.02	0.77±0.11	0.80±0.09	0.81±0.01	p<0.01
MC (%)	4.44±0.19	8.23±0.53	9.55±0.09	10.32±0.06	10.34±0.21	10.60±0.59	12.83±0.15	p>0.05
WHC (ml/l)	25±0.00	25±0.00	27.5±3.54	41±1.41	41±1.41	50±0.00	50±0.00	p<0.01
BD (g/cm3)	0.75±0.00	0.75±0.00	0.74±0.02	0.73±0.00	0.73±0.03	0.71±0.02	0.70±0.00	p>0.05
TOC (%)	0.15±0.04	1.33±0.16	2.14±0.03	2.30±0.25	2.39±0.20	3.35±0.30	3.64±0.74	p>0.05
THC (mg/kg)	12.57±2.81	6.42±4.58	0.33±0.09	0.13±0.00	0.33±0.09	0.13±0.00	0±0.00	p>0.05
TN (%)	0.01±0.00	0.08±0.01	0.11±0.01	0.12±0.00	0.13±0.00	0.19±0.01	0.2±0.01	p>0.05

Values are means ±S.D of three determinations

Correlation of physicochemical parameters of soil

Table 2 below shows plots of selected soil variables. Some of the physicochemical variables had a strong positive and negative (numbers in bold) association, according to the results of the correlation statistic. THC and nitrogen had a negative relationship with r^2= -0.813. What this means is that as the total hydrocarbon content levels increases, the soil's nitrogen content decreases. From all the plots, the correlation between Total organic carbon and nitrogen revealed the highest positive correlation with r^2= 0.995 whereas the relationship of THC and nitrite observed highest negative correlation r^2= -0.882.

Table 2 Correlation statistics of soil physicochemical parameters

	pH	*EC*	*Nitrate*	*Nitrite*	*MC*	*WHC*	*BD*	*TOC*	*THC*	*N*
pH	1.000									
EC	**0.898**	1.000								
Nitrate	**0.813**	**0.983**	1.000							
Nitrite	**0.889**	0.647	0.534	1.000						
MC	**0.825**	0.699	0.616	**0.868**	1.000					
WHC	**0.926**	**0.867**	**0.797**	**0.853**	**0.761**	1.000				
BD	-0.728	**-0.835**	**-0.852**	-0.545	-0.691	**-0.790**	1.000			
TOC	**0.854**	**0.866**	**0.820**	**0.789**	**0.934**	**0.856**	**-0.817**	1.000		
THC	-0.682	-0.523	-0.459	**-0.882**	**-0.873**	-0.706	0.521	**-0.814**	1.000	
N	**0.887**	**0.880**	**0.824**	**0.817**	**0.937**	**0.861**	**-0.779**	**0.995**	**-0.813**	1.000

Total heterotrophic bacterial counts

The result of the total heterotrophic bacteria count is presented in Table 3 below. Counts of heterotrophic bacteria were found to be highest (34.67×10^{6}cfu/g) at the control site and lowest (0.4×10^{6}cfu/g) at 40metres away from the flare stack.

Table 3: Total heterotrophic bacterial counts of each soil samples in relation to distance from the flare point

Distance from the flare point (m)	Total Heterotrophic Bacterial count ($\times10^{6}$cfu/g)
40	0.4±0.33
80	6.67±1.89
120	13.33±10.50
160	6.67±3.77
200	12.00±3.27
1000	14.67±3.77
Control	34.67±6.80

Values are means ±S.D of three determinations

Table 4. Frequency of occurrence of bacteria isolates

below shows the isolated bacteria and their percentage occurrence. The bacteria isolates identified include Streptococcus sp., *Corynebacterium* sp., *Stenotrophomonas* sp., *Staphylococcus* sp., *Micrococcus* sp., *Bacillus* sp., *Acinetobacter* sp., *Burkholderia* sp. *Corynebacterium* sp. and *Bacillus* sp. were the most prevalent bacteria isolated from the soil samples and they had the highest percentage occurrence.

Organism	No. of Occurrence	Percentage (%) Occurrence
Corynebacterium sp.	2	20
Bacillus sp.	2	20
Streptococcus sp.	1	10
Stenotrophomonas sp.	1	10
Staphylococcus sp.	1	10
Micrococcus sp.	1	10
Acinetobacter sp.	1	10
Burkholderia sp.	1	10

DISCUSSION

The physicochemical properties revealed that gas flaring have impacts on areas within the facility and its environ, the results showed a distinct trend as some of the parameters considered exhibited a gradient with increasing distance from the flare point using chi-square goodness of fit.

Values of Soil pH values were generally acidic in sample areas. The distance at 40m away from the flare stack was the most acidic (5.89) while the control site had a near neutral pH (7.06). The range of 5.89±0.01 to 7.06±0.01 with increasing distance is in line with findings of Atuanya and Osabohien (2003); Nwaguo *et al*, (2006), Atuma and Ojeh (2013), Ernest *et al*. (2015) and Ukoima *et al*.(2016). These authors reported that pH changed from acidic range of 4.0-4.2 to 6.4-6.6 as distance from the flare point increased. The low values for pH close to the flare point may be as a result of acidic precipitation (Botkin and Keller, 1998) and increase in acidity level of the soil affects soil nutrient and fertility negatively, hence affect crop production (Uyigue and Enujekwe, 2017).

