Open Access Library Journal
2018, Volume 5, e4297
ISSN Online: 2333-9721
ISSN Print: 2333-9705

The Impacts of Crude Oil Exploitation on Soil in Some Parts of Ogoni Region, Rivers State, Southern Nigeria

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How to cite this paper: Okon, I.E. and Ogba, C.O. (2018) The Impacts of Crude Oil Exploitation on Soil in Some Parts of Ogoni Region, Rivers State, Southern Nigeria. *Open Access Library Journal*, **5**: e4297.
https://doi.org/10.4236/oalib.1104297

Received: December 29, 2017
Accepted: July 13, 2018
Published: July 16, 2018

Abstract

The study examined the impacts of crude oil exploitation on the soil environment of Ogoni region and also identified action plans for the future management of the region. Composite soil samples were collected at two depths: 0 - 15 cm (surface soils) and 15 - 30 cm (subsurface soils) along different positions of landscape in the four study locations. Samples were analysed in the laboratory within 5 days of collection. ANOVA was used to confirm that both soil chemical and physical properties significantly vary in the study locations. The result revealed that sand, silt and clay contents significantly vary in Eleme, Tai, Khana and Gokhana as evident in the calculated F-ratios of 307.70; 606.72; 1312.31; and 1154.02 respectively. This is against the tabulated F-ratio of 3.35 as reflected by the wide variations in sand, silt and clay fractions, and probably owing to differences in parent material. Based on the locations where the soils were sampled, the results indicate that the soils vary widely in chemical characteristics in Eleme (F-ratio = 1674.16; $p < 0.01$; F-critical = 1.88); Tai (F-ratio = 82.67; $p < 0.01$; F-critical = 1.88); Khana (F-ratio = 1467.66; $p < 0.01$; F-critical = 1.88) and Gokhana (F-ratio = 709.49; $p < 0.01$; F-critical = 1.88) against the theoretical value. The soils of the prescribed study area are declared contaminated by heavy metals and hydrocarbon toxicity. The study therefore recommended the immediate implementation of the UNEP Report on Ogoni to attempt a remediation of the pollution impacts on the environment and socioeconomic livelihood. The paper also recommends the regulation of the activities of multinational oil companies in mineral exploration in Nigeria.

Subject Areas

Environmental Sciences

Keywords

Crude Oil Exploitation, Soil Pollution, Physico-Chemical Properties, Oil Spillage

1. Introduction

Oil production in Nigeria has severe environmental and human consequences on the indigenous people who inhabit such areas. Nigeria's export of 2.2 million barrels of oil a day comes from 12% of the country's land [1] yet indigenous minority communities in these areas receive little economic benefits. Development strategies that are focused on increasing foreign investments in Nigeria's oil industry as to boost exports have not caused overall development. The revenue gained has helped to benefit foreign nations and the Nigerian government elite more than the native populations. Indigenous groups are actually impoverished due to environmental degradation from oil production and the lack of adequate regulations on multinational operations thus making the local communities more vulnerable to environmental problems such as food shortages, health hazards, loss of land, pollution, forced migration and unemployment. The affected groups include the Andonis, Edos, Efiks, Ibibios, Ijaws, Ika-Ibos, Ikwerres, Isekiris, Isokus, Kalabaris, Urhobos and Ogonis, whose approximate 36 million people make up one fourth of Nigeria's population. Given that 90% of the Nigeria's total national revenue comes from oil production, and the tendencies of oil companies to maximize profits, both institutions have an interest in maintaining production at the status quo [1].

The history of oil exploitation in Ogoni runs parallel with the history of oil pollution as the commencement of oil exploration and exploitation runs concomitantly with the three major causes of oil pollution namely, the impact of the seismic survey, gas flaring and oil spills [2]. The Ogonis have sought more political autonomy and compensation for environmental damage to their land by oil companies and this has been met with negligence or brutal force. The consequences of oil exploitation on the environment of this region are what informed the need for this study whose objectives include among others to examine the impact of crude oil exploitation on Ogoni soils.

Oil industry activities are inevitably associated with environmental pollution. The major Nigeria's oil region lies exclusively within the Niger Delta and its continental shelf, which is saddled with most of the industry's oil installations and activities (upstream and downstream) and their associated deleterious environmental impacts. The industry operates over a thousand oil producing wells, gas plants; network of thousand kilometres of pipelines (Right of Ways) criss-crossing the Delta bearing crude oil to flow stations, terminals, and refineries. On average, one oil spill occurs every week in Nigeria. Pipelines are laid across farms, waterways and fishing grounds. Some pipes cross communities and living quarters. Approximately, 6000 km of pipelines cover Ogoni land [3].

However, due to incessant oil spills, oil has coated the aerial roots of plants killing parts of the mangrove forest and its faunal dependence. This mangrove forest, which serves as habitat for fish and molluscs as well as a source of raw materials for communities in Ogoni, has been ravaged by oil pollution. The land, the sea and the air (which they have depended on for several thousand years) can no longer support the subsistent life of the Ogoni community. Typical of this example is the abundant mangrove vegetation in Ogoni community of Bodo where the livelihood of the local people was previously sustained through farming and fishing. They also gathered mangrove wood for building and for local energy and fuel. Today, most of the youths and women have become jobless since their local economic support system is no longer sustainable. Gas had been flared for 24 hours daily for 40 years in close proximity to human habitation in nineteen oil locations [4]. This has been done without regard to the negative impacts of such activities on the people and the environment.

2. Geographical Description of the Study Area

The Ogonis are indigenous ethnic minority group in Rivers State in the Niger Delta region of Nigeria (**Figure 1**). Ogoni has an area of 1046.4 square km, which lies between longitude 7˚2'00"E and 7˚18'30"E and latitude 4˚18'30"N and

