



Crude Oil Spills: Effects on Soil Environment and Land Use Pattern in Acid Sand of Akwa Ibom State, Nigeria

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Article History

Received: April 21, 2020

Revised: May 12, 2020

Accepted: May 18, 2020

Published: May 19, 2020

Abstract

Crude oil spills generate a lot of emotional outburst with, very often, some political undertones. Concerns over the soil environment and land use pattern of increasing oil spillage on land and wetlands have mounted with time since oil prospecting started in Nigeria. Crude oil spillage could result in a number ways. One of such is during the process of drilling an oil well when oil well blowout could occur. The other source of spillage is pipeline leakage or malfunction. This research therefore, aimed at assessing the effects of oil spills on the physical attributes of the soil as its effects the land use pattern in oil producing areas of Nigeria. The soil physical disruption of aggregates following spillage in the field is reflected in the reduced aggregate size and water stable aggregate in the soils. Before the spill, stable aggregates of < 2 mm recorded significantly high resistance to erosion. Whereas, the moment the spill occurred, some locations suffered 250% reduction, while some 14% and others 21%. However, increase in aggregates >2 mm after wet sieving increased the initial Mean Weight Diameter (MWD) by 50, 63, and 81% under, Ikot Udo, Ebe Ekpi and Esit Eket spill sites, respectively. As variations in water aggregates of the soil were recognised, the following results on the magnitude of stable aggregates to water were measured at the sites of recently spilled soils; the least class size (0.25 mm) of stable aggregate at Ikot Udo showed an increase of 3.7 percent stable aggregates, 3.5% stable aggregates were measured at Ebe Ekpi, and 3.2% stable aggregates at Esit Eket, relative to the control site. The fact that this granulated soils severely erode under intense storms that caused high runoff in control site suggests that spilled sites are more important in accentuating runoff by sealing the pore spaces by adsorbed oil and grease from the spills, which consequently decreased infiltration rate.

Keywords: Environment; Structure; Aggregates; Flood; Flocculation; Infiltration.

1. Introduction

Either by design or by an accident of nature, it is an incontrovertible fact that Nigeria is a nation richly endowed with oil [1]. Crude oil, or petroleum hydrocarbons as it is often called because of its predominant make-up of carbon and hydrogen, is not a specific single mineral substance [2]. There are many types of crude oil having widely different properties [3]. Such differences of crude oil are related to their behaviour and degradation on spillage [4]. However, crude oils can be divided into heavy and light crudes. The former has API gravity of the order greater than 10 and it is heavier and sinks. It is lighter and floats on water, if the API gravity less than 10 [5].

The Nigerian oil contains light percentage of naphthenic hydrocarbons with ring structures and higher specific gravity of more residues boiling over 370°C [6]. Whether light or heavy gravity, crude oil has been considered as something foreign to the soil and the apparent long standing adverse effects of oil from pipeline leaks or spillages from oil locations on crops and soil environment [7].

The impression has often been given that once oil heavily pollutes land, it remains indefinitely [8]. This is not the case because microorganisms present in soils can attack crude oil and its refined products and break it down. Microbial decomposition of petroleum and petroleum products is of considerable importance. Since petroleum is a rich source of carbon and the hydrocarbons within it are readily attacked aerobically by a variety of microorganisms in soil, it is not surprising that when petroleum is brought in with air and moisture, the mixture is subjected to microbial attack and gets degraded [9].

