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Physico-chemical Alterations and Hydrocarbon Characteristics of Kom-Kom Oil Spill Soils

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Authors' contributions

This work was carried out in collaboration among all authors. Authors LCO and EON designed the study. Author IMO wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The aim of this study is to find the alterations that occurred in the physico-chemical properties and the hydrocarbon content on the crude oil impacted soil in Kom-Kom, Oyigbo, Rivers State Niger Delta, Nigeria.
Study Design: The objectives included to evaluate the physico-chemical parameters of the spilled soil, determine the hydrocarbon content and that of some selected heavy metals. This will help create a baseline data on the environmental status of the area.
Place and Duration of Study: This study was carried out after an oil spill occurred in Feburary, 2018 at Kom-Kom, Oyigbo, Rivers State, Nigeria.
Methodology: The soil samples were obtained randomly at 30cm depth using soil auger from three plots: PA and PB being the plots around the oil spill impacted area and PC being the control area which is about 200m away. Laboratory analyses were carried out on the Physicochemical Parameters (pH, Electric Conductivity, Potassium (K), Phosphate (P), Nitrate (N)); Organics (Total Hydrocarbon Content (THC), Total Petroleum Hydrocarbon (TPH), Polycyclic Aromatic Hydrocarbon (PAH) and Total Organic Carbon (TOC)) and Heavy Metals (Iron (PB), Zinc (Zn), Lead (Pb), Chromium (Cr), Vanadium (V)). The data were analysed using descriptive statistics and One-Way ANOVA.

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Results: pH, K and P values were all significantly different from their respective control values ($p \leq 0.05$). All organic parameters were also significantly different from the control values ($p \leq 0.05$). For heavy metals, only Cr and V values were significantly different in all study sites ($p \leq 0.05$). This study shows that crude oil spill alters the physicochemical attributes of the soil and could significantly affect soil fertility as the people of Kom-Kom are mostly farmers and traders.

Conclusion: With these levels of alteration, this study will serve as a resourceful data source for soil studies in Kom Kom. In order to achieve the third sustainable development goal (SDG) which is to have good health and well-being of people, we recommend immediate and proper clean up using bioremediation approaches as a cheap, eco-friendly and an environmentally sustainable process.

Keywords: Soil; alterations; physico-chemical; heavy metals; total hydrocarbon content (THC); environmental sustainablility; sustainable development goal (SDG); kom-kom.

1. INTRODUCTION

Soil in an integral part of nature. It is important for life, because it provides the medium for plant growth, a habitat for many micro and macro organism, acts as a filtration system for surface water, carbon sequestration and maintenance of atmospheric gases. It is also key component for farming thus environmental sustainability largely depends on proper soil management. Viable use of agricultural soil on which plants depend on is absolutely necessary for yield and productivity.

Soil pollution by crude oil and other petroleum products are presently a huge challenge in the Niger Delta [1]. Soil contamination and pollution as part of land degradation is caused by the presence of xenobiotics (human-made) or other alteration in the natural soil environment. It is typically caused by industrial activity, agricultural chemicals, or improper disposal of waste. The most common chemicals involved are petroleum hydrocarbons, polynuclear aromatic hydrocarbons (such as naphthalene and benzo(a)pyrene), solvents, pesticides, lead, and other heavy metals. Contamination is correlated with the degree of industrialization and concentration of chemical substances. The concern over soil contamination stems primarily from health risks, direct contact with the contaminated soil, vapours from the contaminants, and from secondary contamination of water supplies within and underlying the soil [2].

Crude oil contamination has seriously damaged the soil structure and texture of the Niger Delta as well as its aquatic ecosystems. Oil exploration and activities have been concentrated in Niger-Delta region and it has over 1000 production oil-wells and over 47,000 km of oil and gas flow lines [3]. Contamination of soils with crude oil and refinery products is becoming an ever-increasing problem especially in the light of several breakdowns of oil pipelines and wells and distribution of petroleum-based products [4,5,6].

