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EFFECTS OF CRUDE OIL SPILLAGE ON FERTILITY STATUS OF AGRICUTURAL SOILS IN OWAZA-UKWA WEST, NIGERIA

Research article

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Abstract

This study evaluated the effects of crude oil spillage on fertility status of agricultural soils in Owaza Community of Ukwa West, Abia, State Nigeria. Twenty (20) surface soil samples were collected at depths of 0 - 15 cm and 15 - 30 cm in 5 locations at various vertical distances of 0 - 50 meters and 50 - 100 meters replications using random field sampling techniques. Samples were air dried, crushed and sieved with a 2mm mesh sieve and analyzed for physical, chemical and heavy metal characteristics. Results showed that the fertility status was high but unavailable for plant uptake when compared with standard critical limits. Sand fractions dominated the particle sizes with the highest value at 15 - 30 cm depth (71.90 - 91.33 g/kg). Bulk density recorded a very high value of 2.00 g/cm^3 at location 2. The pH was strongly acidic in all the locations with highest value at 15 – 30 cm depth (3.85 - 4.81). The soils were more polluted by Lead (Pb) than Nickel (Ni) when compared to critical limits of 0.1 ppm and <1.0 ppm respectively. It was discovered that there was significant difference in the fertility status of the soils, in spilled and non-spilled areas since most indicators varied statistically (P<0.05). The control location had low values of organic matter, total nitrogen, and Cation Exchange Capacity (CEC). These results showed that the soils are highly polluted by crude oil and heavy metals and cannot support sustainable agriculture. The soils therefore require such treatments as bioremediation, application of organic farm manure and phytoremediation.

Keywords: Polycyclic Aromatic Hydrocarbons (PAH), Total Organic Carbon (TOC), Cation Exchange Capacity (CEC), Total Nitrogen (TN).

ВЛИЯНИЕ РАЗЛИВА СЫРОЙ НЕФТИ НА ПЛОДОРОДИЕ СЕЛЬСКОХОЗЯЙСТВЕННЫХ ПОЧВ НА ЗАПАДЕ ОВАЗА-УКВА, НИГЕРИЯ

Научная статья

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Аннотация

В этом исследовании оценивалось влияние разлива сырой нефти на состояние плодородия сельскохозяйственных почв в общине Оваза в Уква-Уэст, Абия, штат Нигерия. Двадцать (20) образцов поверхностного грунта были собраны на глубинах 0 - 15 см и 15 - 30 см в 5 местах на различных вертикальных расстояниях 0 - 50 метров и 50 - 100 метров с использованием методов случайного отбора проб. Образцы сушили на воздухе, измельчали и просеивали с помощью сита с ячейками 2 мм и анализировали на физические, химические и тяжелые металлы. Результаты показали, что уровень фертильности был высоким, но недоступным для поглощения растениями по сравнению со стандартными критическими пределами. Фракции песка преобладали в размерах частиц с наибольшим значением на глубине 15 - 30 см (71,90 - 91,33 г/кг). Насыпная плотность зафиксирована очень высоким значением 2,00 г/см3 в местоположении 2. pH был сильнокислым во всех местах с наибольшим значением на глубине 15 – 30 см (3,85 – 4,81). Почвы были более загрязнены свинцом (Pb), чем никелем (Ni) по сравнению с критическими значениями 0,1 ppm и <1,0 ppm соответственно. Установлено, что существует существенная разница в состоянии плодородия почв на разливных и неразливных участках, поскольку большинство показателей статистически различаются (P<0,05). Контрольная точка имела низкие значения органического вещества, общего азота и емкости катионного обмена (CEC). Эти результаты показали, что почвы сильно загрязнены сырой нефтью и тяжелыми металлами и не могут поддерживать устойчивое сельское хозяйство. Поэтому почвы требуют такой обработки, как биоремедиация, внесение органического сельскохозяйственного навоза и фиторемедиация.

Ключевые слова: полициклические ароматические углеводороды (ПАУ), общий органический углерод (TOC), емкость катионного обмена (CEC), общий азот (TN).

Introduction

Crude oil since its discovery has remained a major resource in world's industrialization for the generation of power and energy. Presently, crude oil has become the world's most important commodity [1]. Crude oil the precursor of petroleum is a fossil fuel, meaning that it was made naturally from decaying plants and animals living in ancient seas millions of years ago. Crude oil is not a single chemical but a collection of hundreds of widely different properties and toxicities [2]. Energy production in Industries cannot be achieved effectively without the use of refined petroleum products [3]. The oil sector accounts for 95 % of export earnings and about 85 percent of government revenues.

Despite the above-mentioned benefits, crude oil spillage pollution has adversely affected sustainable agriculture. Due its toxicity, crude oil changes the physico-chemical properties of soils. Crude oil may affect soil in two ways; it may penetrate the soil, where it directly affects the mineral and organic matter, plant root system, microbial population and oxygen content or it may percolate on the soil's surface reducing air and water flow into the soil thereby affecting aeration by clogging pore spaces [4]. Crude oil in soil makes the soil condition unsatisfactory for plant growth due to the reduction in the level of available plant nutrient or a rise in toxic levels of certain elements such as iron and zinc [5]. Crude oil spillage on agricultural soils renders the soils (especially, the biologically active surface layer) toxic and unproductive [6]. The oil reduces the soil's fertility such that most of the essential nutrients are no longer available for plant and crop utilization [7].