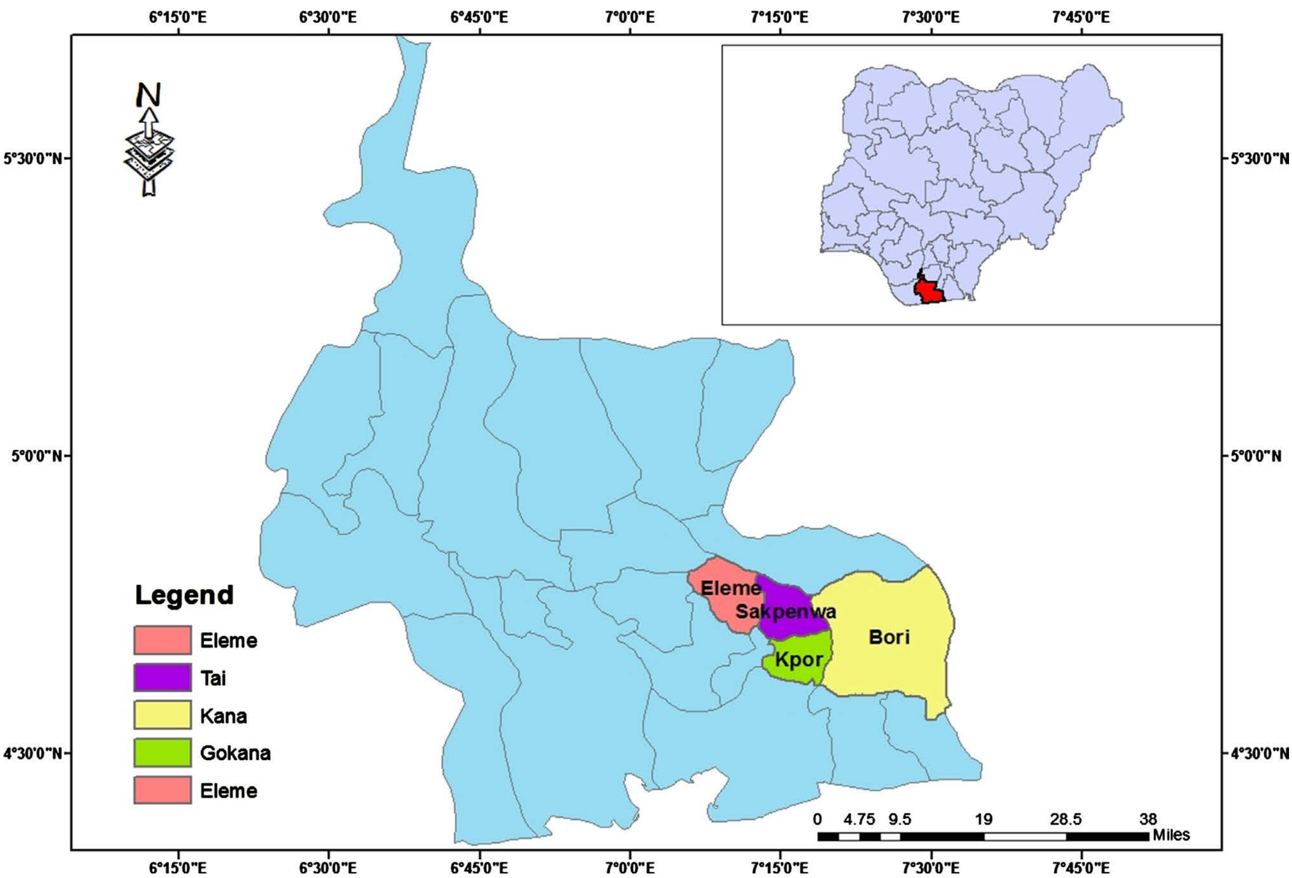

Figure 1. Rivers state showing local government headquarters in Ogoni region. Insert: Nigeria showing rivers state.

4˚31'00"N. Ogoni is bounded in the north by Oyigbo LGA; west by Okrika LGA; south by Ogu/Bolo, Bonny, Andoni and Opobo/Nkoro LGAs; and in the east by Akwa Ibom State, naturally separated by Imo River. The Ogoni people live in the coastal plain terraces northeast of the Niger Delta. Ogoni region is divided into four Local Government Areas, viz: Tai, Eleme, Gokana and Khana, and into six regions/clans in the Delta: Ken - Khana, Baabe, Bori, Tai, Gokana, and Eleme. The region, located within the coastal and rainforest belt, is characterized by mangrove swamp forests and rich rainforest vegetation that the Ogoni people depend on [5].

The Ogoni people are predominantly engaged in farming and fishing for subsistence. They also engage in tapping and distillation of palm wine into a local brewed dry gin, boat building, mat and pottery making. The people also earn their living as civil servants and traders [6]. Before the era of oil production in the late 1950's, Ogonis cultivated several crops ranging from banana to sugar cane. Oil was discovered in the Ogoni territory in early 1958 when SPDC found oil in the Ogoni community of K-Dere popularly and misnomally called the Bomu oil fields [2]. Subsequently, Shell made more discoveries in other Ogoni communities including Ebubu, Yorla, Bodo West and Korokoro. On the average, Ogoni had five major oil fields with 110 oil wells, hooked up to five flow stations at Bomu, Korokoro, Yorla, Bodo West and Ebubu by a necklace of interconnecting pipelines which criss-crossed Ogoni villages [2]. Ogonis have a population of 831,726 people and reside in the northeast area of the Delta. It is made up of four Local Government Areas including: Tai with a population of 117,797 people; Eleme comprising of 190,884 people; Gokana with 228,828 people; and Khana with apopulation of 294,217 [6]. The region's population is however estimated at 1,066,393 by 2015, using the 2.8% national annual growth rate.

3. Methods and Sampling Techniques

The practical problem faced by this research is the large size of the study area. In this regard therefore, a total of twenty communities were chosen for easy comprehension of the research problem. Composite soil samples were collected at two depths: 0 - 15 cm (surface soils) and 15 - 30 cm (subsurface soils) along different locations of the landscape in the four study locations spanning Khana (Bono Ogoi, Okloma, Bolem, Kporghor and Sim luekon); Gokana (K-Dere, Biara, Yeghe, Barako and Kiani); Eleme (Akpajo, Ejaka, Ogali, Agbonchia and Onne); and Tai Local Government Areas (Okwale, Luuku, Kpang, Bere and Kani) within the Ogoni region, Rivers State. These communities were systematically chosen to represent local government headquarters, areas of major oil production facility and areas without an oil production facility.

The soil samples collected were air-dried (room temperature), ground with wooden roller and sieved via 2 mm mesh. Particle size distribution was determined by Bouyoucos hydrometer method [7] using sodium hexa-metaphosphate as a dispersant and the textural classes determined using the textural triangle chart.

Soil pH was determined using the method of IITA [8]. The method of [9] was used in the determination of organic carbon. Available phosphorus was determined using [10] No. 1 method. Total nitrogen was determined by the micro-Kjeldahl digestion method. Exchangeable bases (Ca, Mg K and Na) were extracted with neutral IM NH4 OAc, pH 7.0; the potassium and sodium in the extract was by flame photometry while calcium and magnesium was by Versenate EDTA titration method [8]. Cation exchange capacity (CEC) was obtained by the summation of exchangeable bases. Heavy metal contents of the soils were extracted by digestion of the samples with a mixture of concentrated HN03 and HCl and their concentrations determined by Atomic Absorption Spectrophotometry (AAS) using "Buck Scientific 200A" by flame atomization [11]. Total hydrocarbon (THC) was determined by extracting the soil with carbon tetrachloride and measuring the total hydrocarbon content calorimetrically at 420 nm using spectronic 20 (**Table 1**).