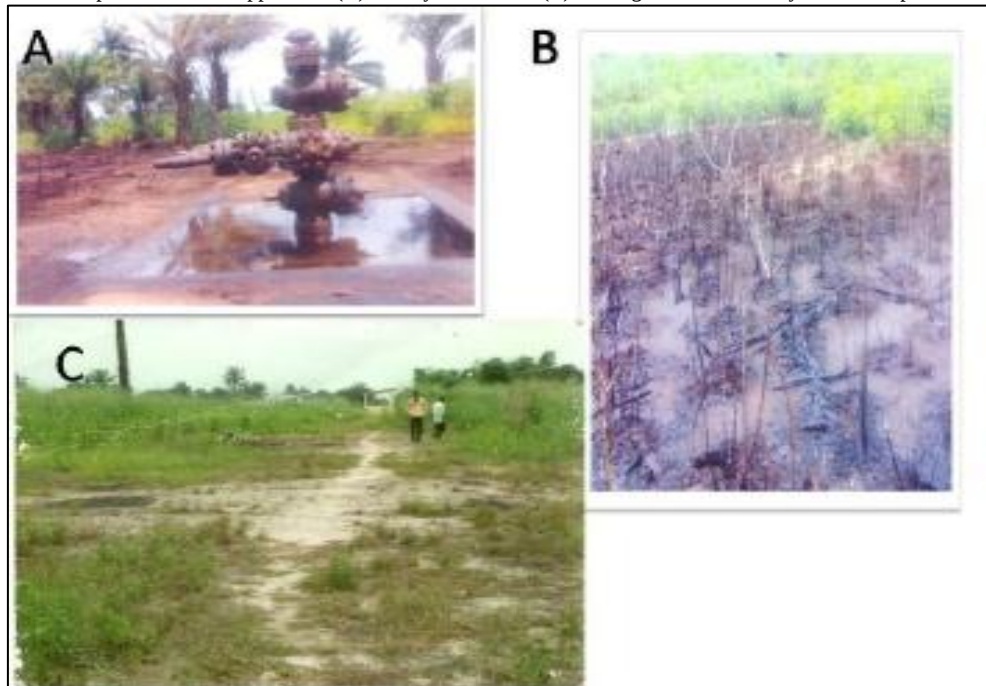
Oil pollution from the agricultural standpoint could be looked at from two angles: 1) Its effect on the soil environment, and 2) its effect on land use pattern. Our field and laboratory studies have revealed that oil on landing on the leaves of plants penetrates the leaves and interferes with its functioning chiefly by reducing transpiration and photosynthesis. Where oil pollution is light, the leaves become yellow and drop soon after, but under heavy pollution complete shedding of leaves results.

Oil by itself on polluting the soil is not toxic to plants but it exerts its adverse effects on plants indirectly by creating certain conditions which make nutrients essential for plant growth e.g. mineral- nitrogen (NH_4 and NO_3) unavailable to the plants, while the adverse conditions it creates in the soil makes some nutrients that are toxic to

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plants, like manganese more available to the plants. Oil Spillage is unsuitable for crop growth and depending on the degree of pollution, the soil may remain unsuitable for crop growth for months or several years (Plate 1).

Plate-1. Oil spilled from the capped well (A) destroyed farmland (B) and vegetation after five years in the spilled area (C)



However, crop growth is generally improved under slight pollution of the soil and this stimulation of crop growth is attributed to nitrogen fixation in the soil and addition of nutrients from oil-killed microorganisms or from the oil itself [10].

Just how long oil would remain in the soil is a very important question to be answered but unfortunately an outright answer cannot be given, this depends on the type of crude oil, the level or degree of pollution, the climate of the area and whether the soil is to be left to naturally rehabilitate itself or whether scientific principles for rehabilitation are to be applied. For example, in June this year, oil spill occurred at Idung Akpentuen (Esit Eket), and Ebe Ekpi communities where one of the tank farms and Oil Well 3 of Frontier Oil are located, respectively. Oil pollution of the magnitude that results in the soil being fully saturated with a pool of oil 10 or more centimeters over the surface in a wetland environment where soil aeration is very poor. With dismay of the communities being under severe pollution, the youth protested for immediate rehabilitation (Plate 2). According to Odu [11] natural rehabilitation could take much more than 25 years. However, by applying scientific principles coupled with earth movement as part of the operation, the area can be rehabilitated in a year or two.

Plate-2. Protesting youths of Esit Eket at the entrance of Frontier Oil locations to register their grievances over the recent oil pollution and flooding



2. Materials and Methods

2.1. Location of Study Area

This study was conducted in Esit-Eket. Esit-Eket is a town and Local Government Area of Akwa Ibom State, Southern Nigeria. The Eket/Esit-Eket. The area is bounded between 4°39'38"N 8°04'0"E / 4.66056°N 8.06667°E / 4.66056.

2.2. Climate

There are two main seasons in Akwa Ibom State; the wet and dry seasons, depending on the movement of the Inter-Tropical Discontinuity (ITD) which is the zone separating the warm humid maritime air mass with its associated South westerly winds from North easterly winds. The rainfall pattern is bimodal, with rainfall beginning in about early March and ends around mid-November. The wet season has features including high proportion of total annual rainfall, with peak in July and September with moisture stress period between 2-3 weeks in August, often called "August Break". The dry season has its existence between late November to early March with features like: very high temperature annual mean monthly temperature of 28°C to 30°C, having the period with highest temperature between January and March (described as a period of overhead passage of the sun), and harmattan with dry dusty wind between early December and late January. Uyo has a mean annual rainfall of about 2484mm, mean annual temperature of 27°C, with varying relative humidity through the year from 70-80% [12].

