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Effects of Varying Concentrations of Crude Oil on Some Physicochemical Properties of Agricultural Soil

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Authors' contributions

This work was carried out in collaboration among all authors. Author IFA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BBE and AFC managed the analyses of the study. Author AFC managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This research investigated the effects of varying concentrations of crude oil on some physicochemical characteristics of crude oil polluted agricultural soils from Igodan- Lisa, Oba-Ile and Ido-Ani areas of Ondo State, Nigeria. The soil samples were exposed to 1-4% (w/w) crude oil and analyzed monthly for six periods using standard physical and chemical analytical techniques. Results indicated that the physicochemical properties were altered. The physicochemical parameters varied with increase in the amount of crude oil spilled and time. The pH and moisture contents (MC) progressively decreased with increase in concentration of crude oil applied to the samples. Polluted soils had lower pH values (4.91- 6.17) and MC (15.24% to 26.83%) relative to control samples. The organic matter content increased with increased amount of crude oil spilled in

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the range of 6.65-10.93%. The organic carbon contents progressively increased with concentration of crude oil and sampling days. At 4% crude oil pollution, the organic carbon content in the samples were 6.04-8.28%, 5.39-7.82% and 6.05-8.21% for Igodan-Lisa, Oba-Ile and Ido-Ani soils respectively at 0-180 days of experiment. The changes in soil physicochemical suggested that soil integrity and quality is altered by crude oil contamination. The increased acidity with time also suggested the release of acidic metabolites in bioremediation by intrinsic microorganisms.

Keywords: Varying concentrations; physicochemical characteristics; agricultural soils; crude oil; bioremediation; soil quality.

1. INTRODUCTION

Oil and gas is a major resource and energy that has been driving the economy of Nigeria since about six decades when commercial exploitation of petroleum started. Apart from crude oil being the mainstay of the Nigeria's economy, industries also rely extensively on petroleum derivatives without which they cannot function and produce to optimal capacity. Agriculture which is the main occupation of the people of Ondo State provides the second largest support to the nation's economy. Unfortunately, the processes of exploitation, exploration, processing and storage as well as transportation of petroleum and its derivatives have resulted in enormous abuse of man's environment especially in the Niger-Delta Region of Nigeria, rendering farmlands to wastelands as a result of the toxic effects of spilled oil on agricultural lands.

Crude oil spillage into the environment is a common occurrence world over. The discharge of petroleum hydrocarbon and its derivatives is of greater dimension in the Niger Delta region due mainly to diverse human activities; including pipeline vandalisation, negligence during production operations and fuel tanker loading processes, corrosion and pipeline leakages and oil tanker terrestrial accidents. Pollution of the environment by petroleum occurs when petroleum or its derivatives are introduced or spilled into the environment at levels harmful either directly to the environment or indirectly to the dependents of the environment [1].

Soil is a primary receiver of crude oil spill as well as many different types of products and chemicals such as herbicides, biocides and pesticides which are hydrocarbon products. Soil can be defined in many ways to suit different professions and purposes. To the agriculturist, soil is a medium for growth, anchorage for plants, providing nutrients (macro and micro), water and air necessary for plant growth, crop production and profitable agriculture [2]. Soil also provides habitat for micro flora and micro fauna and a dynamic entity where complex interactions among its biological, chemical and physical components take place. All these components and properties determine the functioning of soil for different purposes [3]. Soil type and properties affect agricultural productivity and quality through its function as a medium for plant growth and as regulator of water flow and nutrient cycling [3]. Soil quality is the capacity of soil to function within ecosystem boundaries. Soil is made of four components; sand, silt, clay and humus (decayed organic materials). Sand is important for keeping the soil loose, aerated and well drained. Clay minerals hold water and nutrients in the soil just loosely enough to allow plant roots absorb them. The humus component provides the bulk of soil's fertility [4]. Among soil physicochemical properties normally used to evaluate soil quality include soil texture, bulk density, organic carbon content, soil reaction (pH), cation exchange capacity while soil respiration, earthworm presence and microbial biodiversity are biological factors.

Soil pH is the degree of acidity or alkalinity of soil. The pH value is a very important property that affects many other physicochemical and biological properties. Soil reaction (pH) measures acidity of soil on a scale of 0–14. A pH value of 6.5-7.5 is considered optimum for growth of many plants [5]. Extreme pH values decrease microbial activity in soils, thereby affecting many soil processes such as organic matter decomposition, nitrification and the biological nitrogen fixation. Water content or moisture content is the quantity or amount of water contained in a material. Oyem and Oyem [5] asserted that water in the soil, in term of volume and movement, is the single factor determining plant growth and the solvent in which all chemical reactions take place as well as the most important factor determining remediation of salt water and hydrocarbon spills. Microbial activity in soil is generally greatest at water contents ranging between 50-80% of the maximum water holding capacity [1]. Other soil characteristics affecting soil quality include organic matter and organic carbon contents. Soil organic matter is principal soil property affecting biological activity in soil. It is composed of organic compounds from decomposed remains of living organisms and their waste products in the environment. It functions as the carbon source for many soil organisms including soil micro biota [3]. It has also been reported that the interactions between organic pollutants and soil particles are largely determined by soil organic matter content [6].