4. Hypotheses

1) **H0**: Soil physical properties do not significantly vary in the study locations.
H1: Soil physical properties significantly vary in the study locations.
2) **H0**: Soil chemical properties do not significantly vary in the study locations.

Table 1. Methods and equipment for physico-chemical analyses.

Analytical equipment/method and reference	Parameter (s)
Cyberscan pH 20 meter	PH, Eh
Cyberscan low 20 conductivity meter	Temperature, conductivity, TDS
Microprocessor Oximeter 196	Dissolved Oxygen (DO)
Atomic Absorption Spectrophotometer (ASS)	K, Na, Heavy metals
Spectrophotometrically by:	
(a) Turbidimetry using barium chloride [12]	Sulphate, SO_4^{2-}
(b) Diazotisation method [13]	Nitrite (NO_2)
(c) As nitrite after reduction in a calcium reduction system [13]	Nitrite (NO_3)
(d) Molybdenum blue method [13].	Phosphate (PO_4^{3-})
(e) Formazine standards according to HACH	Turbidity (NTU)
(f) Nesslerization method [12]	Ammonium (NH_4^+)
Titrimetrically using:	
(a) Silver nitrate and potassium dichromate as indicator [14]	Chloride (Cl)
(b) Complexometric technique using EDTA as Titrant [12].	Calcium (Ca), Magnesium (mg)
(c) Titration using indicators like muraxide etc.	Total hardness, bizabonate and alkalinity
Difference between initial oxygen concentration in sample and concentration after 5 days incubation in DO bottles at 20˚C [12]	Biochemical Oxygen demand, BOD5

H1: Soil chemical properties significantly vary in the study locations.

Estimates in variation of soil physical characteristics (sand, silt, and clay contents) were analysed using analysis of variance (ANOVA) for the four different sites across the study locations. Thus, ANOVA was adopted to see if variation occurs in sand, silt and clay contents across sites.

5. Results and Discussion of Findings

5.1. Physical Characteristics of the Soil

The physical properties of the soils sampled from the prescribed study area are summarized in **Table 2**. The sand, silt and clay fractions varied in texture along the sampling locations. The texture of the soils sampled along the stations varied from sandy loam and loamy sand texture depending on the pedogenesis and edaphic features of the study area. Soil texture determines water intake, storage capacity, ease of tillage and amount of aeration influencing its fertility capability and status [15].

Sand fractions ranged from 67.28% to 77.01% with a mean value of 82.80% (surface soils) and between 64.92% to 76.11% with a mean of 68.74% (subsurface soils); Silt from 12.90% to 28.46% and 13.20% to 29.24% with means of 20.23% and 21.78% respectively; clay contents from 1.90% to 14.90% and 2.54% to 24.62% with means of 7.19% and 9.48% respectively for surface and subsurface soil samples collected from the study area (**Table 2**). This high sand content of the soils is characterized by sand formed on unconsolidated coastal plain sand and sandstones. Since sandy soil is not fit for crop production, the presence of oil-spill which significantly increased the percentage sand has adverse effect on the fertility of the affected soils. This is as a result of a probable high drainage of oil into the lower horizon of the soil causing aeration problem as the air pores get blocked with oil, which prevent the easy flow of nutrients to the soil (**Figure 2**). The soils are characterized as coarse-textured with a high proportion of sand fraction exceeding 70%. Such soils lack adsorptive capacity for basic plant nutrients and water. Consequently, such soils have weak surface aggregation and are vulnerable to erosion [15].

5.2. Chemical Characteristics of the Soil

The chemical properties of the soils under study are summarized in **Table 3** in relation to the sampling stations. Basically, results obtained from laboratory analyses were compared with acceptable conditions under which crops can thrive in the study area [8]. It is discussed under the following nutrient concentrations:

5.2.1. Soil pH

Soil pH is fundamental to the understanding of soil systems, because it is an indicator of many reactions in the soils. It shows whether the soil is acidic, neutral or basic and provides useful information on the availability of the exchangeable

Table 2. Physical properties of the soil in Ogoni region, rivers state.

Parameter (%)	KHANA LGA				GOKANA LGA				ELEME LGA				TAI LGA			
	Surface soils		Sub-surface		Surface soils		Sub-surface		Surface soils		Sub-surface		Surface soils		Sub-surface	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Sand	69.11 - 79.18	73.37	67.24 - 72.20	69.97	72.22 - 79.99	75.62	70.06 - 72.26	71.20	67.28 - 79.01	71.96	62.18 - 76.11	68.41	66.11 - 77.71	72.35	62.79 - 70.42	67.09
Silt	18.10 - 22.76	20.08	19.84 - 24.04	21.24	18.13 - 20.11	18.69	15.28 - 26.26	18.58	12.90 - 28.46	20.98	13.20 - 29.29	22.02	14.18 - 20.12	17.81	16.02 - 26.10	20.89
Clay	1.63 - 9.77	6.55	7.66 - 9.98	8.78	1.75 - 7.67	5.69	1.48 - 14.66	8.22	1.90 - 14.90	27.42	2.54 - 24.62	9.57	7.43 - 13.77	9.84	5.13 - 17.71	12.02
Texture	Loamy sand		Sandy loam		Sandy loam		Loam sandy		Sandy loam		Loam sandy		Loamy sandy		Sandy loam	

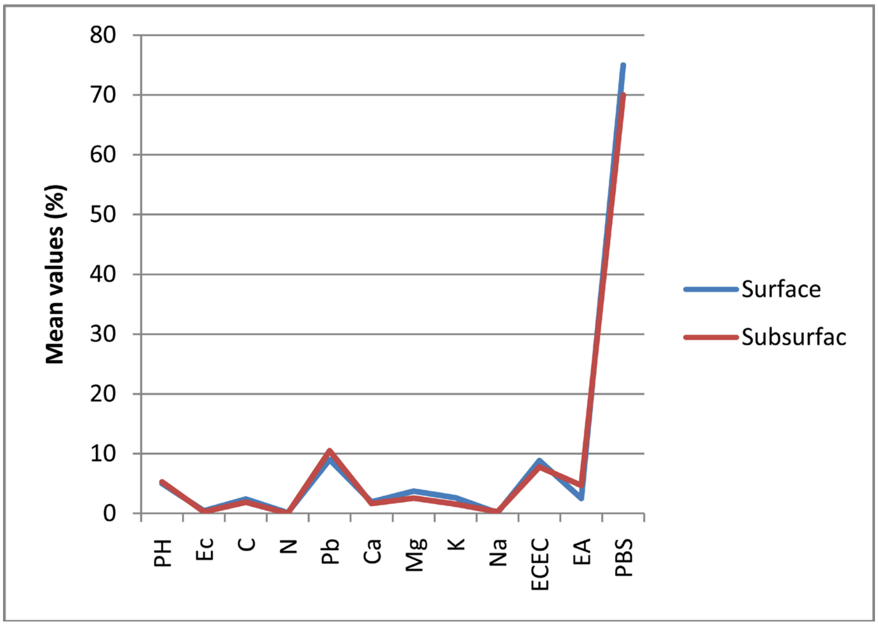

Figure 2. Soil physical properties in Ogoni region.

