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Impact of Crude Oil Spillage and Gas Flaring activities on Soil Properties at Izombe in South East, Nigeria

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Abstract

The study was to ascertain the effect of crude oil spillage and gas flare on soil properties at Izombe. Composite samples were collected from three different locations; oil spillage, gas flaring and control sites using random sampling method. Collected samples were subjected to laboratory analyses and data generated were statistically analyzed using coefficient of variation (CV) and correlation. Soil pH(H_2O) were strongly – moderately acidic. Organic carbon had 7.43 g/kg, 21.23 g/kg and 2.12 g/kg for soils under control, oil spillage and gas flare sites, respectively. The CV showed that organic carbon (96.13 %), total nitrogen (79.54 %), Fe (100.92 %), and Pb (54.04 %) recorded high variation among the studied sites. pH(H_2O) correlated positively (r= 745, r= 0.634, r= 0.982) with Fe, Pb and Zn. The result shows that soil properties under oil spillage site were mostly affected followed by gas flare site when compared with control site.

Keywords: *Oil spillage, gas flare, soil properties, composite sample, soil, Izombe*

Introduction

Crude oil spillage and gas flaring are issues in oil producing areas of Nigeria, and they have negatively affected the environment, mostly the pedosphere (Faniran and Areola, 1985). Crude oil spillage could be as a result of accidental discharge of crude oils into the environment through operational mishap, equipment failure, and intentional damage to pipelines conveying the crude oil. In majority of the oil producing communities, large amount of crude oil has been absorbed by agricultural land. Crude oil spillage can cause the reduction of the available nutrients in the soil and adds some toxic elements in the soil, which results to the death of the plants and diminished soil fertility (Aghalino, 2000). Odjugo, (2002) stated that crude oil pollution has deleterious effects on plant growth, soil macronutrients, microorganism and the terrestrial ecosystem in general. As a result of crude oil pollution, soil physical properties such as pore spaces might be clogged thereby reducing soil aeration, infiltration of water into the soil, increased bulk density of the soil which may affect plant growth. Previous studies on crude oil pollution of soil had revealed its adverse effects on soil productivity (Okpowasili and Odokuma, 1990; Aghalino, 2000; Odjugo, 2002). It is not an over statement to say that an ecological war is rapidly destroying human life, flora, and fauna of the area and there is no greater threat on society and development than the continuous degradation of our soil environment through oil spillage and gas flaring.

Gas flaring could be described as the cheapest means of expelling excess hydrocarbon gathered in an oil/gas production flow station/site. Gas flaring is environmentally unsustainable hence; successive governments have tried to discourage its practice through policy instructions and sanctions. Gas flare in most oil fields in Nigeria are located at ground level and surrounded by thick vegetation, farmland and villages with a distance of about 20 m from the flare (Abdulkareem, 2005). The flaring of gases releases huge volumes of green house gases to the atmosphere, which returns to the soil as acid rain (Ikoro, 2003). Gas flaring has affected soils found within gas flare areas (Faniran and Areola, 1985; UNDP, 2004). Apart from affecting the chemical properties of the soil, it also resulted in poor soil fertility or nutrient content, leading to poor crop productivity in the area. The soil mantle of the earth is indispensable for the maintenance of the plant life, affording mechanical support and supplying nutrient and water (Abdulkareem, 2005). However, soils found in the crude oil producing areas are one of the most degraded as a result of the environmental pollution by the oil industry in the region (Turner et al., 1990). In Izombe, gas flaring is the major source of thermal pollution which has been occurring over years and this is believed to have affected soil properties and other related environmental activities.

The crude oil spillage and gas flaring phenomenon have not been studied well in Izombe. The negative impact of this oil exploration activity includes destruction of wild life, loss of fertile soil, pollution of air and water and damage to the ecosystem of the host communities, thereby disrupting the normal functioning of ecosystem service provision (Aghalino, 2000). Roberts, (1997) reported that ecological problems observed as a result of crude oil spillage and gas flaring includes a brownish vegetation, soil erosion, diminishing resources of the natural ecosystem, soil fertility loss and adverse effect on the live, health and economy of the people. However, there is need for continuous research on the problems associated with pollution resulting from crude oil spillage and gas flaring and their effects on the soil environment. Hence, this study is to ascertain the effects of the crude oil spillage and gas flaring on the physicochemical properties of soils at Izombe.