Crude oil is a complex mixture of different kinds of hydrocarbons, liquid in their natural state and composed of aliphatics, aromatics and asphaltene fractions along with nitrogen, sulphur and oxygen containing compounds. Many of these compounds are known to be highly toxic to humans, animals, plants and microorganisms. The sources of crude oil spill into the environment differ and the amount spilled varies from minor to disaster. Crude oil destroys soil richness, causes alterations in soil physicochemical and microbiological properties [7] and cause severe damages to the environment and all forms of life dependent on the environment [1]. The release of crude oil damages the environment due to the presence of many toxic compounds such as polycyclic aromatic hydrocarbons, benzene and its substituted and cycloalkane rings in relatively high concentration [8]. Crude oil spillage on agricultural land and the attendant fouling effect can render the soil (especially the biologically active surface layer) toxic and unproductive [9,10]. The overall effects of crude oil spillage on agricultural land may be due to the nutritional imbalance (especially of carbon and nitrogen) created by the spilled oil [9,11], causing reduced agricultural yield and adversely affecting the socio-economic lives of the people residing in the affected area due to high levels of unemployment and poverty rates and hence increased hunger.

The high incidence of crude oil spill and the concomitant effects on both biotic and abiotic components of the ecosystem are of great concern to Environmental Researchers. These concerns have consequently resulted in the development of many remediation options towards returning crude oil polluted environment to its pre-contamination status in order to restore soil quality to support agriculture. Remediation of crude oil contaminated site refers to removing or transforming contaminants to harmless or less harmful substances [12]. Several physicochemical and biological approaches have been applied to remediate polluted soil and water environments. The effects and time for reclamation of crude oil polluted soil depend on the quantity and the concentration of the pollutant [13,14]. Among the remediation techniques, bioremediation as a contaminant removal strategy relies on the metabolic capabilities of microorganisms to detoxify or remove organic pollutants from the environment. It is considered a safe, ecosystem friendly and cost effective approach relative to the physicochemical methods [15]. The effectiveness of bioremediation technologies applied to hydrocarbon polluted soil is dependent upon physical and chemical conditions as well as the presence of native microbial population (primarily bacteria, yeast and mold) with ability to degrade hydrocarbon pollutant and environmental conditions. In order to monitor the effectiveness of bioremediation strategy, it becomes pertinent to understand the effects of crude oil concentration on the technological parameters affecting soil quality. Therefore, this research is undertaken to evaluate the effects of varying concentrations of crude oil on some physicochemical properties of agricultural soils in order to evaluate the progress and effectiveness of bioremediation in restoration of soil quality to boost agricultural productivity and improve the livelihood the people in the risk areas of crude oil pollution.

2. MATERIALS AND METHODS

2.1 Sample Collection

The soil samples used in this study were collected from Igodan- Lisa (6°27'0''N, 4°47'0''E), Oba- Ile (7°16'0''N, 5° 15' 0''E) and Ido-Ani (7°17' 0''N, 5°52'0''E) all in Ondo State, Nigeria. According to Ikuesan [16] the soil texture and total petroleum hydrocarbon contents of the soils were as follows; Igodan- Lisa (Sand; 51.32%, Silt; 36.34%, Clay; 13.21%, Total Petroleum Hydrocarbon; 13.27 mg/kg) Oba- Ile (Sand; 67.35%, Silt; 20.35%, Clay; 12.67%, Total Petroleum Hydrocarbon ; 10.57 mg/kg) and Ido-Ani (Sand; 68.36%, Silt; 15.68%, Clay; 14.66%, Total Petroleum Hydrocarbon; 11.96 mg/kg).

The samples were collected into sterile black cellophane bags using the hand auger at depth of 15-20 cm. The crude oil used in this study was standard - grade crude oil (Bonny light) collected from Bille Flow Station in Port Harcourt, Nigeria.

2.2 Soil Treatment

The samples were then partially air-dried at 28 ± 2°C and passed through a 2mm mesh to remove large particles, debris and stones. A total of 45 plastic buckets were filled with sieved experimental soil and then used for this study to prepare triplicate samples of each concentration (0-4% w/w). Crude oil was then added to the soil in the plastic buckets at different concentrations to obtain 0-4% (w/w) contamination according to the method of [17,18]. The crude oil was then thoroughly mixed with the soil using the spatula. The untreated samples (0% w/w) were the controls.

2.3 Analysis of Soil Physicochemical Properties

The physicochemical characteristics of control and polluted soil samples were determined as follows. The pH of samples was determined by the glass electrode pH meter (Jenway 3051) method in 1:1 w/v soil: water slurry which was standardized at pH 7.0 using phosphate buffer solution [19]. The weight loss method was used to determine the moisture content [20,21]. The moisture content was adjusted to 25% by adding water in order to enhance microbial activities. Organic matter (OM) and Organic carbon (OC) were measured by dichromate-oxidation of Walkley-Black method [19,21].

The effects of crude oil contamination on the physicochemical properties of soil was then determined following the methods described above. The physicochemical parameters evaluated were pH, moisture content, percentage organic matter and organic carbon. Triplicate samples of the various treatment containers were tilled weekly with spatula for necessary aeration and proper mixing of the oil with the soils. Analysis of the physicochemical characteristics of each agricultural soil sample (0-4% w/w) from Igodan-Lisa, Oba-Ile and Ido-Ani were carried out at 7 days post contamination as day zero [14] and then periodically evaluated at intervals of 30 days using standard physical and chemical methods as earlier described.