cations. Soil pH controls plant nutrient availability and microbial reactions in soils. The pH of the air-dried soils ranged from 4.2 to 5.8 (surface soils) and 4.2 to 5.6 (subsurface soils) with means of 5.0 and 5.3 respectively (**Table 3**) within Khana, Gokana, Eleme and Tai study locations. This depicts strong acidity in the ecological zone. The project environment is strongly acidic across the sampling stations due to the leaching of basic cations from the soil *solum*. Such acidic soil condition can induce phosphate fixation and consequently reduce the ability of microbes to fix atmospheric nitrogen. The strong acid condition indicates that certain elements such as Zinc, Iron, Manganese and Aluminium are available in soils of the study environment. The soils are all slightly acidic and this acidity cannot be attributed entirely to the oil spill since other non-oil producing areas such as Yeghe and Kpong are equally acidic. The acidity is typical of the soils of southern part of Nigeria and is ascribed to the excessive precipitation which leads to leaching loose of most of the basic cations in the soil [16].

5.2.2. Electrical Conductivity (EC)

The electrical conductivity values varied from 0.025 to 0.049 dSm^{-1} (surface soils) while 0.026 to 0.500 dSm^{-1} were recorded for the subsurface soil samples in all the sampling stations (**Table 3**). This range of values indicates that the soils are non-saline as all the values along the stations are below 4 dSm^{-1} [17] and do not exceed the critical value of 2 dSm^{-1} for sensitive crop species [18]. These results suggest that the soils do not have salinity problem.

5.2.3. Organic Carbon and Total Nitrogen contents

Carbon is an essential plant nutrient and the foundation of all life [19]. Carbon compound are enzymatically oxidized to produce carbon dioxide, water, energy, and decomposer biomass. Soil organic matter contributes to soil aggregation and

Table 3. Nutrient concentration of the soils in Ogoni region, rivers state.

Parameter (%)	KHANA LGA				GOKANA LGA				ELEME LGA				TAI LGA			
	Surface soils		Sub-surface		Surface soils		Sub-surface		Surface soils		Sub-surface		Surface soils		Sub-surface	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
pH	4.3 - 5.7	4.9	4.2 - 5.4	5.0	4.2 - 5.5	5.0	4.9 - 5.6	5.3	5.2 - 5.8	5.5	5.0 - 5.2	5.1	5.1 - 5.6	5.3	4.6 - 5.3	5.1
Ec (dSm)	0.025 - 0.004	0.037	0.040 - 0.043	0.043	0.036 - 0.043	0.043	0.026 - 0.039	0.039	0.034 - 0.042	0.039	0.037 - 0.040	0.038	0.035 - 0.040	0.040	0.033 - 0.043	0.045
Org Carbon	1.21 - 3.53	2.19	1.00 - 2.10	1.89	1.29 - 2.41	1.76	1.01 - 1.40	1.14	1.00 - 3.15	2.19	1.20 - 2.18	1.92	1.78 - 3.80	2.74	1.00 - 2.79	2.02
Tot nitrogen	0.03 - 0.07	0.05	0.03 - 0.05	0.04	0.04 - 0.07	0.06	0.02 - 0.05	0.04	0.04 - 0.07	0.05	0.03 - 0.05	0.04	0.04 - 0.08	0.06	0.04 - 0.06	0.05
Phosphorus	8 - 12	10	8 - 12	9	7 - 12	10	8 - 12	9	7 - 9	10	7 - 14	10	6 - 12	1.65	0.96 - 2.01	1.35
Calcium	1.77 - 3.22	2.45	2.05 - 3.01	2.46	1.24 - 2.79	2.26	1.21 - 2.90	2.15	0.88 - 1.42	1.24	0.40 - 1.98	1.33	0.56 - 3.11	1.65	0.96 - 2.01	1.35
Magnesium	1.44 - 3.62	2.59	1.20 - 2.65	2.08	1.40 - 2.80	1.38	1.00 - 2.96	1.45	1.90 - 2.43	2.15	1.84 - 2.38	2.20	1.79 - 6.24	3.21	1.09 - 4.11	2.13
Sodium	0.09 - 0.26	0.132	0.06 - 0.18	0.12	0.01 - 0.20	0.10	0.07 - 0.28	0.13	0.07 - 0.09	0.08	0.06 - 0.09	0.07	0.07 - 0.24	0.11	0.05 - 0.11	0.07
Potassium	1.40 - 3.11	2.38	1.93 - 3.11	2.49	1.09 - 2.19	1.71	1.00 - 1.77	1.22	1.00 - 2.15	1.71	0.08 - 2.00	1.41	1.22 - 2.19	1.73	1.04 - 2.67	1.62
Exc acidity	2.66 - 3.81	3.12	1.79 - 8.06	5.57	1.31 - 3.00	2.29	1.26 - 2.18	1.95	2.07 - 3.18	2.56	2.00 - 3.19	2.28	1.22 - 3.40	2.19	1.24 - 3.40	2.13
ECEC	9.74 - 1167	10.65	9.19 - 10.92	9.70	5.87 - 9.52	8.19	5.63 - 8.44	6.90	7.11 - 8.40	7.80	5.89 - 9.37	7.28	6.66 - 12.12	8.89	4.77 - 9.92	7.29
Base sat	65 - 76	10.67	63 - 81	76	65 - 81	72	63 - 85	71	60 - 73	66	64 - 74	68	64 - 90	75	55 - 83	70

reduces susceptibility to erosion [20]. The organic carbon in soils of the study area ranged from 1.00% to 3.80% and between 1.00% to 2.79% for surface and subsurface soils respectively across the prescribed stations (**Table 3**). Such soils are rated medium in fertility status [21]. The results indicate that organic carbon decreases with depth in all the stations used for this study. From the results, Tai station recorded the highest level of organic carbon contents, while the lowest content was obtained in Eleme, Tai and Khana of the ecological zone. Thus, in spite of the level of pollution, the soils can sustain crop production in the ecological zone.