Crude oil is known to reduce the availability of plant nutrient in soil [7,8,9]. Contaminated sites pose significant environmental hazards for terrestrial as well as aquatic ecosystems as they are important sources of pollution which may result in ecotoxicological effects [10]. Due to the hydrophobic characteristics of crude oil, soil pores are blocked on contamination hence getting air and water movement arrested leading to a drastic reduction in soil-water and soil-nutrient supply for plant. Petroleum hydrocarbons have many different effects according to the species. However, in most fauna, growth and metabolic activity are reduced. The effects of oil spillages on the ecosystem in the Niger Delta have been very severe. These include damage to and loss of biodiversity as seen in the mangroves of the Niger Delta, reduction of arable land, reduction of available potable water and blockages of water ways [11,12,13]. The biodegradation of petroleum hydrocarbons is often made difficult and slow due to the presence of heavy metals. Heavy metals show toxicity toward most species of biodegrading microorganisms including algae, bacteria and fungi [14,15] and these metal toxicity depends on the amount available to organisms, the entry route, the absorbed dose, and the exposure time of the microorganism [16].

Studies on petroleum hydrocarbon and heavy metals in the Niger Delta environment have been carried out and reported by several researchers [13,17,18,19,20,21,22,23]. Heavy metals have serious adverse effects on environment and human health most of which are observed after long exposure [24].

Environmental Policy formulation, adoption and implementation are generally developing concepts that came about in the late 1960. These concepts are still evolving in developing economy like Nigeria even when they claim to be put into force. Whereas compared to the Western world these policy concepts are taken seriously, yielding encouraging results [25]. If these environmental policies are adhere to, oil spills will be reduced and there will be an improved environmental sustainability.

There are several physical-chemical technologies for the treatment of soils contaminated with organic and hazardous materials such as petroleum hydrocarbons. They include vapour extraction, stabilization, solidification, soil flushing, soil washing, thermal desorption, and incineration [26,27]. These methods have some disadvantages. Most of these techniques are expensive to implement at full scale and require continuous monitoring and control for optimum performance, which may not be environmentally sustainable.

Bioremediation is a method that involves a natural process of cleaning up an oil spill site. It is cost effective, relatively easy to implement, nonintrusive hence allows for continued site use. Contaminants are usually converted to innocuous products. Contaminants are sometimes destroyed and not just transferred to another environmental media and it is environmentally friendly [28]. There are various methods which include but not limited to mycoremediation [29,30], which is the use of fungi to degrade and phytoremediation [16], which is the used of plants for degradation.

The aim of this study is to find the alterations that occurred in the physico-chemical properties and the hydrocarbon content on the crude oil impacted soil in Kom- Kom, Oyigbo, Rivers State Niger Delta, Nigeria. The objectives included to evaluate the physico-chemical parameters of the spilled soil, determine the hydrocarbon content and that of some selected heavy metals. This will help create a baseline data on the environmental status of the area.

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out after an oil spill occurred in Feburary, 2018 at Kom-Kom, Oyigbo, Rivers State, Nigeria (Fig. 1). The area carries the Trans-Delta Bonny Light Line of Shell Petroleum Development Company (SPDC). Kom-Kom is a small settlement with farmers and traders [23]. The soil type is loamy and the area carries various food crops including maize (*Zea mays*), waterleaf (*Talinum fruticosum*) and cassava (*Manihot esculenta*) [23].

2.2 Soil Sample Collection

Ten (10) soil samples were randomly obtained from two plots (PA and PB) around the spill point and three (3) soil samples collected from an area about 200 meters away from the spill point as the control (PC). They were collected using hand auger at 30 cm depth and taken immediately to the laboratory for analyses [23].

2.3 Laboratory Analysis

Laboratory analyses were done in line with the United States Environmental Protection Agency (USEPA) analytical protocol. Parameters analyzed were Physicochemical Parameters (pH, Electric Conductivity, Phosphate, Nitrate); Organics (Total Hydrocarbon Content, Total Petroleum Hydrocarbon, Polynuclear Aromatic Hydrocarbon); Heavy Metals (Iron, Lead, Zinc, Chromium, and Vanadium).

The Physico-chemical parameters; pH was analysed with a pH meter, electrical conductivity was done with a conductivity meter, nitrate and phosphate was analysed with a spectrophotometer and potassium was analysed using atomic absorption spectrometer (AAS). The Organic parameters were analysed using gas chromatograph flame ionization detector system. Heavy Metals were analysed using a properly calibrated AAS with specific metallic standards [30].

2.4 Data Analysis

The results collected from the laboratory were statistically analysed using Descriptive analysis and One-Way ANOVA followed by Duncan Multiple Range Test (Post Hoc). Xcel Stat was used to process these statistical analyses.