3. RESULTS

The results obtained in this study revealed that crude oil pollution of soil at all levels of contamination resulted in remarkable alterations in soil physicochemical properties affecting soil quality. The physicochemical characteristics of crude oil polluted (varying concentration of 1 - 4%) and unpolluted (controls) agricultural soils over a study period of 180 days are shown in Figs. 1-3 and Tables 1 (a-c). The observed changes were much more noticed in the polluted soils as the concentration of applied crude oil increased. The soil acidity (pH), organic matter (OM) and organic carbon (OC) contents increased as the level of crude oil contamination increased. Conversely, the moisture content decreased with increase in concentration of crude oil applied to soil. The result of the pH of the soil samples is shown in Figs. 1(a-c). The pH for all treated samples were lower at the end of the study period compared with the unpolluted samples, thus, the soil acidity increased. The pH of the control samples was almost stable at near neutral over the study period. The pH of crude oil contaminated soils progressively decreased both with increase in concentration of crude oil applied and sampling days. The experimentally polluted samples had acidic pH of 4.91-6.17 at 1-4% (w/w) levels of contamination compared with 7.03–7.28 in the control samples during the study period of 180 days.

Conversely, at 2–4% (w/w) there was also a significant reduction in moisture content (MC) of crude oil contaminated soils with increase in the amount of applied crude oil, but showed progressive and gradual increase with time in all samples except samples SS3, SS4 and SS5 (control samples) and at 3% (w/w) crude oil contamination where MC reduced time up to 30 days before the gradual increase. The MC values of polluted soils range between 15.24% -26.83% relative to control samples (23.03 - 27.26%) as shown in Figs. 2(a-c).

In contrast to the observed decrease in pH and MC, the organic matter (OM) and organic carbon (OC) contents respectively showed significant increases (Figs. 3a-c) and (Tables 1a-c) contents with increase in the concentration of crude oil applied. However, while the OM values which increased with concentration decreased as the sampling days progressed, the OC of