Soil electrical conductivity (EC) is considered to be a measure of the concentrations of ions in soils, and is linked to the presence of dissolved solutes ;it is also an indirect measure of ionic concentration in the soil. .Electrical conductivity ranged from 7.36 -175.1 μScm^{-1}, This result was in line with the work of Nwabudike (2002) on the physicochemical and microbial properties of soil in gas flare site at Ekpan Delta state. Atuma and Ojeh (2013) and Uzoekwe (2019) also reported higher values in the control site in comparison to the gas flared site. Soil conductivity value is directly linked to the soil nitrogen content and soil nutrient and encourages microbial proliferation and soil fertility. The moisture content results revealed that the heat produced from the flare had an influence on the soils within the gas flaring area.. The direct effect of heat from the flare stack results in low moisture content of the soil (4.44%).With movement away from the flare stack, there was an increment in the moisture content of the soil samples, the control have the highest moisture content (12.83%). This observation is in agreement with studies by Ernest *et al*. (2015) and Umeda *et al*. (2020) who reported that moisture content of the soil increased with increasing distance away from the gas flare stack. Low soil moisture content is known to have a detrimental impact on water activity which can directly affect microbial activities.

Total Nitrogen, Nitrates and Nitrites levels also showed similar distribution pattern as moisture content and soil pH as their values increased with distance away from the flare stacks and values at 40m from the gas flaring stack were (0.01, 9.96, and 0.47mg/kg respectively) which were lower than the control (0.2, 12.21, 0.81mg/kg respectively). This is in accordance with the reports of Atumah and Ojeh (2013); Okeke and Okpala (2014) and Umeda *et al*. (2020) who opined that the percentage mean total nitrogen values increased with distance from the flaring epicenter, which might be as a result of increase in soil temperature within the flaring epicenter which lowers down the availability of nitrogen. Plants are known to require nitrogen for various functions including the synthesis of enzymes, amino acids, proteins and chlorophyll, which is the light-capturing molecule (Follet *et al*.,1985). Nitrogen is an essential soil nutrient and its presence is vital for effective soil performance and usage for agricultural purposes (Chibuzo, 2016). Nitrate is the form of nitrogen that is available to plants for use and continuous low levels of nitrate occasioned by gas flaring activities can affect soil fertility and eventually contribute to food scarcity in that locale.

The total organic carbon values increased as the distance from the flare stack increased. The lowest value (0.15%) was obtained from soil samples collected at 40m distance from the flare stack while the highest value (3.64%) was obtained from the control soil samples. These results were an indication that organic carbon concentrations are higher in soils where gas flaring is not practiced, while it is lower in those soils impacted by gas flaring activities. From the results in table 3. it is seen that there exists a strong negative correlation between TOC and THC with r^2= -0.814. This could imply that high THC levels can lead to low levels of TOC. Atuma and Ojeh (2013) posited that organic carbon content decreases towards the flare site. Chibuzo

(2016) also reported higher organic carbon content values for the control site than areas within the gas flaring activity. However, this finding contrasted with previous data reported by Atuanya and Osabohien (2003) who investigated the effect of gas flaring on physicochemical and microbial properties of the soil at Ekpan flare site. The authors indicated that soil samples from gas flare heavily impacted area had high organic carbon content which is likely due to spilled carbon containing oil carryover during the process of gas flaring.

The total hydrocarbon content values decreased as the distance from the gas flare stack increased. The total hydrocarbon content recorded at the distance 40m away from the flare stack was 12.57±2.81mg/kg while the total hydrocarbon content levels at 1km was 0.13±0.00mg/kg and it was undetected at the control. Furthermore, similar results have been reported by Nwabudike (2002); Atuanya and Osabohien (2003), and Ezeigbo *et al*. (2013) who investigated the impact gas flaring on soils within gas flaring vicinity .

There are many essential ecosystem services which are performed by bacteria present in the soil environment among which are improvement of the soil structure and its aggregation, cycling of nutrients in soil and recycling of water. Furthermore, they contribute to the formation of soil micro aggregates as their secretions bind soil particles together. These micro aggregates serve as the building blocks for the improvement of soil structure which, in turn, increase the rate of water infiltration and the ability of the soil to hold water (Ingham, 2009). Hence, a healthy bacteria population is vital for overall soil productivity. An increase in total heterotrophic bacteria counts was observed as distance increased away from the flare stack. It is important to note that these bacteria from the study site may have developed some thermophilic properties over time for their survival. This trend is similar with the findings reported by Nwaugo *et al*. (2005), Ezeigbo *et al*. (2013), Ukoima *et al*. (2016) and Umeda *et al*. (2020) who investigated the impacts which gas flaring had on soils. The following bacteria were isolated from the study site; *Streptococcus* sp., *Corynebacterium* sp., *Stenotrophomonas* sp., *Staphylococcus* sp., *Micrococcus* sp., *Bacillus* sp., *Acinetobacter* sp. and *Burkholderia* sp.

CONCLUSION AND RECOMMENDATION

As a result of the data and records gathered, it can be concluded that gas flaring, which emits petroleum hydrocarbon pollutants, has a direct impact on the soil's physicochemical qualities. This was discovered to adversely impact the abundance of heterotrophic bacteria, as the bacteria population in the area of gas flaring was shown to be low compared to the control location. This means that gas emissions affect bacteria population activities in the soil, which are beneficial in organic matter decomposition, agriculture, and global nutrient cycle.

Gas flaring, without a doubt, is a waste of resources that also poses major health and environmental risk. It is consequently critical for the government, oil corporations, non-governmental organizations (NGOs), environmentalists, academics, host communities, and all other stakeholders of the Nigerian oil and gas industry to implement rules that will stop the gas flaring trend and its associated emissions.

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