Nitrogen in the form of protein is present in the protoplasm of every cell. The available form of Nitrogen in the soil is ammonium or nitrate ion. Total nitrogen varied from 0.03% to 0.08% and 0.02% to 0.06% for surface and subsurface soils respectively in all the stations sampled for this study (**Table 3**). This range of values is rated low when compared with the medium range of 0.10% to 0.45% [21] for soils of the area under study. In a similar manner, total nitrogen decreases with depth in all the stations where the samples were collected. These locational ranges of values is consistent with the works of [22] who reported average total percentage of 0.08 in soils of the Cross River Coastal plain sands and mean range of 0.10% to 0.14% reported by Abii and Nwosu [4] for surface and subsurface soils of Eleme in Rivers State. Thus, there is variation in the contents of total nitrogen in this ecological zone.

5.2.4. Available Phosphorus and Exchangeable Cations

Phosphorus is an essential part of nucleoprotein in the cells nuclei, which control cell division and growth, and of deoxyribonucleic acid (DNA) molecules. In the study environment, available phosphorous ranged from 6 to 12 mg kg^{-1} (surface soils) and between 7 to 14 mg kg^{-1} for the subsurface soil samples (**Table 3**). Available P contents were generally moderate (*i.e.* polluted, but not significantly) in all the stations as values are below 15 mg kg^{-1} [15]. This range of values is consistent with the findings of Ekundayo [16] who reported near mean value of 10 mg kg^{-1} for arable soils of South-Eastern Nigeria.

The exchangeable cations (Ca, Mg, K and Na) are positively charged ions usually absorbed by electrostatic or columbic attraction to soil surface colloids. Plants absorb it in exchangeable form [21]. The exchangeable cations for the surface soils were as follows: Ca (0.56 - 3.22 cmol kg^{-1}); Mg (1.09 - 6.24 cmol kg^{-1}); K (1.00 - 3.11 cmol kg^{-1}) and Na (0.01 - 0.26 cmol kg^{-1}). Conversely, the following values were recorded for the subsurface soils: Ca (0.40 to 3.01 cmol kg^{-1}); Mg (1.00 - 4.11 cmol kg^{-1}); K (0.08 to 3.11 cmol kg^{-1}) (<10.0 cmol kg^{-1}) for both surface and subsurface soils. Magnesium was moderate for both seasons and Na (0.05 to 0.28 cmol kg^{-1}) (**Figure 3**); K was considerable (>1.2 cmol kg^{-1}) in both surface and subsurface soils and Na was within the permissible limits (>0.3 cmol kg^{-1}) (**Table 3**). Thus, there is a slight locational difference among the exchangeable bases in soils of the environment. In sum, there is a low cation reserve in the soils.

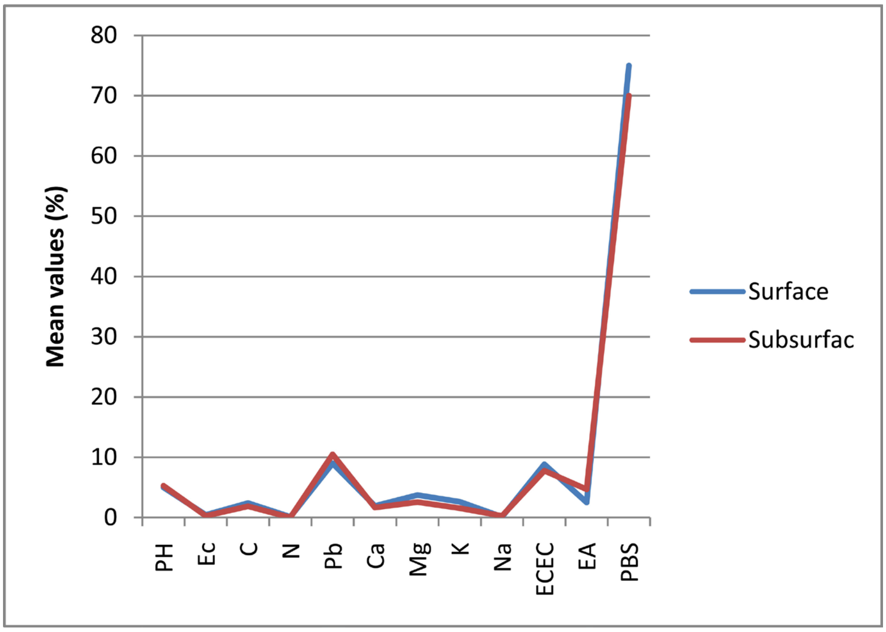

Figure 3. Chemical characteristics of soil in the study area.

5.2.5. Effective Cation Exchange Capacity (ECEC)

Effective cation exchange capacity (ECEC) was very moderate in both surface and subsurface soils with range values of 5.87 to 11.67 cmol kg^{-1} recorded in the surface soils compared to range values of 4.77 to 10.92 cmol kg^{-1} for the subsurface soil samples (>10.0 cmol kg^{-1}).

5.2.6. Exchange Acidity (EA)

Exchange acidity value for the surface soils (1.22 in Tai LGA to 3.81 cmol kg^{-1} in Khana LGA) and subsurface soils (1.24 to 8.06 cmol kg^{-1}) were above range when compared with a medium range of 2.1 to 4.1 cmol kg^{-1} (Table 2), Albeit impact of Al^{3+} in the soil solution could be significant in terms of influencing the biochemical behaviour of these soils.

5.2.7. Percent Base Saturation (PBS)

Percent base saturation ranged from 60 to 90 and 55 to 85 for surface and subsurface soil samples respectively across the prescribed stations under study (Table 3). With the mean percentage base saturation above the threshold limits in surface and subsurface soil samples, basic nutrient must have occurred in available forms in soil solution in spite of the low cation reserves across the stations. This collaborate earlier results of Abii *et al.* [4] on the effect of oil spillage on the soil of Eleme, Rivers State, which indicated that base saturation range of 60 - 85 and 50 - 80 for surface and subsurface respectively.

5.3. Heavy Metal Status

The heavy metals status in soils of the study area is summarized in Table 4. Heavy metals exist in variable oxidation states, particularly those that belong to the d-group of the periodic table, each with different reactive, toxicological,

Table 4. Heavy metal and total hydrocarbon contents (THC) of Ogoni soils.