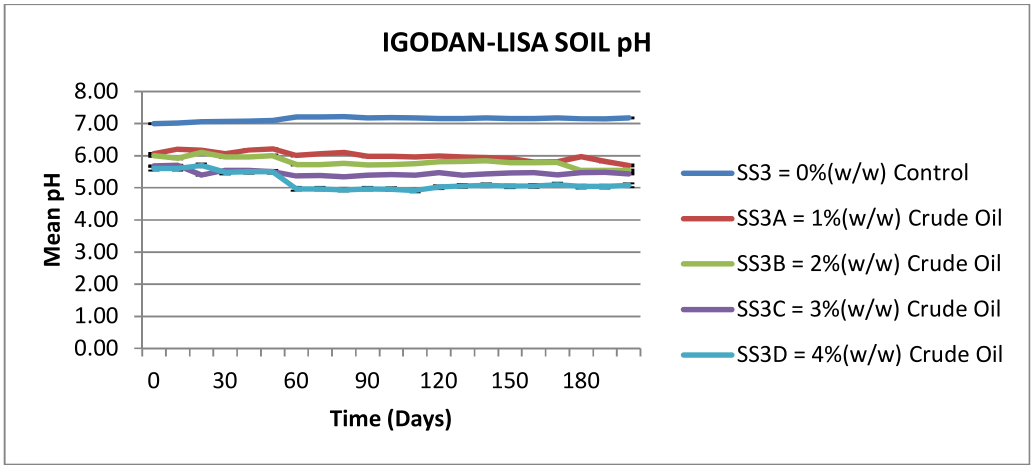

Fig. 1a. Effect of crude oil concentration on the pH of Igodan-Lisa soil

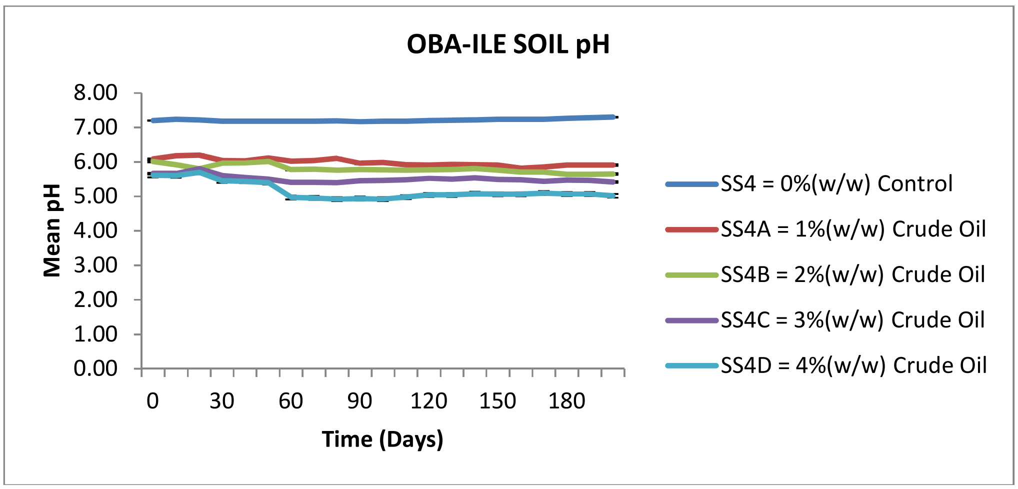

Fig. 1b. Effect of crude oil concentration on the pH of Oba-Ile soil

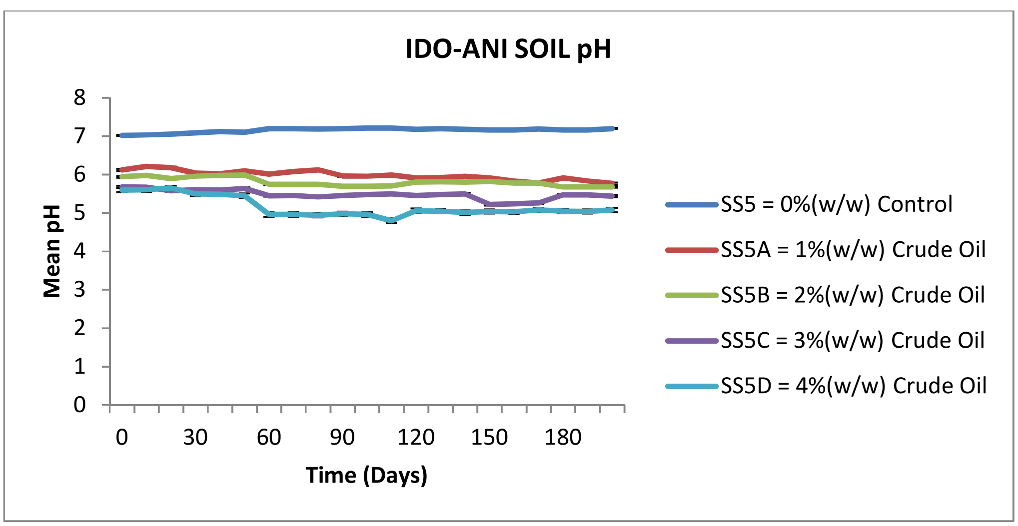

Fig. 1c. Effect of crude oil concentration on the pH of Ido-Ani soil

samples progressively increased. Results revealed lower OM (3.13–7.72) at the end of study in polluted soil samples compared to 5.73 –8.11 in unpolluted soils, whereas, the polluted samples showed significant increase in OC (3.26 –8.28) relative the control (2.25–4.45) samples. The OC contents shown in Tables 1(a-c) progressively increased with concentration of crude oil applied and sampling days. Tables 1(a-c) revealed that at 4% (w/w) crude oil

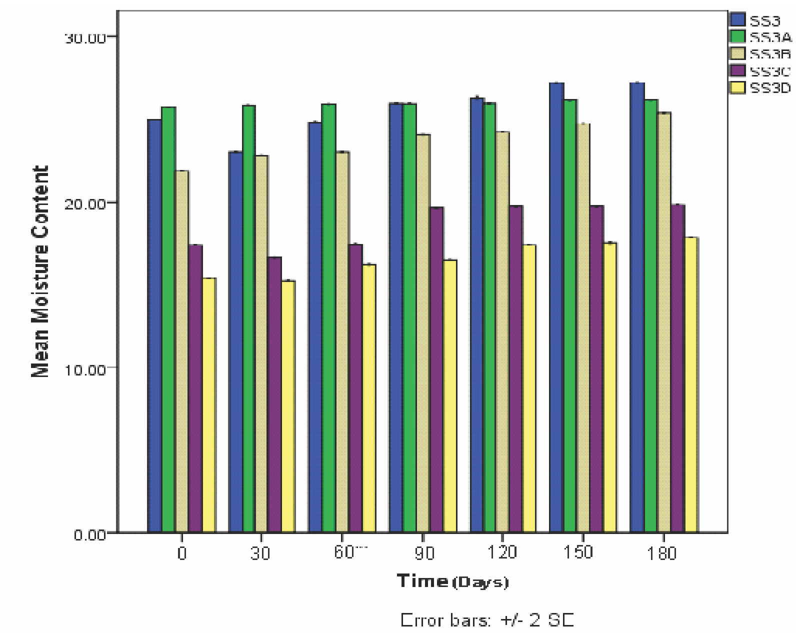

Fig. 2a. Effect of crude oil concentration on the moisture content of Igodan-Lisa soil
Legend: SS3 = 0%(w/w) (control); SS_{3A} = 1%(w/w) Crude Oil; SS_{3B} = 2%(w/w) Crude oil; SS_{3C} = 3%(w/w) Crude Oil; SS_{3D} = 4%(w/w) Crude Oil