2.3. Geology and Soils

The state is underlain by one geological formation, the coastal plain sands comprising largely poorly consolidated sands [13]. They are dominated by low activity clays, low organic matter content and are susceptible to accelerated erosion and soil degradation [14].

2.4. Determination of Texture and Soil's Primary Particles

Particle size distribution was determined using Bouyoucos hydrometer method [15]. Measured 50 g of prepared soil sample was weighed into a mechanical stirrer cup and filled up to one and a half inch to the top by distilled water, and 20 ml of sodium hexamethaphosphate (calgon) was added to the mixture. The mechanical stirrer cup containing the suspension was replaced into a mechanical stirrer and stirred for 10 minutes. Thereafter, cup was removed and the whole content emptied into a measuring cylinder with the use of a wash bottle, water was topped to 1000 ml and the temperature (T_1) of the suspension was taken using a thermometer. The content of the cylinder was shaken vigorously before the hydrometer was slowly inserted into the suspension between 45 seconds and one minute for the hydrometer reading (H_1). After allowing the suspension to settle for two hours, another hydrometer reading (H_2) and temperature (T_2) were taken. Particle size distribution was then calculated thus:

$$\% \text{Sand} = 100 - (H_1 + 0.2 (T_1 - 20)2)$$

$$\% \text{Clay} = (H_2 - 0.2 (T_2 - 20)2)$$

$$\% \text{Silt} = 100 - (\% \text{Sand} + \% \text{Clay})$$

The individual primary particles from different locations were subjected to soil texture computer software for the determination of textural classes.

2.5. Determination of Bulk Density and Porosity

The internal diameter and the height of the core cylinders were measured before using them to take soil samples. The initial weight of the samples was taken (W_1). Thereafter, the core samples were placed directly in the oven at 105 °C to attain a constant weight (W_2). At this point, the dry soils were discarded from the cylinder and the weight of the empty core cylinders was taken. Soil Bulk Density was calculated from the mass-volume relationship, as described in Gulser and Candemir Gruber, *et al.* [16] thus:

$$\text{Bulk density (gcm}^{-3}\text{)} = \frac{\text{Mass of dry soil}}{\text{Volume of core cylinder}}$$

The total porosity of the soil was calculated from the bulk density data using the standard formula:

$$\text{Total porosity (\%)} = \left[1 - \frac{\text{Bulk density}}{\text{Particle density}} \right] \times 100$$

2.6. Determination of Aggregate Stability of the Soil Samples

This was done using the wet sieve method. A set of sieves 2 mm, 1 mm, 0.5 mm and 0.25 mm were placed on each other in descending order. Measured 100 g of undisturbed soil sample was placed on the topmost 2 mm sieve and the pack of sieves was carefully submerged into a 25 litre bucket of water until the sieves are completely covered with water and then removed. The procedure was repeated for 10 times and the soils trapped on each of the sieve fraction were carefully washed into moisture cans where they were oven dried and the dry soil recorded for each sieve fraction. This was then used to calculate the mean weight diameter of the soils.

2.7. Determination of Saturated Hydraulic Conductivity

This was done using the constant head permeameter method. The undisturbed soil samples were saturated by capillary for 24 hours. Before each determination, a cylinder core was securely held on the core sample using a masking tape. A funnel was placed on the tripod stand with a conical flask underneath it. The joint core cylinders were placed on the funnel, water was then poured into the upper cylinder and a constant head was maintained over

the soil for five minutes. The quantity of water collected during this time frame was then used in calculating the saturated hydraulic conductivity (K_s) of the soils as follows:

$$K_s (\text{cm hr}^{-1}) = \frac{qL}{\Delta H}$$

where q is calculated as:

$$q (\text{cm hr}^{-1}) = \frac{Q}{At}$$

Q = Volume of water that passed through the column in a given time (cm^3)

A = cross sectional area of the cylinder (cm^2)

And ΔH , the hydraulic difference between the top and bottom of cylinder is calculated as:

$$\Delta H = H_A - H_B$$

$$H_A = h + L$$

$$H_B = 0 + 0$$

$$\text{Therefore } \frac{\Delta H}{L} = \left(\frac{h}{L} + 1 \right)$$

2.8. Determination of Soil pH and Electrical Conductivity (EC_{25})

Soil pH was measured in 1:2.5 soil and water ratio using a digital pH meter [17]. Exactly 20 g of prepared soil was weighed into a 50 ml beaker and 20 ml of distilled water was added to it and allowed to stand for 30 minutes while stirring occasionally with a glass rod. The electrode of the pH meter was inserted into the partly settled suspension and the pH measured.