Materials and Methods

Study Area

The study area is located in Addax Oil Company exploration area at Izombe in Imo state of South-east, Nigeria. It lies between latitude $5^o\ 12'$ N and $5^o\ 56'$ N and longitude $6^o\ 38'$ E and $7^o\ 25'$ E. The annual rainfall ranges from 2500 mm to 3000 mm with mean temperature of 28 ^oC (NIMET, 2014). The original vegetation of the study area is the modified tropical rainforest which has been altered by human activities. The greater part of the vegetation is made up of trees, shrubs, legumes. The geology of the area consists of alluvium which is marine deltaic deposits (Lekwa, 1985).

Field study and sample collection

Five composite soil samples were collected from each of the designated locations which consist of crude oil spillage site, gas flaring site and farm land which serves as control. The samples were collected at a depth of 20 cm. Core samples were collected for bulk density determination. A total of 15 composite samples were collected. The samples were prepared for laboratory analyses.

Laboratory Analyses

Particle size distribution was determined by hydrometer method (Gee and Or, 2002). Bulk density was determined by core method (Grossman and Reinsch, 2002). Soil pH was determined using 1:2.5 soil – liquid ratio using a pH meter (Thomas, 1996). Organic carbon was determined by wet digestion method (Nelson and Sommers, 1982). Total nitrogen was determined by micro-Kjeldah digestion technique (Bremner, 1996). Available phosphorous was determined using Bray II method (Olsen and Sommers, 1982). Exchangeable acidity was determined by the method described by MacLean (1982). Exchangeable bases were determined by neutral ammonium acetate procedure buffered at pH 7.0 (Thomas, 1982). Available micro nutrients (Fe, Cu and Zn) were extracted by DTPA as described by Sahlemedhin and Taye, (2000) and all these micro nutrients were determined using atomic absorption spectrophotometer.

Statistical Analyses

The variability of soil properties among the studied sites were measured by estimating coefficient of variation (CV). The coefficient of variation was ranked according to the procedure of Wilding (1985) where CV < 15% = low variation, CV >15 < 35% = moderate variation, CV > 35 % = high variation. Correlation was also used to compare relationship between selected soil parameters.

Results and Discussion

The results of the studied soil properties as stated in Table 1 showed that sand particle are 827 g/kg, 727 g/kg and 847 g/kg for soils under control; oil spillage and gas flare sites, respectively. The high amount of sand particles could be attributed to parent material and climatic activities of the area. This agreed with the findings of other researchers (Onweremadu et al., 2011; Osujieke *et al.,* 2016) in soils under similar geology. The high sand size in gas flared site over other sites could be associated with high temperature generated by the flaring processes which facilitates intense weathering process that resulted to coarse particle formation. The result of the coefficient of variation showed that sand particle size recorded low variation (8 %). The clay particle recorded moderate variation (32.26 %) among the studied sites. The variation could be attributed to activities of oil spillage and gas flaring in the sites which may have altered the rate of weathering. Bulk density was high at the gas flared site (1.64 g/kg) followed by control site (1.59 g/kg) while the oil spillage site (1.12 g/kg) is the least. The bulk density had moderate variation (19.79 %) among the studied sites. The variation is dependent on different finer particle size, oil spillage the covers that pore space of soils the studied sites. Electrical conductivity (EC) had an increasing trend of 4.56 dS/m < 4.67 dS/m < 5.32 dS/m for soils under control, gas flare and oil spillage sites. The EC recorded low variation (8.47 %) among the sites. The high value of electrical conductivity of crude oil spilled soil may be due to a high presence of charged ions (cations and anions) in the soil (Akubugwo *et al.,* 2016). The value of electrical conductivity represents the ratio of soil salinity, so the key to determine salinity of soil is to obtain the electrical conductivity.

The control site was moderately acidic while, the oil spilled and gas flared sites were strongly acidic according to the ratings of Singer and Munns, (1999). The acidic nature of soil could be attributed to the oil spillage and gas flaring activities. This is in line with the reports of Osuji and Adesiyan, (2005) and Atuma and Ojeh, (2013) on soils of oil exploration activities at Ogbodo-Isiokpo and Ebedie-Ukwani, both in Niger Delta region of Nigeria.