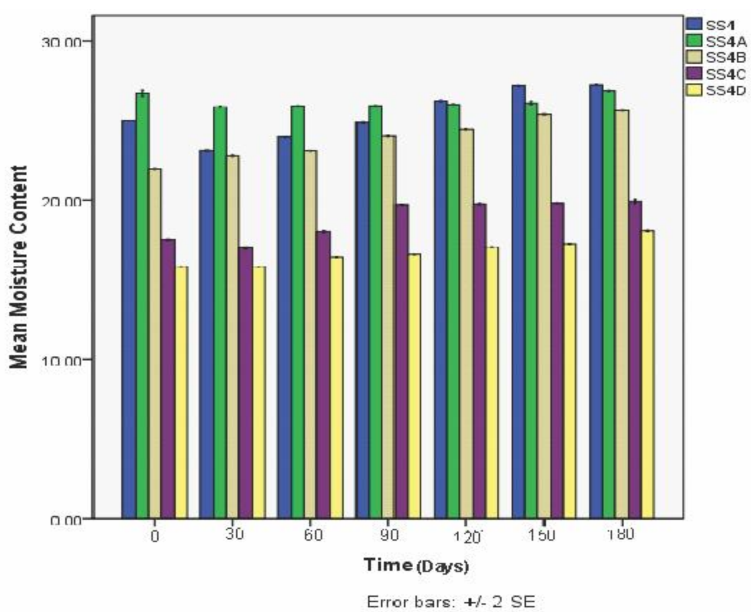

Fig. 2b. Effect of crude oil concentration on the moisture content of Oba-Ile soil
Legend: SS_4 = 0%(w/w) (control); SS_{4A} = 1%(w/w) Crude Oil; SS_{4B} = 2%(w/w) Crude oil; SS_{4C} = 3%(w/w) Crude Oil; SS_{4D} = 4%(w/w) Crude Oil

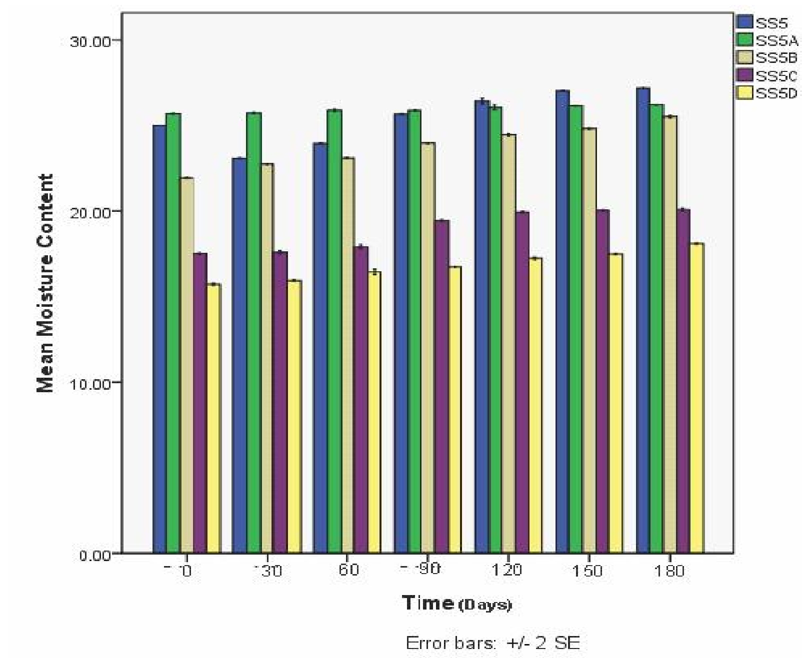

Fig. 2c. Effect of crude oil concentration on the moisture content of Ido- Ani soil
Legend: SS5 = 0%(w/w) (control); SS_{5A} = 1%(w/w) Crude Oil; SS_{5B} = 2%(w/w) Crude oil ; SS_{5C} = 3%(w/w) Crude Oil ; SS_{5D} = 4%(w/w) Crude Oil

contamination of the soil samples, the OC content in samples were 6.04-8.28%, 5.39-7.82% and 6.05-8.21% respectively for Igodan-Lisa, Oba-Ile and Ido Ani at 0-180 days sampling periods.

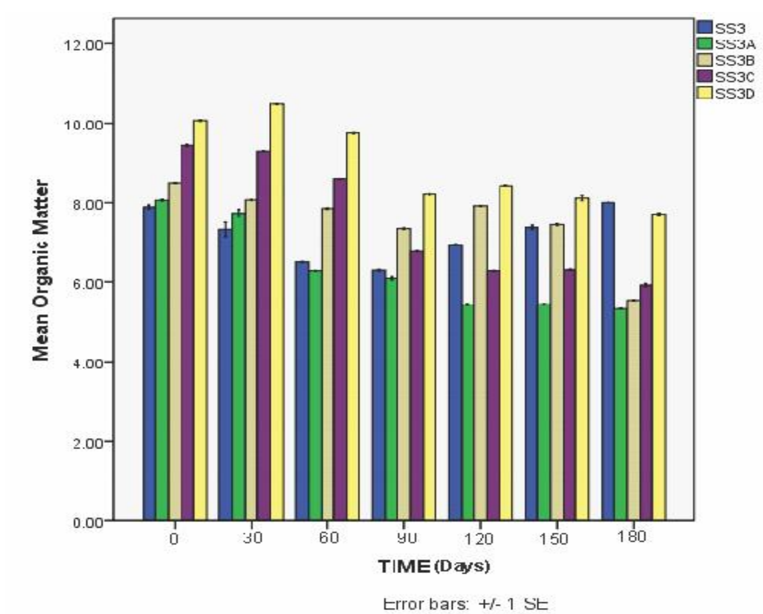

Fig. 3a. Effect of crude oil concentration on the organic matter content of Igodan-Lisa soil
Legend: SS3 = 0%(w/w) (control); SS_{3A} = 1%(w/w) Crude Oil; SS_{3B} = 2%(w/w) Crude oil; SS_{3C} = 3%(w/w) Crude Oil; SS_{3D} = 4%(w/w) Crude Oil