Parameter (%)	KHANA LGA				GOKANA LGA				ELEME LGA				TAI LGA			
	Surface soils		Sub-surface		Surface soils		Sub-surface		Surface soils		Sub-surface		Surface soils		Sub-surface	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Iron	3002.2 - 8112.0	5259.5	2660.3 - 6626.1	4242.9	426.1 - 3211.1	1796.4	262.1 - 3026.0	1606.4	1998.2 - 2671.1	2272.5	1779.1 - 2201.6	1591.98	2429.10 - 6701.04	4356.77	1264.0 - 4356.8	11594.8
Zinc	2.16 - 41.41	21.06	2.05 - 56.26	27.41	11.11 - 46.21	30.13	17.16 - 50.26	13.30	12.80 - 41.28	27.29	9.80 - 44.19	23.822	4.00 - 26.18	10.292	3.91 - 21.24	8.344
Copper	1.11 - 4.20	1.84	0.40 - 4.04	1.81	1.44 - 8.60	3.98	1.18 - 6.26	2.47	1.26 - 3.91	2.47	1.71 - 2.98	2.202	0.19 - 2.66	1.59	1.04 - 2.60	1.688
Chromium	1.07 - 4.11	2.13	1.00 - 2.26	1.70	1.09 - 2.16	1.46	1.01 - 3.36	1.71	2.04 - 3.98	3.03	1.06 - 3.08	1.862	1.04 - 6.26	2.594	1.00 - 3.68	2.16
Manganese	111.20 - 267.11	186.42	170.2 - 300.6	212.47	101.24 - 217.19	153.80	109.00 - 272.69	190.83	110.26 - 267.18	201.67	117.80 - 267.18	203.058	118.28 - 264.98	202.2	109.00 - 313.20	167.862
Cadmium	1.04 - 2.64	2.13	1.01 - 2.48	1.59	1.02 - 2.11	1.638	1.00 - 2.46	1.53	1.28 - 3.28	2.43	1.11 - 2.98	1.852	1.11 - 3.08	2.214	0.93 - 2.36	1.912
Nickel	11.20 - 28.60	22.70	10.96 - 23.11	17.24	11.41 - 26.67	17.55	9.81 - 23.03	15.18	11.28 - 26.34	18.27	10.00 - 19.20	15.09	11.60 - 28.74	18.264	0.80 - 26.09	15.074
Lead	10.70 - 24.24	18.42	12.04 - 20.10	15.71	4.11 - 21.17	11.998	2.00 - 21.11	10.51	1.26 - 21.11	11.03	1.80 - 20.12	9.442	1.80 - 28.10	14.0	2.14 - 20.08	11.942
Vanadium	2.12 - 4.18	2.97	2.01 - 4.10	3.04	1.41 - 2.46	2.066	1.06 - 2.14	1.40	2.19 - 6.24	4.04	2.18 - 6.86	4.884	4.12 - 8.28	5.954	4.00 - 8.96	6.016
THC	165.18 - 265.11	197.9	126.70 - 218.71	131.47	1.77.78 - 276.06	232.50	100.11 - 204.11	170.57	103.22 - 264.66	161.55	99.81 - 220.90	150.956	219.11 - 301.42	259.922	107.20 - 218 - 12	192.606

physiological and bioconcentration potential. Though some heavy metals, such as Cadium (Cd), Lead (Pb) and Zinc (Zn) are toxic in their cationic form, many others require biochemical transformation to organic metallic compounds [23].

5.3.1. Iron (Fe) and Manganese (Mn) Status

Iron is one of the most abundant elements in the earth's crust with variable oxidation states of +2 and +3 (Fe^{2+} and Fe^{3+}). In the study environment, mean iron contents ranged from 426.11 to 6701.04 mg kg^{-1} (surface soils) and between 262.06 to 6626.11 mg kg^{-1} for the subsurface soils (**Table 4**). The results show that iron contents were high in surface soils compared to the subsurface soils. This range of values is within the natural limits for mineral soil environment [20].

Manganese contents ranged from 111.20 to 313.20 mg kg^{-1} (surface soils) and between 109.00 to 313.20 mg kg^{-1} in the sub-surface soils (**Table 4**). There are mild variations in the mean contents of this parameter. In spite of these, manganese contents are within the tolerable limits established for mineral soil environment [20].

5.3.2. Copper (Cu) and Zinc (Zn) Status

Copper (Cu) is an essential micronutrient required for plant growth, and is normally found in soils only in trace amount. Copper can be retained in soils by adsorption via non-specific and specific interactions, as well as precipitation reaction with hydroxides, carbonates, phosphates and silicates [24]. In the study area, Copper contents varied from 0.19 to 1.44 mg kg^{-1} (surface soils) while the range value of 0.40 to 6.26 mg kg^{-1} were recorded for the subsurface soils (**Table 4**). Comparatively, mean copper contents were high in the surface soils compared to the subsurface soils of the study area. This range of values is within the maximum permissible limits of 2 - 100 mg kg^{-1} [25] established for mineral soil environment. With the low contents of Cu therefore, the study area is safe in terms of water quality, crop growth and ecological sustainability [24].

Zinc is mainly found in rock forming minerals. It could be present in industrial discharges and not considered very toxic to humans or other organism. The mean concentration of zinc in soils within the Ogoni kingdom varied from 2.16 to 56.26 mg kg^{-1} for the surface soils and 0.19 - 6.26 mg kg^{-1} for the subsurface soil samples (**Table 4**). Though, this dose of concentration is within the threshold limits of 10 - 300 mg kg^{-1} established for mineral soils [25].

5.3.3. Chromium (Cr) and Nickel (Ni)

Concentration of chromium varied from 1.00 to 6.26 mg kg^{-1} (surface soils) and between 1.00 to 3.68 mg kg^{-1} (subsurface soils) (**Table 4**). Comparatively, Chromium contents were slightly higher in the surface soils in contrast to the subsurface soils in the area (**Table 4**). Despite the concentration, it is still within the safe limits of 5 - 1000 mg kg^{-1} established for mineral soil environments [25] [26].

Nickel concentration in soils of the study area varied from 11.28 to 28.74 mg kg^{-1} and 10.00 - 26.09 mg kg^{-1} respectively for surface and subsurface soils (Table 4). Comparatively, Nickel was slightly higher in the subsurface soils in contrast to the subsurface soils. This range of values is within the allowable limits of 1 - 1000 mg kg^{-1} established for mineral soil environment [25] [26].