Table 1: Selected soil properties of the studied sites

Soil properties	Control	Oil spillage	Gas flare	Mean	CV (%)
Sand (g/kg)	827.0	727.0	847.0	800.3	8.0
Silt (g/kg)	91.0	231.0	91.0	137.67	58.71
Clay (g/kg)	82.0	42.0	62.0	62.0	32.26
Texture	SL	SL	SL		
TP (%)	44.14	56.90	50.04	50.36	12.68
BD (g/cm^3)	1.59	1.12	1.64	1.45	19.79
pH(H_2O)	5.81	4.66	5.57	5.35	11.35
OC (g/kg)	7.43	21.23	2.12	10.26	96.14
TN (g/kg)	0.84	1.82	0.28	0.98	79.54
Av.P (mg/kg)	4.56	5.32	4.66	4.85	8.52
Ca (cmol/kg)	1.60	1.60	2.00	1.73	13.32
Mg (cmol/kg)	0.80	1.20	0.80	0.93	24.74
K (cmol/kg)	0.09	0.09	0.12	0.10	17.32
Na (cmol/kg)	0.08	0.64	0.16	0.29	103.25
TEA (cmol/kg)	1.60	2.24	1.92	1.92	16.67
EC (dS/m)	4.56	5.32	4.67	4.85	8.47
Fe (mg/kg)	0.09	0.64	0.16	0.30	100.92
Pb (mg/kg)	1.57	3.81	1.66	2.35	54.04
Zn (mg/kg)	0.28	0.54	0.44	0.42	31.23

TP= total porosity, BD= bulk density, OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, TEA= total exchangeable acidity, EC= electrical conductivity, CV= coefficient of variation

The pH is not only essential for determining the availability of many soil nutrients but also in determining the fate of many soil pollutants, their breakdown and possible movement through the soil. It is known that strongly acidic soils usually have high concentrations of soluble aluminum and manganese, which are toxic to many plants; nitrogen fixation and decomposition activities are also known to be hindered in strongly acidic soils (Manahan, 1994). Gas flaring activities leads to increase in soil acidity, it also renders soils unproductive agriculturally, because solubility and hence the uptake of nutrients from soil is reduced. The organic carbon (OC) as recorded in the sites showed that the control site (7.34 g/kg) and gas flared site (2.12 g/kg) were low while, the oil spilled site (21.23 g/kg) was high when compared with the ratings of Enwezor *et al.* (1990) and Landon, (1991). Organic Carbon recorded high variation among the studied sites. The high variation could be associated with the deposit of hydrocarbon in oil spilled site while the gas flaring activities hamper the activities that promote OC content in the soil. This observation is also in line with the report of Lee *et al.* (2002) and Osuji and Onojake, (2006) on crude oil polluted soil. Environmental conditions of weathering and climatic predispositions could be observed from the organic carbon variation. The total nitrogen (TN) followed similar trend as that of organic carbon. This showed that TN is dependent on OC. The available phosphorus were low in soils under control site (4.56 mg/kg) and gas flared site (4.66 mg/kg) while, at the oil spilled site (5.32 mg/kg), it is moderate according to the ratings of Landon, (1991) (<5 mg/kg, ≥5≤15 mg/kg, >15 mg/kg). The available phosphorus recorded low variation (8.52 %) among the studied sites.

The Fe, Pb and Zn content (Table 1) of the studied sites were low when compared with the rating of Kparmwang *et al.* (2000). The oil spillage site contains more Fe (0.64 mg/kg), Pb (3.81 mg/kg) and Zn (0.54 mg/kg) over other (gas flared and control) sites which are attributable to hydrocarbon content of the soil. The increase in heavy metal concentration may be due to hydrocarbon pollution which is in line with the observation of Kakulu *et al.* (1985) who opined that crude petroleum contributed to a large extent the metal pollution in the Niger Delta area of Nigeria. Oil pollution generally increases the concentrations of heavy metals in the soil (Zhang *et al.,* 2005).