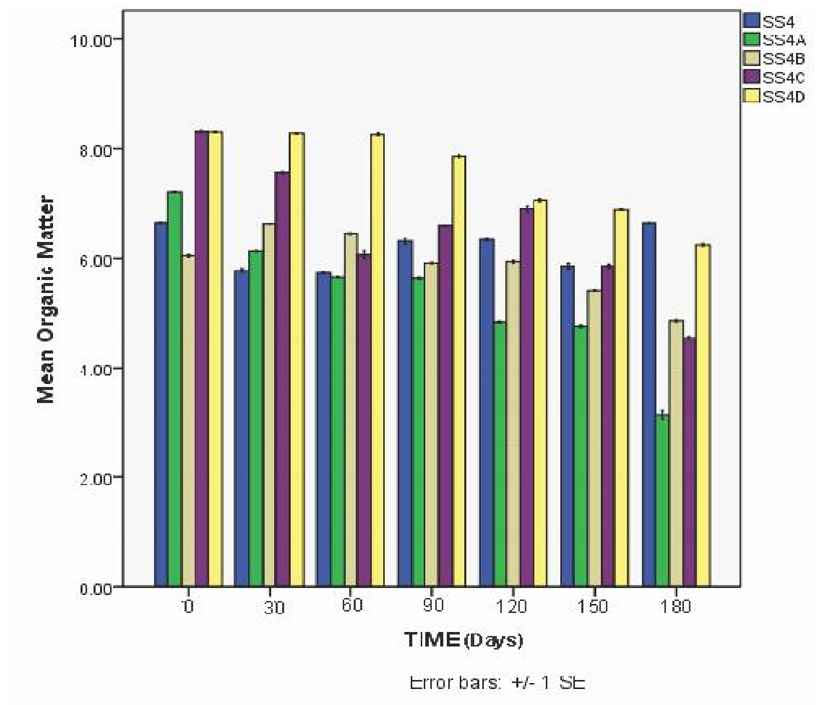

Fig. 3b. Effect of crude oil concentration on the organic matter content of Oba-Ile soil
Legend: SS4 = 0%(w/w) (control); SS_{4A} = 1%(w/w) Crude Oil; SS_{4B} = 2%(w/w) Crude oil; SS_{4C} = 3%(w/w) Crude Oil; SS_{4D} = 4%(w/w) Crude Oil

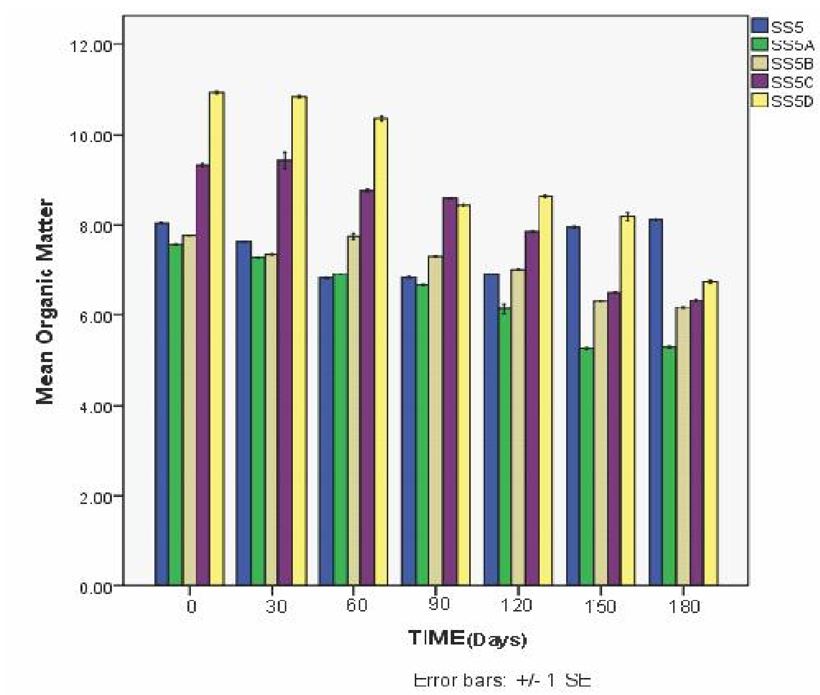

Fig. 3c. Effect of crude oil concentration on the organic matter content of Ido-Ani
Legend: SS5 = 0%(w/w) (control); SS_{5A} = 1%(w/w) Crude Oil; SS_{5B} = 2%(w/w) Crude oil; SS_{5C} = 3%(w/w) Crude Oil; SS_{5D} = 4%(w/w) Crude Oil

Table 1a. Effect of crude oil concentration on the organic carbon content of Igodan- Lisa soil

Time (days)	SS_3	SS_{3A}	SS_{3B}	SS_{3C}	SS_{3D}
0	2.80 ± 0.01^a	3.74 ± 0.02^a	4.38 ± 0.00^a	4.99 ± 0.01^a	6.04 ± 0.01^a
30	3.29 ± 0.01^b	4.190 ± 0.00^b	4.45 ± 0.01^b	5.12 ± 0.00^b	6.20 ± 0.01^b
60	3.79 ± 0.01^c	4.49 ± 0.01^c	4.78 ± 0.00^c	5.46 ± 0.02^c	6.61 ± 0.01^c
90	3.91 ± 0.01^d	4.66 ± 0.01^d	4.97 ± 0.02^d	5.67 ± 0.01^d	6.89 ± 0.01^d
120	4.11 ± 0.01^e	4.86 ± 0.00^e	5.17 ± 0.01^e	5.90 ± 0.01^e	7.16 ± 0.00^e
150	4.33 ± 0.06^f	5.18 ± 0.01^f	5.60 ± 0.02^f	6.42 ± 0.01^f	7.77 ± 0.01^f
180	4.44 ± 0.02^g	5.89 ± 0.02^g	6.53 ± 0.02^g	7.15 ± 0.01^g	8.28 ± 0.00^g