3. RESULTS AND DISCUSSION

The mean values of the soil physicochemical and fertility parameters are seen in Table 1. The soil pH was generally slightly acid. Plot A (PA), plot B (PB) and control (PC) ranged from 6.1 to 6.5, 6.0

to 6.3 and 4.1 to 4.8 with mean values of 6.34, 6.17 and 4.55 respectively. Significant ($p \leq 0.05$) difference was found between pH in PC and PA as well as PB as presented in Table 1. The lower pH in PC could be attributed to leave litters as there were trees in the area which could result to increased putrefaction. This agrees with the opinion of Vinje, [31] who conducted a study at the Planet Natural Research Centre US and observed that leave litter and mulching are known to increase soil acidity. Electrical conductivity (EC) had mean values of 264 µS/cm, 224.8 µS/cm and 209.3 µS/cm for PA, PB and PC respectively with no significant ($p \leq 0.05$) difference across the plots. No significant ($p \leq 0.05$) difference was observed in the soil Nitrate for all three plots. Phosphorus is an essential part of cell, which control cell division and enhances growth. In this study, phosphorus in the soil showed higher mean values of 14.797 mg/kg for PC, there was no statistically observed significant ($p \leq 0.05$) difference between PC and PA. However, PC was significantly ($p \leq 0.05$) different from PB. For plant growth, three key elements are necessary and they are categorized as macro-nutrient (Nitrogen, Phosphorus and Potassium). In this study they were relatively low compared to the soil agricultural standards [32]. Potassium showed significant ($p \leq 0.05$) difference in PA (3.892 mg/kg) and PC (1.287 mg/kg) and also between PA (3.892 mg/kg) and PB (1.623 mg/kg). There is no significant ($p \leq 0.05$) difference between PB (1.623 mg/kg) and PC (1.287 mg/kg).

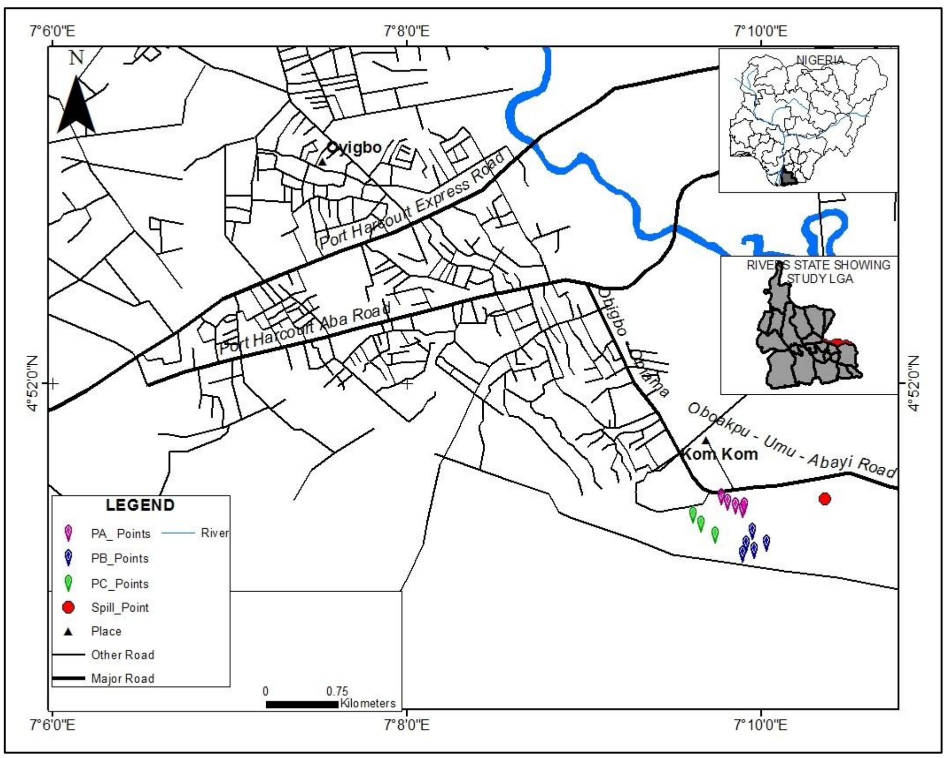

Fig. 1. Map of study area showing the spill point and sampling plots [23]