The result as stated in Table 2 showed that sand had negative correlation (r= -0.804, r= -0.993, r= -0.963, r= -0.993, r= -0.688) with total porosity, organic carbon, Fe, Pb and Zn but, it correlated positively and significantly (r= 0.998, p= 0.05) with bulk density. Bulk density correlated negatively (r= -0.983, r= -0.979, r= -0.736) with OC, Fe and Zn while, it had a negative significant correlation (r= -0.999, p= 0.05) with Pb. The soil pH(H_2O) correlated positively (r= 0.435, r= 0.756, r= 745, r= 0.634, r= 0.982) with OC, Fe, Pb and Zn. The available phosphorus has positive correlation (r= 0.988, r= 0.860) with Pb and Zn while, it correlated positively and significantly (r= 1.000, r= 1.000, p= 0.05) with ECEC and Fe. However, the sign of the coefficient indicates the direction of the relationship. If both variables tend to increase or decrease together, the coefficient is positive while, if one variable tends to increase as the other decreases, the coefficient is negative.

Table 2: Correlation Matrix of the Studied Soils

	Sand	Silt	Clay	TP	BD	pH (H_2O)	OC	TN	Av.P	Ca	Mg	K	Na	TEA	EC	Fe	Pb	Zn
Sand	1																	
Silt	-0.988	1																
Clay	0.778	-0.866	1															
TP	-0.804	0.887	-0.999*	1														
BD	0.998*	-0.996	0.819	-0.843	1													
pH(H_2O)	-0.537	0.661	-0.948	0.933	-0.594	1												
OC	-0.993	0.963	-0.699	0.730	-0.983	0.435	1											
TN	-0.978	0.933	-0.629	0.662	-0.961	0.348	0.995	1										
Av.P	-0.962	0.993	-0.920	0.936	-0.978	0.747	0.923	0.883	1									
Ca	0.629	-0.500	0.000	-0.043	0.574	0.319	-0.715	-0.778	-0.391	1								
Mg	-0.988	-1.000	-0.866	0.887	-0.996	0.661	0.963	0.933	0.993	-0.500	1							
K	0.629	-0.500	0.000	-0.043	0.574	0.319	-0.715	-0.778	-0.391	1.000*	-0.500	1						
Na	-0.959	0.991	-0.924	0.940	-0.976	0.755	0.919	0.878	1.000*	-0.381	0.991	-0.381	1					
TEA	-0.933	0.866	-0.500	0.537	-0.906	0.198	0.969	0.988	0.799	-0.866	0.866	-0.866	0.720	1				
EC	-0.958	0.991	-0.925	0.941	-0.976	0.756	0.918	0.877	1.000*	-0.380	0.991	-0.380	1.000*	0.791	1			
Fe	-0.963	0.993	-0.919	0.935	-0.979	0.745	0.925	0.885	1.000*	-0395	0.993	-0.395	1.000*	0.802	1.000*	1		
Pb	-0.993	0.999*	-0.848	0.870	-0.999*	0.634	0.972	0.945	0.988	-0.530	0.999*	-0.530	0.986	0.883	0.986	0.988	1	
Zn	-0.688	0.792	-0.991	0.985	-0.736	0.982	0.599	0.520	0.806	0.132	0.792	0.132	0.866	0.381	0.867	0.850	0.770	1

TP= total porosity, BD= bulk density, OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, TEA= total exchangeable acidity, EC= electrical conductivity

Conclusion

This research was undertaken to examine the impact of crude oil spillage and gas flaring on soil of Izombe. From the study, it is observed that crude oil spillage and gas flaring have enormous effects on the soil physicochemical properties and the entire environment of the study area. However, it is worthy to note that crude oil spillage and gas flaring affected agricultural and economic activities of Izombe community in Nigeria. Therefore, both the government and the oil companies should keep up to the challenges of monitoring, evaluating and managing the oil drilling environment for a sustainable agricultural and environmental development. The use of agricultural lime is strongly recommended to provide some buffering capacity to the soil. However, there is need to embrace modern technology, implement policies that will ameliorate oil spillage and gas flare. Also, introduce agricultural practices such as organic agriculture, liming with ashes and use of non acidic fertilizers that can adopt mitigated environmental condition of the study areas.

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