5.3.4. Lead (pb) and Cadmium (Cd)

Mean lead (Pb) contents are low and ranged from 1.26 to 28.10 mg kg^{-1} and 1.80 to 20.12 mg kg^{-1} for surface soils and subsurface soils respectively (Table 4). Thus, mild variation in Pb contents in soils of the study area was recorded. These values are within the maximum tolerable limits of 2 - 200 mg kg^{-1} for the soils ecological settings [25] [26].

Cadmium is a non-essential element that diminishes growth of organisms. It is widely spread but occurs in mild concentration and considered a potential *carcinogen*. The concentration of Cadmium varied from 1.02 to 3.28 mg kg^{-1} and between 0.80 to 26.09 mg kg^{-1} for surface soils and subsurface soils respectively (Table 4), though the concentration of Cadmium is within the tolerable limits established by FEPA [27].

5.3.5. Vanadium (V)

Vanadium contents varied from 1.41 to 8.28 mg kg^{-1} and 1.06 to 8.96 mg kg^{-1} for surface and subsurface soils respectively (Table 4). This range is within the threshold limits of 20 - 500 mg kg^{-1} for soils of the ecological zone under consideration [25].

5.3.6. Total Hydrocarbon Content (THC)

Petroleum is a naturally occurring complex mixture of organic compounds formed from decomposition of fossil materials overtime. Total hydrocarbon contents (THC) of the soils was very high as evident in the mean of 259.92 and 192.60 mg kg^{-1} in surface and subsurface soils respectively of the project area (Table 4). The high THC values above 100 mg kg^{-1} in the soils indicate that the soils are polluted by petroleum source contaminants [28].

In summary, despite the values of the heavy metals, the soils are within the threshold limits established in typical mineral soils [25] [20]. The high contents of nickel and vanadium (often associated with heavy metals) may be attributed to the activities in the region although the nature of the parent materials may not give sufficient explanation. Thus, the soils of the study area are declared contaminated by heavy metals and hydrocarbon toxicity. Taking cognizance of the sandy loam and loamy sand texture, medium organic carbon contents, the soils have weak surface aggregation and inherently low fertility status. Figure 4 further attempts a coefficient of determination, R^2 which is a measure of the total variation in surface soils in Ogoni region that is explained statistically or determined by the distribution of subsurface soil. Therefore, a coefficient of determination, R^2, of 0.005 and 0.001 for both surface and subsurface respectively indicates that none of the variation in surface soil can be attributed to a linear

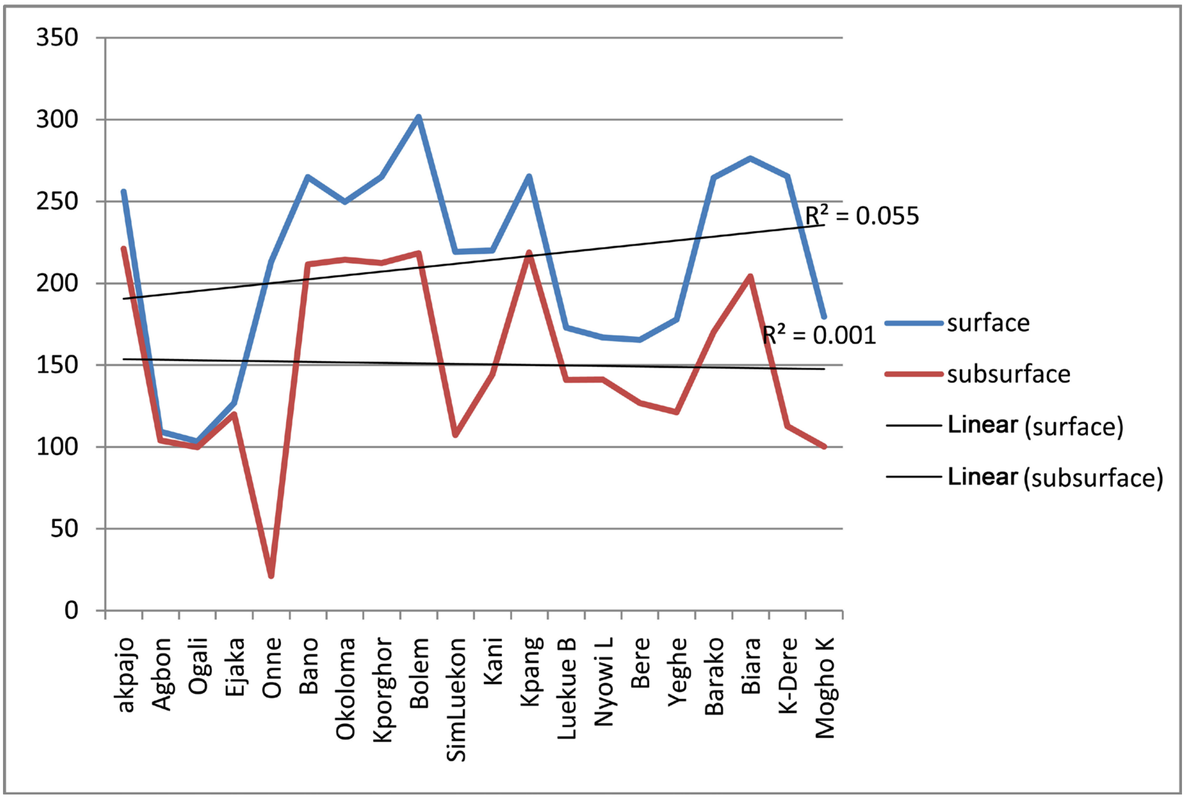

Figure 4. Graph showing total hydrocarbon content (THC) of soils in the study area.

relation with the subsurface soil. The results also show a none-linear relationship in different soil texture, though with high variation between sample points.

5.4. Test of Research Hypothesis 1

5.4.1. Hypothesis 1

H_0: Soil physical properties do not significantly vary in the study locations.

H_1: Soil physical properties significantly vary in the study locations.

Estimates in variation of soil physical characteristics (sand, silt, and clay contents) are succinctly presented in Table 5 using analysis of variance (ANOVA) for the four different sites across the study locations. Thus, ANOVA was adopted to see if variation occurs in sand, silt and clay contents across sites. From the result, sand, silt and clay contents significantly vary in Eleme, Tai, Khana and Gokhana as evident in the calculated F-ratios of 307.6958; 606.7196; 1312.3140; and 1154.0230 respectively against the tabulated F-ratio of 3.3541 at reflected by the wide variations in sand, silt and clay fractions, probably owing to differences in parent material, influence of the 1% level of significance (see Table 5). Therefore, the alternate hypothesis that soil physico-chemical properties significantly vary in the study locations is accepted. The results posit that soil physical characteristics changes with site as (1998) in the Niger Delta significantly show wide variations based on the reasons outlined earlier. Soil physical parameters are relevant in understanding the genesis, their lithology and its morphological features.