Table 1. Results of physicochemical parameters

Plot	pH	Electric conductivity, µS/cm	Potassium, mg/kg	Nitrate, mg/kg	Phosphate, mg/kg
PA	6.34^{a}	264.0^{a}	3.89^{a}	3.74^{a}	11.2^{a}
PB	6.17^{a}	224.8^{a}	1.62^{b}	4.42^{a}	10.8^{b}
PC	4.55^{b}	209.3^{a}	1.29^{b}	5.66^{a}	$14.8b^{a}$

Means with the same letters in each column are not significantly different according to Duncan multiple range test (DMRT) at 5% level of probability;
The alphabets (a and b) indicate the means that are in the same subset from the ad hoc test carried from the AVOVA

Table 2 shows the mean values of the organic parameters. Total hydrocarbon content (THC) was significantly (p ≤0.05) high in PB (4339.0 mg/kg) compared with PC (19.84 mg/kg) (Table 2). This was in line with the report by Gighi et *al*.[33], where they found high THC in the soil impacted with crude oil in Kpean, Rivers State, Nigeria. Similar scenario played out with the Total Petroleum Hydrocarbon (TPH) reported in this study. Again PB (4125.4 mg/kg) had the highest mean value TPH and PC had the lowest (17.606 mg/kg). Osuji et *al*.[8], opined that high hydrocarbon levels (3400–6800 mg/kg) affect both above-ground and subterranean flora and fauna, which are essential indices in the biogeochemical cycle that affects availability of plant nutrients. The biological effects of crude oil consist of acute and chronic toxic effects. Acute toxic effects of petroleum hydrocarbons include death of organisms and various sedative effects, seedling mortality and defoliation of lower zones of shrubs and trees. The chronic toxicity of petroleum hydrocarbons are mainly sub-lethal effects. They occur following acute (i.e. short-term-single exposure) or chronic (continuous) exposure. The effects are mainly the disruption in energetic processes, interference with biosynthetic processes and structural development and toxic effect on reproduction [34]. Significant (p ≤0.05) difference was found in the Polycyclic Aromatic Hydrocarbon (PAH) of PC (0.023 mg/kg) and the other two plots; PA (0.962 mg/kg) and PB (0.684 mg/kg). Total Organic Carbon (TOC) is a measure of the amount of organic carbon contained within soil. Organic carbon in soil is the result of the decomposition of plant and animal matter, living and dead microorganisms, roots from plants and soil biota. In a related study by Wegwu et *al*.[35], total organic carbon ranged between 1.38 – 3.27% for the impacted soil. This is in line with what was observed in this study 1.40 and 1.87% for the contaminated plots.

The mean values for the heavy metals are summarised in Table 3. The soil values for Iron in PA, PB and PC ranged from 21.98 mg/kg to 58.14 mg/kg, 16.92 mg/kg to 35.12 mg/kg and 12.05 mg/kg to 21.04 mg/kg with mean values of 33.52±14.74 mg/kg, 24.67±7.78 mg/kg and 16.01±4.59 mg/kg respectively. Zinc values in PA, PB and PC ranged from 0.89 mg/kg to 2.11 mg/kg, 0.24 mg/kg to 2.17 mg/kg and 0.62 mg/kg to 1.21 mg/kg with mean values of 1.45±0.52 mg/kg, 0.37±0.81 mg/kg and 0.92±0.29 mg/kg respectively. Soil analysis results for Lead PA, PB and PC ranged from 0.014 mg/kg to 0.065 mg/kg, 0.009 mg/kg to 0.032 mg/kg and 0.017 mg/kg to 0.025 mg/kg with mean values of 0.134±0.02 mg/kg, 0.121±0.02 mg/kg and 0.022±0.01 mg/kg respectively. Chromium results had values for PA, PB and PC ranging from 0.292 mg/kg to 0.430 mg/kg, 0.126 mg/kg to 0.232 mg/kg and 0.056 mg/kg to 0.058 mg/kg with mean values of 0.362±0.06 mg/kg, 0.170±0.04 mg/kg and 0.057±0.001 mg/kg respectively. Results of soil analysis for Vanadium for PA, PB and PC ranged from 0.414 mg/kg to 0.658 mg/kg, 0.310 mg/kg to 0.424 mg/kg and 0.030 mg/kg to 0.043 mg/kg with mean values of 0.564±0.09 mg/kg, 0.367±0.04 mg/kg and 0.039±0.01 mg/kg respectively.