Legend: SS_3 = 0% Contamination (control); SS_{3A} = 1% Crude Oil Contamination; SS_{3B} = 2% Crude oil Contamination; SS_{3C} = 3% Crude Oil Contamination; SS_{3D} = 4% Crude Oil Contamination

Table 1b. Effect of crude oil concentration on the organic carbon content of Oba-ile soil

Time (days)	SS_4	SS_{4A}	SS_{4B}	SS_{4C}	SS_{4D}
0	2.25 ± 0.01^a	3.26 ± 0.00^a	3.87 ± 0.01^a	4.49 ± 0.01^a	5.39 ± 0.01^a
30	2.78 ± 0.01^b	3.18 ± 0.00^b	4.14 ± 0.01^b	4.67 ± 0.01^b	5.63 ± 0.02^b
60	3.25 ± 0.01^c	4.30 ± 0.02^c	4.67 ± 0.01^c	5.02 ± 0.00^c	6.10 ± 0.01^c
90	3.35 ± 0.00^d	4.45 ± 0.01^d	4.82 ± 0.01^d	5.28 ± 0.00^d	6.39 ± 0.01^d
120	3.53 ± 0.01^e	4.66 ± 0.00^e	5.04 ± 0.01^e	5.59 ± 0.02^e	6.62 ± 0.01^e
150	3.69 ± 0.01^f	4.83 ± 0.00^f	5.28 ± 0.00^f	6.18 ± 0.01^f	7.19 ± 0.01^f
180	3.90 ± 0.00^g	5.09 ± 0.01^g	6.19 ± 0.02^g	7.03 ± 0.01^g	7.82 ± 0.00^g

Legend: SS_4 = 0% Contamination (control); SS_{4A} = 1% Crude Oil Contamination; SS_{4B} = 2% Crude oil Contamination; SS_{4C} = 3% Crude Oil Contamination; SS_{4D} = 4% Crude Oil Contamination

Table 1c. Effect of crude oil concentration on the organic carbon content of Ido-Ani soil

Time (days)	SS_5	SS_{5A}	SS_{5B}	SS_{5C}	SS_{5D}
0	2.79 ± 0.01^a	3.77 ± 0.02^a	4.37 ± 0.01^a	5.02 ± 0.02^a	6.05 ± 0.01^a
30	3.29 ± 0.01^b	4.20 ± 0.02^b	4.47 ± 0.01^b	5.15 ± 0.01^b	6.23 ± 0.01^b
60	3.78 ± 0.02^c	4.50 ± 0.01^c	4.77 ± 0.06^c	5.49 ± 0.01^c	6.65 ± 0.01^c
90	3.91 ± 0.00^d	4.63 ± 0.02^d	5.03 ± 0.02^d	5.71 ± 0.01^d	6.93 ± 0.01^d
120	4.10 ± 0.01^e	4.85 ± 0.02^e	5.24 ± 0.05^e	5.92 ± 0.02^e	7.17 ± 0.01^e
150	4.29 ± 0.01^f	5.22 ± 0.01^f	5.69 ± 0.01^f	6.45 ± 0.01^f	7.83 ± 0.07^f
180	4.45 ± 0.05^g	5.83 ± 0.12^g	6.55 ± 0.01^g	7.27 ± 0.01^g	8.21 ± 0.01^g

Legend: SS5 = 0% Contamination (control); SS_{5A} = 1% Crude Oil Contamination; SS_{5B} = 2% Crude oil Contamination; SS_{5C} = 3% Crude Oil Contamination; SS_{5D} = 4% Crude Oil Contamination

4. DISCUSSION

It has been reported that the effects and time for reclamation of polluted soil depend on the quantity and concentration of the pollutant [13, 14]. A thorough knowledge of the impact of oil pollution on the physicochemical properties of the soil as a technological parameters for its elimination is very critical. In this study, the effects of varying concentrations of crude oil on some physicochemical properties of soils were evaluated. Contamination of the three arable experimental soil samples of Igodan-Lisa, Oba-Ile and Ido-Ani at 1-4% (w/w) caused alterations in the physicochemical properties of the soils. This finding is in line with the findings of [7,20] who stated that oil spills cause alterations in the physicochemical and microbiological properties of soils.

The results of varying concentrations of crude oil on some physicochemical properties of the agricultural soils revealed observable changes in pH, contents of moisture, organic matter and organic carbon. All of these parameters are significant in determining soil quality and also influence the efficiency of bioremediation as strategy for hydrocarbon pollutant removal. The degree of acidity and alkalinity of soil is a very important property affecting many other physicochemical and biological properties and can as well be used as index to assess soil quality and suitability of the environment for bioremediation of polluted soil.