Electrical conductivity was determined in 1:2.5 soil and water ratio using conductivity bridge. About 20 g of prepared soil was weighed into a 50 ml beaker and 20 ml of distilled water was added to it and allowed to stand for 30 minutes while stirring occasionally with a glass rod. The electrical conductivity electrode was inserted into the partly settled suspension and the electrical conductivity measured.

2.9. Elemental Analysis of the Experimental Soil Samples

2.9.1. Organic Carbon

Organic carbon was determined using Walkley and Black wet oxidation method [18]. About 1 g of soil sample was weighed into an Erlenmeyer flask and 10ml of $K_2Cr_2O_7$ was added to it. 20 ml of concentrated H_2SO_4 was added and the suspension was swirled gently for a minute and then allowed to stand for 30 minutes. The suspended was diluted with 100ml distilled water and 5 drop of diphenylamine indicator added to it. This was then titrated with 0.5 N ferrous sulphate solution to light blue end point. The same procedure was repeated on a blank reagent without soil sample. Organic carbon was calculated as:

$$\% \text{ Organic carbon} = \frac{N(V_1 - V_2)0.3f}{w}$$

Where N = Normality of ferrous sulphate solution, V_1 = ml of ferrous ammonium sulphate required for the blank, V_2 = ml of ferrous ammonium sulphate required for the sample, w = mass of sample in gram and f = correction factor = 1.33

Thereafter, organic matter was calculated thus:

$$\% \text{ organic matter} = \% \text{ org. C.} \times 1.729$$

2.9.2. Organic Total Nitrogen

Organic Total nitrogen was determined using micro Kjeldahl digestion and distillation method [19]. Measured 2 g of finely ground sample was weighed into the Kjeldahl digestion flask. 10g of potassium sulphate (K_2SO_4), 0.5g of copper sulphate ($CuSO_4$) and 20ml of concentrated hydrogen sulphate (H_2SO_4) were added. The flask was then heated gently on a digestion stand until frothing subsided and then heated for 5 hours. The heat was regulated during the boiling time so that H_2SO_4 condenses about middle of the way up the neck of the flask. The flask was then allowed to cool and 20 ml of distilled water was added to it. The digest was thereafter transferred into a distillation and 20 ml of 20% NaOH was added to the flask. Boric acid (H_3BO_3) indicator was put in an Erlenmeyer flask and placed under the distillation apparatus and distillation was done immediately until the distillate reached 35 ml mark on the Erlenmeyer flask. Total nitrogen was then determined by titrating with 0.05N HCl until the colour changed from green to pink. Nitrogen was then calculated thus:

$$\%N = \frac{T \times M \times 14 \times 100}{wt \text{ of soil used}}$$

Where T = Titre value

M = Molarity of HCl

2.9.3. Available Phosphorus

Available phosphorus was extracted by Bray p-1 method of Bray and Kurtz as described by Brady and Weil [20] and phosphorus in the extract was obtained by blue colour method of Murphy and Riley as described by Nelson [18]. Three gram (3 g) of prepared soil sample was weighed into a shaking cup and 20ml of Bray P-1 solution (0.03M-NH₄F in 0.025M HCl) was added. The mixture was shaken using a mechanical shaker for 1 minute and thereafter filtered with Whatman filter paper. Applying the Murphy and Riley method of phosphorus extraction, 5 ml of the soil extract was pipette into a 50 ml volumetric flask and 8ml of reagent B was added. Distilled water was added to mark up a 40ml mark. The colour was then allowed to develop for 20 minutes and the absorbance was read at 650 nm matching it against a reagent blank.

2.9.4. Exchangeable Bases

Exchangeable bases were extracted using 1 N ammonium acetate. Exactly 58 ml of glacial acetic acid was added to 600 ml of distilled water in a 2 litre beaker and 70 ml of concentrated NH_4OH . The solution was then cooled and adjusted to pH of 7 with acetic acid using pH meter. The solution was thereafter transferred to a 1 liter beaker, mixed and stored in a pyrex reagent bottle and used for the determination of calcium and magnesium through EDTA (Ethylene diamine tetra acetic acid) titration as well as sodium and potassium measured by flame photometer.

2.9.5. Exchangeable Acidity

Exchangeable acidity was extracted with one normal potassium chloride solution (1NKCl).and acidity determined by titration as described by Thomas [21]. Soil sample measured 2.5 g was weighed into a shaking bottle and 50 ml of 1NKCl added to it. The solution was shaken on a mechanical shaker for 1 hour and then filtered with Whatman filter paper. 25 ml of the extract was pipette into a 250 ml conical flask and 50 ml of distilled water added to it as well as drops of phenolphthalein indicator. The solution was then titrated with 0.02N NaOH to a permanent pink end and the titre value recorded.