Table 5. ANOVA summary results showing variations in soil physical characteristics

Source of variation	Sum of squares	Df	Mean square	F-ratio	D-value
		Eleme site			
Between Groups	21,226.15	2	10,613.08	307.6958***	2.16886E−19
Within Groups	931.2867	27	34.4921		
Total	22,157.44	29			
		Tai site			
Between Groups	20,211.97	2	10,105.99	606.7196***	
Within Groups	449.7327	27	16.6568		3.63197E−23
Total	20,661.71	29			
		Khana site			
Between Groups	23,232	2	11,616	1312.3140***	
Within Groups	238.9916	27	8.8515		1.27641E−27
Total	23,470.99	29			
		Gokana site			
Between Groups		2	12,448.13	1154.0230***	
Within Groups		27	10.7867		7.10267E−27
Total		29			

Note: F-critical = 3.3541; *** = significant at 1% level.

5.4.2. Hypothesis 2

H_0: Soil chemical properties do not significantly vary in the study locations.

H_1: Soil chemical properties significantly vary in the study locations.

The summary result of the soils around the Ogoni area is shown in Table 6 based on the locations where the soils were sampled. Essentially, the analysis of variance (ANOVA) was used to test the extent of variance in the chemical properties. The choice of ANOVA was informed by the nature of the soils around the operating oil companies. The results presented indicates that the soils vary widely in chemical characteristics in Eleme (F-ratio = 1674.1630; $p < 0.01$; F-critical = 1.8784); Tai (F-ratio = 82.6671; $p < 0.01$; F-critical = 1.8784); Khana (F-ratio = 1467.6620; $p < 0.01$; F-critical = 1.8784) and Gokhana (F-ratio = 709.4864; $p < 0.01$; F-critical = 1.8784) against the theoretical value as shown in Table 6. Therefore in testing this hypothesis, the alternate that chemical property of soil vary across different study locations in the study area. Clearly, the variation in the chemical properties in all the sites sampled may be ascribed to variation in the soil parent material, the stage of pedogenetic formation where the soils were formed. Thus, an understanding of the chemical characteristics is guided mostly by the factors outlined above.

5.5. Testing of Research Hypothesis

The results posit that soil physical characteristics which are relevant in understanding the genesis, their lithology and their morphological features changes with site as at (2010) in the Niger Delta significantly show wide variations based

Table 6. ANOVA summary result showing variations in soil chemical characteristics.

Source of variation	Sum of squares	Df	Mean square	F-ratio	D-value
		Eleme site			
Between Groups	39,001.50	11	3545.5910	1674.1630***	3.2E−115
Within Groups	228.7255	108	2.117829		
Total	39,230.22	119			
		Tai site			
Between Groups	41,360.01	11	3760.0010	82.6671***	4.35016E−47
Within Groups	4866.7490	108	45.48363		
Total	46,226.76	119			
		Khana site			
Between Groups	44,713.15	11	4064.8320	1467.6220***	3.7745E−112
Within Groups	299.1246	108	2.7696		
Total	45,012.27	119			
		Gokana site			
Between Groups		11	3996.32	709.4864***	2.77665E−95
Within Groups		108	5.632694		
Total		119			

Note: F-critical = 1.8784; *** = significant at 1% level.

on wide variations in sand, silt and clay fractions, and probably owing to differences in parent material. Clearly, the variation in the chemical properties in all the sites sampled may be ascribed to variation in the soil parent material and the stage of pedogenetic formation. Thus, an understanding of the chemical characteristics is guided mostly by the factors outlined above.

6. Conclusions

The physical properties of the soils sampled in terms of sand, silt and clay fractions varied in texture along the sampling locations. The texture of the soils sampled along the stations varied from sandy loam and loamy sand texture depending on the pedogenesis and edaphic features of the study area. For example, Tai and Khana LGAs correspond to areas with loam sandy and sandy loam for surface and subsurface soils respectively, while Gokana and Eleme LGAs indicates sandy loam and loamy sand respectively for surface and subsurface soils. The soils are characterized as coarse-textured with a high proportion of sand fraction exceeding 70%, 22% for silt and 8% for clay fractions. Thus, the soils of the prescribed study area are declared contaminated by heavy metals and hydrocarbon toxicity, though contaminated by metals but not significant. Also taking cognizance of the sandy loam and loamy sand texture, medium in organic carbon contents, the soils have weak surface aggregation and inherently medium in fertility status.

From the result, sand, silt and clay contents significantly vary in Eleme, Tai, Khana and Gokhana as evident in the calculated F-ratios of 307.70; 606.72;

1312.31; and 1154.02 respectively against the tabulated F-ratio of 3.35 as reflected by the wide variations in sand, silt and clay fractions, and probably owing to differences in parent material. Conversely, the summary result of the soils around the Ogoni area based on the locations where the soils were sampled. The results presented indicate that the soils vary widely in chemical characteristics in Eleme (F-ratio = 1674.16; $p < 0.01$; F-critical = 1.88); Tai (F-ratio = 82.67; $p < 0.01$; F-critical = 1.88); Khana (F-ratio = 1467.66; $p < 0.01$; F-critical = 1.88) and Gokhana (F-ratio = 709.49; $p < 0.01$; F-critical = 1.88) against the theoretical value. Therefore, the alternate hypothesis that soil physico-chemical properties significantly vary in the study locations is accepted.

7. Recommendations

The oil industry has undoubtedly brought economic benefits to many people, but it has left its trail a complex mix of environmental pollution problems, the most notable of which is oil pollution and physical destruction of landscape. Preventing environmental degradation is a task that must be vigorously pursued judging from the enormous economic loss and environmental destruction arising from oil exploration, transportation and marketing. From the findings in this study, the following recommendations are therefore made:

1) There is need to ensure effective enforcement of National Environmental Standards Agency (NESA) regulation, guidelines and standards, which arises from researches and critical observation of environmental situation in the oil producing areas.

2) In order to protect and preserve our environment from pollution caused by petroleum related operations, a long term and comprehensive environmental monitoring programme should be instituted. The monitoring programme however should have as its basis the provision for establishment of comprehensive environmental base data in Nigeria.

3) There is need for the inclusion of communities in the echelon of oil spill management. The role of the communities committee, which will be made up of all stakeholders of the producing areas can be affected through a community oil spill committee. The General operational guidelines of the committee may be provided by the government through the Nigerian National Petroleum Corporation.

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