In this study, results revealed that the pH status of the polluted soils varied and extent of this depended on the concentration of spilled oil. The values of pH in the control samples ranged 7.03-7.28, suggesting that the pH of the control samples were almost neutral or slightly alkaline compared to the acidic pH of 4.91-6.17 obtained for crude oil contaminated soil samples at 1-4% (w/w) contamination levels. The observed decrease in pH which implies increased acidity agrees with the reports of [22,23] who observed increased acidity as following increased crude oil pollution of soil. The decrease in pH with increase in levels of oil in soil samples, however, deviates from the reports of [18,24] who observed increase in pH as the level of pollution increased. The decrease in pH with increase in the amount of crude oil used in the treatments implies that at all levels of crude oil contamination, the pH of the samples were altered becoming more acidic as concentration and study period increased. This finding agrees with the reports of [21,25,26] who ascribed the progressive decrease in pH of crude oil polluted soil with time to the accumulation of acidic metabolites resulting from microbial degradation or metabolism of the spilled soils. A pH of 6.5-7.5 is considered optimum for the growth of many plants [5]. Oyem and Oyem [5] reported that pH affects plant growth primarily by its effects on nutrient availability and that high or low pH causes deficiencies of essential nutrients that plants need to grow. The results of this study therefore show that the effect of 1-4% oil pollution of soil is a fall in pH below the limit favorable for plant and crop growth and survival. Therefore, plant growth in this adverse pH condition may be stunted for reasons of deficiencies of nutrients and may as well be more prone to disease and fungal attack and consequently the destruction of vegetation. Also, pH affects microbial activities, growth and survival. Different microbial strains exhibit their maximum growth potentials in a limited pH range [27]. The values of pH obtained in this study for crude oil polluted soils fall below the optimum pH (6.0–8.0) for microbial growth and bioremediation of crude oil polluted soil [1]. This implies that the efficiency of soil microbes in breaking down organic pollutants will be limited or slow.

All soil microorganisms require moisture for growth and other metabolic activities. The effective transport of soluble nutrients, food and waste metabolic products in and out of the microbial cells depends on available moisture. In the present study, the moisture content (MC) of crude oil polluted soils decreased with increase in the level of pollution. The moisture content (MC) of polluted soils reduced compared with the control samples (Figs. 2a-c). The observation in this study supports the reports of [19,26,28]. Essien and John [28] asserted that moisture content per unit weight of soil sample was less in crude oil polluted soils than in unpolluted (control) soil samples. The reduction in MC of polluted soil was ascribed to coating of the soil surface by hydrophobic hydrocarbon that reduces the water holding capacity of the soil and reduction in the binding property of clay soil [29]. The progressive increase in moisture content with increased sampling days may also be attributed to insufficient aeration of the soil that might have arisen from the displacement of air in the soil; this probably encouraged water logging and reduced rate of evaporation [21]. Also, the increase in MC with time may be the result of degradation by microorganisms during which organic compounds in crude oil are converted to carbon dioxide and water as products of microbial degradation and therefore suggesting reclamation of the crude oil spilled soils.

The data from this study revealed appreciable increases in organic matter contents following the increase in the level of applied petroleum oil against the control soils, thereby agreeing with the reports of [30,31,32] who reported a surge in organic matter content of contaminated soil. The observed response to increase in the level of crude oil spilled was thereafter followed by a remarkable gradual decrease in the percentage organic matter with time (Figs. 3a-c). The continual decrease in organic matter content of contaminated soil might have resulted from crude oil mineralization by native microbial population. This research revealed that the percentage organic carbon in crude oil contaminated soils were higher than in uncontaminated control soils. This is line with the findings of [33] that pollution of sandy loam soil by crude oil led to an increase in soil organic carbon. This increase in organic carbon also agrees with the report of [23] which suggested that crude oil pollution adversely affects the ecosystem through the provision of excess carbon that might be unavailable for microbial use. The increased organic carbon will consequently create nutritional imbalance especially of carbon and nitrogen since crude oil contain large amount of carbon containing compounds. The progressive increase in carbon content over the study period could also be attributed to the accumulation of organic acid resulting from degradation. Osuji and Nwoye [21] however, reported a slightly lower total organic carbon and total organic matter in polluted soils than in the control. Their report asserted that severe hydrocarbon contamination is indicated by high soil acidity (low pH) and high MC, low TOC and TOM all implying low soil fertility which in turn implies low agricultural productivity and reduced source of livelihood in the affected area.

5. CONCLUSION AND RECOMMENDATION

The impacts of crude oil pollution on agricultural lands have generated great concerns to government, environmental researchers and among the people living in the oil producing areas of Niger Delta region where residents depend solely on sales from farms as means of livelihood. The hitherto agricultural lands have become wastelands and unproductive for profitable agriculture. On the basis of the results obtained in this study, it can be concluded that crude oil pollution no matter the quantity and size (minor, medium, major and catastrophic) caused impaired changes in physicochemical properties of soil, thereby destroying soil integrity and quality and hence, agricultural productivity. The extent of this depended on the amount of crude oil spilled. The pH of soil samples was reduced below the limit favorable for plant and microbial growth and bioremediation. Hence, crude oil polluted soil could be limed. It is suggested to deal with crude oil spillage than dealing with the consequences. This implies the need for increased public awareness on the prospective environmental consequences of crude oil spill and enforcement of regulatory environmental laws. Prompt response in term of contingency fund to meet the needs and concerns of those affected by spill and application of appropriate remediation strategies to oil spilled sites is recommended in order to restore soil quality and improve agriculture and the socio- economic lives of the residents of the Niger–Delta areas where crude oil spill is a common occurrence.

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COMPETING INTERESTS

Authors have declared that no competing interest exists.

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