2.9.6. Effective Cation Exchange Capacity

Effective cation exchange capacity was obtained by summation method

$$\text{ECEC} = \text{TEB} + \text{EA}$$

TEB is total exchangeable bases, EA is exchangeable acidity

2.9.7. Base Saturation

Base saturation percentage was calculated using the equation

$$\%BS = \frac{\text{Total exchangeable bases}}{\text{Effective cation exchange capacity}} \times 100$$

2.9.8. Statistical Analysis

Data obtained in the study were analysed using GenStat (Discovery edition 3) statistical software. Soil data were compared among locations and significant means were separated by Duncan Multiple range test (DMRT) at 5% probability level.

3. Results and Discussion

3.1. Effect of Oil Spill on Soil Physical Parameters

3.1.1. Effect on Texture and Soil's Primary Particles

Details of the physical soil properties used for this study are shown in Tables 1. The textural classification of the baseline soil with Ebe Ekpi spilled sites were similar (sand) but significantly different from spilled sites of Ikot Udo and Esit Eket (loamy sand). Coarse sand content at the recently sites were in the trend of control > Esit Eket > Ikot Udo = Ebe Ekpi. However, CS content decreased significantly by 2.6, 9.9 and 12.4% respectively, at Ikot Udo (old spilled site), Ebe Ekpi and Esit Eket one month after the spill. Generally, the content of coarse sand particles in the control site was consistently higher than spilled sites. Relative to control site, fine sand increased significantly after the spill by 7.6% at Ikot Udo and Ebe Ekpi and 10.5% at Esit Eket. The silt fraction decreased significantly from 31.2 to 24.1 g kg^{-1} and 18.9 g kg^{-1} at the spilled sites and similar trend occurred in the clay content of the soil.

Since the extent to which the silt and clay separates were aggregated showed a correlation of 51.5% with organic matter and of 48.0% with clay. These results suggest that the colloids from the crude oil source did not only increase the aggregation of clay particles, but also enhances large aggregates. It is interesting to note that, even though the non-spilled sites were poorly aggregated, the amount of aggregates that present correlated with the small quantity of organic matter.

3.1.2. Effect on Bulk Density Porosity and Moisture Content

The bulk density of the soils was not significantly affected by the spill and the same trend was true for porosity. Further evaluation of the pore spaces distribution in terms of micro and macro pores revealed no significant difference in the distribution of micropore space in all the sites, except at Esit Eket that recorded slightly higher value of 0.22 m^3m^{-3} macro pore space against 0.19 m^3m^{-3} in the control.

The average available moisture content on the surface soil for plant absorption after spill significantly increased by 36.9% and 34.9% at Ebe Ekpi and Esit Eket respectively, when compared with control plot. This shows that oil at the early stage of spillage retained more water on the surface soil than the control site due to hydrophobicity.

The native soils are generally coarse textured and therefore exhibit low water and nutrients holding capacities, poor aggregation of soil particles resulting in susceptibility to erosion. Thus, making the fertility status of these soils low. The fact that this granulated soils severely erode under intense storms that cause high runoff in control site suggests that spilled site are more important in accentuating runoff by sealing the pore spaces, which consequently decreased infiltration rate. The deteriorating effect upon soil granulation has been recognized by most soil physicists [22, 23]. It was further observed that spill soil protects the soil from scouring influence of overland flow to such an extent that the content of larger pores was 34 to 53 per cent higher than that on adjacent un-spilled soils. The clogging influence of dispersed particles on soil porosity has been confirmed by several investigations [24].

3.1.3. Effect on Aggregate Stability

Aggregates distribution of soils by wet sieving under oil spillage is presented in Table 2. The Table shows the distribution of the wet stable aggregates size classes as affected by crude oil spill. There were significant differences ($p < 0.05$) in the distributions of water stable aggregates (WSA) among the spilled site within the periods of investigation. The soil physical disruption of aggregates following spillage in the field is reflected in the reduced aggregate size and water stable aggregate in the soils as presented in Table 2. Before the spill, stable aggregates of < 2 mm (micro-aggregates) recorded significantly high resistance to erosion. Whereas, the moment the spill occurred, Esit Eket suffered the highest (250%) reduction, 14% at Ebe Ekpi and 21% at Ikot Udo site.