From Table 3, the Heavy metals did not exceed any of the guideline values [36,37]. However, PA had the highest Fe and Pb values (33.521 mg/kg and 0.034mg/kg) and PC had the lowest Fe and Pb values (16.009 mg/kg and 0.002mg/kg). Based on the DMRT, There was no significant (p ≤0.05) difference amongst Fe, Pb and Zn. Significant (p ≤0.05) difference was observed in all the plots for Cr and V. Chromium (Cr) is the least toxic of the trace elements on the basis of its oversupply and essentiality. Cr (VI) compounds are approximately 100 times more toxic than Cr (III) salts. Inhalation of dust having chromium caused lung cancer with painless perforation of nasal septum [38]. Chattopadhyay et *al*. [39] reported in their study on mobility and bioavailability of chromium that microbial conversion of Cr ranged from 0.12 – 0.18 mg kg^{-1} dry weight, while mean was 0.14 mg kg^{-1} dry weight.

Table 2. Results of organic parameters

Plot	THC, mg/kg	TPH, mg/kg	PAH, mg/kg	TOC, %
PA	3281 ^{a}	3004 $^{a\ b}$	0.962 ^{a}	1.40 $^{a\ b}$
PB	4339 ^{a}	4125 ^{a}	0.684 ^{a}	1.87 ^{a}
PC	19.84 ^{b}	17.61 ^{b}	0.023 ^{b}	0.689 ^{b}

Means with the same letters in each column are not significantly different according to Duncan multiple range test (DMRT) at 5% level of probability;
The alphabets (a and b) indicate the means that are in the same subset from the ad hoc test carried from the AVOVA

Table 3. Comparing heavy metals concentrations with EGASPIN soil target and intervention values (DPR 2018) and NIST values (2000)

Heavy metals	PA, mg/kg	PB mg/kg	PC, mg/kg	EGASPIN		NIST values	Remark
				Target value (mg/kg)	Intervention value (mg/kg)		
Iron (Fe)	33.52 [a]	24.67 [a]	16.01 [a]	ND	ND	ND	ND
Lead (Pb)	0.034 [a]	0.027 [a]	0.022 [a]	85	530	18.9±0.5	GVNE
Zinc (Zn)	1.45 [a]	0.730 [a]	0.920 [a]	140	720	106±3	GVNE
Chromium (Cr)	0.362 [a]	0.170 [b]	0.0570 [c]	100	380	130±4	GVNE
Vanadium (V)	0.564 [a]	0.367 [b]	0.0390 [c]	ND	ND	112±5	GVNE

Means with the same letters in each row are not significantly different according to Duncan multiple range test (DMRT) at 5% level of probability;
The alphabets (a, b and c) indicate the means that are in the same subset from the ad hoc test carried from the AVOVA;
GVNE: Guideline values not exceeded; EGASPIN = Environmental guidelines and standards for the petroleum industry in Nigeria; Target values: They are values which indicate the sediment quality levels ultimately aimed for (or the baseline levels); Intervention values: They are values which indicate the quality for which functionality of sediment for human, animal and plant life are threatened with being seriously impaired. Concentrations in excess of the intervention values correspond to serious contamination; NIST: National institute of standards and technology; ND: No data

This corroborates with the result obtained from this study, where Cr values were 0.362mg/kg and 0.170 mg/kg for the impacted soil and 0.057 mg/kg for the control soil.

4. CONCLUSION AND RECOMMENDATIONS

Observation from this study shows that crude oil spill certainly caused alterations in the physico-chemical properties and hydrocarbon content of soil. Crude oil spills should be prevented and highly avoided, because with high levels of THC and TPH as found in this study, it prevents farmers from farming or lead to low yield and can lead to hunger in such community that depends. In cases where plants survive, it can lead to bioaccumulation of carcinogenic substances. With these levels of alteration, this study will serve as a resourceful data source for soil studies in Kom Kom,Oyigbo L.G.A., Rivers State, Nigeria. Pipelines running through villages like Kom-Kom should have proper security apparatus to prevent sabotage. Immediate and proper clean up should be carried out in such area to enable healthy living in such community. This will help to achieve the third sustainable development goal which is achieving good health and well-being of people. For sustainability, bioremediation of the polluted soil is recommended as it is cheaper and ecofriendly.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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