However, increase in macro-aggregates (aggregates > 2 mm) after wet sieving increased the initial MWD by 50, 63, and 81% under, Ikot Udo, Ebe Ekpi and Esit Eket spill sites, respectively. As variations in water aggregates of the soil were recognised, the following results on the magnitude of stable aggregates to water were measured at the sites of recently spilled soils; the least class size (0.25 mm) of stable aggregate at Ikot Udo showed an increase of 3.7 percent stable aggregates, 3.5% stable aggregates was measured at Ebe Ekpi, and 3.2% stable aggregates at Esit Eket, relative to the control site,

The same premise held for 0.5 mm class size of stable aggregates, where soils at Ebe Ekpi held 2.6%, Esit Eket recorded 2.5% and Ikot Udo measured 1.2% held more stable aggregates to water than the control.

In other hand, percent stable aggregates to water of 1.0 mm class size at Ebe Ekpi soils (2.0%) was significantly higher than aggregates held at Ikot Udo (1.2%), and Esit Eket (1.1%). The control site consistently maintained the least stable aggregates (0.9). The results of 2 mm aggregate class size revealed that there was significant change in the quantity of stable aggregates to water at the three spilled sites. Assessment of the largest stable aggregates class size showed that soils at Ikot Udo recorded significantly high ($p < 0.05$) stable aggregates of 3.2% compared with to the other spilled sites 1.3% (Ebe Ekpi), 1.5% (Esit Eket).

Also, mean weight diameter (MWD) index of assessing stability of aggregates collaborated the significant superiority at Ikot Udo spilled site with 0.27 mm quasi-stable aggregation to water than the other sites. The trend of MWD of stable aggregates was in the order of Ikot Udo $>$ Esit Eket $>$ Ebe Ekpi $>$ control site.

3.1.4. Effect on Saturated Hydraulic Conductivity

As shown in Table 2, the baseline saturated hydraulic conductivity (K_{sat}) was moderately rapid, but when the spill occurred, the rates of K_{sat} on the soils significantly ($p < 0.05$) increased by 27 and 52.3%, respectively at Esit Eket and Ebe Ekpi. The highest (rapid) conductivity was noticed at Ebe Ekpi (8.56 cm hr^{-1}) followed by Esit Eket (7.13 cm hr^{-1}). K_{sat} ranged from 4.10 cm hr^{-1} in control site to 8.56 cm hr^{-1} Ebe Ekpi.

The decrease in infiltration rate and hydraulic conductivity in control site could be partly attributed to the sealing of capillary pores of the surface leaving behind the subsoil. It is important to remark also that sufficient emphasis has been placed upon the deteriorating action of oil in the soil in the long run. The immediate influence is confined to shallow layer in the surface of spilled soil and the structure was so broken down as it limits the air and moisture relations of the entire profile. According to Kirkby, *et al.* [25] and Toshihiro and Kathleen [26], water retention and transmission properties are pore-dependent, hydrophobicity and compaction tends to decrease pore continuity. Vanelislande, *et al.* [27], with Zhang, *et al.* [28] noticed that decrease infiltration rate was due to high bulk density, the formation of the surface seal due to crust formation. In general, high saturated conductivity of the soil at Ebe Ekpi would enhance ground water pollution. The characteristic of low permeability reduces the rate at which oil and oil water emulsion can move downward or laterally through the soil which is seen at the control site.

3.2. Effect of Oil Spill on Soil Chemical Parameters

The chemical properties of the soil samples collected from the spilled and control sites are presented in Tables 3

3.2.1. pH and Electrical Conductivity (EC_{25})

The pH (6.4 to 6.5- slightly acidic) of the surface soil layer of the spilled site did not differ from the control after spillage. The lower acidic values in the surface layers of soils indicate low degree of leaching. The soils pH values were moderately acidic that would be suitable for the cultivation of most arable crops. The pH was highly correlated with Ca levels in spilled plots and this may reflect the influence of oil spillage in retaining more of the calcareous materials in the soil during crude oil spill. Of the measured chemical properties, pH exhibited the least amount of variation. This is in consonance with Cox, *et al.* [29] that investigated variability of soil properties in fields similar to this study.

The electrical conductivity values of the soils ranged from 0.04 at Ebe Ekpi to 0.12 dS m^{-1} recorded at Esit Eket spilled site indicating that the soils were non-saline before and after the spilled.

3.2.2. Organic Carbon

After the spill, OC content significantly ($P < 0.05$) increased to 8.90 and 8.99 g kg^{-1} at Esit Eket and Ikot Udo, respectively and 9.27 g kg^{-1} for Ebe Ekpi soil. It is worthy of note that crude oil increases more than 24.8% the carbon content of the soil. The observed differences in the organic C content of the soils could have resulted from differences in the volume of oil within the field, accumulation of organic materials, and the rate of decomposition of the accumulated materials [20]. Earlier, Martens [30], and Tejada and Gonzalez [31], attributed the rate of decomposition of several components to the amount and quality of the biomass, the soil type, and quantity of clay minerals present in the soils. The significantly higher amounts of organic C content in the surface spilled sites might

be due to high rate of mineralization [32] of trapped eroded materials (soil and trash) in the field after spillage event, resulting from thick bio-filter tarp formed by on the soil surface [33, 34].

3.2.3. Total Nitrogen

Total nitrogen content observed in the control plot was significantly low relative to the spilled areas. The results of Total N at the spilled areas were 71 to 75 times (0.44 to 0.56 g kg^{-1}) higher than the baseline N. Corresponding values at old spilled site (Ikot Udo) was 0.46 g kg^{-1} , 0.56 and 0.44 g kg^{-1} for recently spilled site at Ebe Ekpi and Esit Eket respectively. This significantly high nitrogen content in spilled sites compared with no spilled site may explain the rather slow rate of total N loss from the soil after spillage.

3.2.4. Available Phosphorus

The available phosphorus concentrations for baseline, recently and old spilled sites are presented in Table 3. When the four phosphorus concentrations were compared, available P of old spilled area (Ikot Udo) was significantly higher (22.25 mg kg^{-1}) other areas followed by Esit Eket (16.32 mg kg^{-1}). There was no significant change in the concentration of available P between the control and the recently spilled site at Ebe Ekpi (14.25 and 14.92 mg kg^{-1})

3.2.5. Potassium

The results of Table 3 revealed that the potassium (K) content of the baseline soil did not differ among the sites visited. The average K values ranged from 0.31 at the control site to $0.37 \text{ cmol kg}^{-1}$ at Ebe Ekpi spilled site. The concentration of K was lowered by 16% at the recently spilled site but increased by 2% at the old spilled site.

3.2.6. Calcium

There was significant difference in Ca concentration among the sites after spillage. The concentration significantly increased from 4.80 to $5.20 \text{ cmol kg}^{-1}$ and $5.33 \text{ cmol kg}^{-1}$ at Esit Eket and Ebe Ekpi soils (recently spilled areas) and further to $6.40 \text{ cmol kg}^{-1}$ at the old spilled site of Ikot Udo. These portrays that, the concentration of Ca was significantly higher ($p < 0.05\%$) by 33% at the old spilled site and average of 8% in the recently spilled sites.

3.2.7. Magnesium

Exchangeable Mg varied from 1.60 to $2.13 \text{ cmol kg}^{-1}$ in the sites under investigation. It increased by 10 and 33% at the old and recently spilled sites respectively. This points out to the fact that crude oil increased basic cation of Mg in the soil.

3.2.8. Sodium

Though, there was no significant difference ($p > 0.05$) among the sites investigated with regards to the concentration of Na, and the trend was not similar to other exchangeable bases. The concentration of Na ranged from 0.05 to $0.07 \text{ cmol kg}^{-1}$ at the commencement of the experiment. At the end of the first cropping cycle, Na concentration varied from 0.15 to $0.31 \text{ cmol kg}^{-1}$ from recently spilled site of Ebe Ekpi to non-spilled site, respectively. However, when spillage occurred in the area Na decreased by 19.2% at the old spilled site and 63.1% at the recently spilled area. This shows that crude oil spillage enhances Na reduction in the soil.

3.2.9. Exchangeable Acidity

Exchangeable acidity (EA) level of the soil at the control sites was $1.67 \text{ cmol kg}^{-1}$ on 0-5 cm soil depth. The concentration of EA reduced significantly by 47.3, 10.7 and 14.6% at old spilled and the two recently spilled sites, respectively.

3.2.10. Effective Cations Exchanged Capacity (ECEC)

The baseline results of the surface soil showed that ECEC $9.17 \text{ cmol kg}^{-1}$. The percent increase of ECEC was in the order of Ikot Udo (10.97%) > Esit Eket (10.97%) > Ebe Ekpi (6.38%) with moderate coefficient of variation (CV = 22.7%).

3.2.11. Base Saturation of the Surface

Base saturation of the baseline surface (0-5 cm) soil depth was 83.7%. The results after spill showed that base saturation of the soil was greater (< 1%) by insignificant rate, with least coefficient of variation (3.4%).

4. Summary and Conclusion

Soil conditions at an oil spillage site are of primary importance. Even where potable groundwater underlies a site, available information shows that suitably graded soils can impede or eliminate downward migration of land-deposited oils.

Many pollutants are retained in soils by chemical and physical sorption onto the soil particle surfaces. Silts and clayey soils tend to have a greater sorptive capacity than sands.

No permanent damage to soil is thus expected except where oil completely submerges the soil in an area and poor drainage condition would prevent downward seepage of oil. Very heavily polluted soils can be easily reclaimed by applying scientific principles but very light pollutions of the order of 1% or below which in actual fact may be

beneficial to plant growth can be left for natural rehabilitation within 6 months and much higher concentrations of the order of 5% can easily be taken care of by farmers within the same period simply by the aeration effected by hoeing or cultivating the land.

From the agricultural and scientific points of view. Therefore, oil pollution is just a temporary setback to farming processes and during this period of temporary setback, the inhabitants of the area or the landowners may suffer a lot of inconveniences economically in terms of destruction of their crops and deprivation of their land from farming. This confirmed that poverty and environment are closely related. But worthy of note is the fact that human activities in oil exploration areas can make their environment a gold mine of riches or bedrock of poverty.

Table-1. Effects of crude oil spill on soil physical properties of the surface soils in Akwa Ibom State

Locations	Spill periods	Sand	FS	CS	Silt	Clay	Texture	BD	Micro P	Macro P	P	AWC
			g kg^{-1}					Mg m^{-3}			$\text{m}^3 \text{m}^{-3}$	
Control	Nil	906.6ns	385.2b	521.4c	31.2b	62.2a	Sandy	1.57ns	0.21ns	0.19	0.41	0.37a
Ikot Udo	> 5 years	873.4	365.7a	507.7b	31.3b	95.3c	LS	1.51	0.22	0.20	0.43	0.37a
Ebe Ekpi	Recent	900.0	425.7d	474.3a	18.9a	81.1b	Sandy	1.57	0.21	0.20	0.41	0.50b
Esit Eket	Recent	880.0	414.5c	465.5a	24.1a	95.9c	LS	1.56	0.21	0.22	0.41	0.51b
CV%		1.2	7.1	6.2	34.8	19.2		5.8	8.9	8.6	8.1	34.4

Means within a column followed by different letter (s) differ at the 0.05 probability level according to Duncan multiple range test (DMRT). ns is not significant. BD = bulk density, P = porosity, FS = fine sand; CS = coarse sand, LS= loamy sand AWC = available water content, CV = coefficient of variation

Table-2. Soil aggregates and saturated hydraulic conductivity as influenced by crude oil spill on soils

	Wet sieving	Spill locations			
Parameters	Aggregate sizes (mm)	Control	Ikot udo	Ebe Ekpi	Esit Eket
		Spill periods			
		Nil	> 5 years	Recent	Recent
	0.25	1.0a	3.7c	3.5bc	3.2b
	0.5	1.0a	2.5b	2.0b	2.6b
WSA, %	1	0.9a	1.1a	2.1b	1.2a
	2	0.4ns	0.4	0.2	0.3
	4	1.2a	1.5a	1.3a	3.2b
MWD, mm		0.08a	0.2b	0.18b	0.27c
Ksat, cm hr^{-1}		4.10a	5.09b	8.56d	7.13c

Means followed by different letter along the row are significantly different. WSA depicts water stable aggregates; MWD depicts mean weight diameter; Ksat depicts saturated hydraulic conductivity

Table-3. Effects of crude oil spill on soil chemical properties of the soils in Akwa Ibom State

Locations	Spill periods	pH	EC	OC	TN	Av P	K	Ca	Mg	Na	EA	ECEC	BS %
			dS m^{-1}	g kg^{-1}		mg kg^{-1}			cmol kg^{-1}				
Control	Nil	6.4ns	0.07ns	7.20a	0.36a	14.25a	0.36ns	4.80a	1.60a	0.31	1.65c	9.17b	83.70ns
Ikot udo	> 5 yrs	6.5	0.06	8.99b	0.46b	22.25c	0.31	6.40c	1.77b	0.26	1.44b	10.97c	86.40
Ebe Ekpi	Recent	6.5	0.04	9.27c	0.56c	14.92a	0.37	5.33b	1.73b	0.15	1.49b	6.38a	80.75
Esit Eket	Recent	6.5	0.12	8.90b	0.44b	16.32b	0.36	5.20b	2.13c	0.19	1.12a	10.71c	87.08
CV%		1.9	46.9	10.9	10.7	21.5	7.7	12.8	12.9	31.4	15.6	22.7	3.4

Means within a column followed by different letter (s) differ at the 0.05 probability level according to Duncan multiple range test (DMRT). ns is not significant. EC = electrical conductivity, OC = soil organic carbon; TN = total nitrogen; EA = exchangeable acidity; ECEC = effective cation exchange capacity; BS = base saturation; CV = coefficient of variation

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