Soil contamination with crude oil spillage is a major global concern today. Crude oil pollution of the environment may arise from oil well drilling, production operations, transportation and storage in the upstream industry, and refining, transportation, and marketing in the downstream industry. Pollution can also be from anthropogenic sources [8]. Soil contaminated with crude oil not only affects plant growth but has a serious hazard to human health [9], causes organic pollution of groundwater which limits its use, causes economic loss, environmental problems and decreases agricultural productivity [10]. Once in soil, aromatic hydrocarbons, including Polycyclic Aromatic Hydrocarbons (PAH) are poorly mobile and can have a long-term effect on soil, plants, or groundwater [10]. Crude oil degrades soil properties involved in soil-plant-water relationships which include texture, infiltration, hydraulic conductivity, moisture content, pH and density, which affect root and leaf development, and plant growth and yield [11]. Spilled crude oil, which is denser than water, reduces and restricts permeability; organic hydrocarbons which fill soil spores expel water and air, thus depriving the plant roots much needed water and air [12].

Nigeria had an estimated 36.2 billion barrels of proven oil reserves as of January 2009 [13]. A year after the discovery of crude oil in Olobiri in the Niger Delta in 1957, a huge deposit of Oil and Gas were discovered at multiple areas in Abia State. Owaza Community has the major crude oil field out of the six oil fields in Ukwa West [14]. Owaza Community has experienced adverse agricultural effects from crude spillage pollution. Agricultural soils in Owaza have declined in fertility and this questions sustainable agriculture in the nearest future. Therefore, the study of soil reaction to crude oil is very necessary and will provide guide to faster and more eco-friendly remediation [15].

The scope of study is on determining the effects of oil spillage on the fertility status of agricultural soils in Owaza Community and will consider both effects on plant growth and pollution of food crops by heavy metals because of crude oil spillage pollution in the area. This study will properly assess the concentration level of physical and chemical properties of the soil at various sample level. This will help determine the correlation and variation between sample soil fertility and selected physical and chemical properties and lastly to determine possible heavy metal pollution of the soils through correlation with observed levels in the soil.

Materials and Method

2.1. Presentation of the study area

This study was carried out in Owaza Community of Ukwa West Local Government Area of Abia State, Nigeria. It lies between latitude 7°11'25"E and longitude 4°58'36"N, as shown in the map below (Fig. 3.1). It has an area of 271km^2 and a population of 88,555 at the 2006 census. It is a major crude oil producing region in the Port Harcourt District 2 (PHC2) with more than 100 wells and 300 flow lines. Two *(2)* flow stations are operated by the Shell Petroleum Development Company Limited (SPDC). Ukwa West has six (6) oil fields with Owaza as the largest. The sites for sample collection covered the major polluted areas of the region with a control location.

2.2. Sampling and sampling locations

Twenty (20) soil samples were collected at five (5) locations at a depth of 0-15cm for Topsoil and 15-30 cm for Subsoil and distance of 0-50m and 50-100m replications. Distance from each location varied from 500 m to 700 m interval. Sixteen (16) soil samples (8 Topsoil and 8 Subsoil) were from crude oil polluted sites. Four (4) soil samples (2 Topsoil and 2 Subsoil) were collected from the control location. Twenty (20) core samples were collected using the same techniques.

Topsoil and Subsoil samples were collected from five locations named below.

1. Location One: Imo River Well 59 Flow Line located between longitude 4°59'57" N and latitude 7°13'10" E.
2. Location Two: Imo River Well 30 Flow Line located between longitude 4°59'34" N and latitude 7°14'27" E.
3. Location Three: Imo River Well 64 Flow Line located between longitude 4°58'1" N and latitude 7°14'37" E.
4. Location Four: Imo River Well 7 Flow Line located between longitude 4°38'37" N and latitude 7°13'30" E.
5. Control: The Control is located between longitude 4°58'36" N and latitude 7° 11' 21'E.

Figure 1 - A Map Showing Owaza, Nigeria and its Environs
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2.3. Methods

2.3.1. Physicochemical characteristics determination

Soil samples were transported to the laboratory after collection and sampling where they were used for physical, chemical, and heavy metal analysis. Soil samples were air-dried, ground to fine particles with mortar and pestle, sieved through 2mm mesh sieve and used for physical and chemical analysis. Particle size determination was by the hydrometer method as cited in [4]. pH, Moisture Content and Dry Conductivity were determined as described by [4]. The pH was determined using a Jenniary digital pH meter in a sample/water ratio of 1： 1O, that is, twenty grams (20g) of each sample was weighed in a beaker. 200ml of distilled water was added to it. pH was also determined in potassium chloride solution. The pH electrode was dipped into the solution with the conductivity electrode. Potassium (K), Magnesium (Mg), Sodium (Na), Calcium (Ca), Total Organic Carbon (TOC), Available Phosphorus (P), Total Nitrogen (TN) were determined on a multi-parameter photometer. Cation Exchange Capacity (CEC) was determined by neutral ammonium acetate (NH4OAC) leachate method while heavy metals analysis of Lead (Pb) and Nickel (Ni) were determined using the Atomic Absorption Spectrometric (AAS) Techniques (using Buck Scientific Atomic Absorption/Emission Spectrometry 200) according to the method of Association of Official Analytical Chemists [4]).

2.4. Statistical analysis and data presentation

The Statistical analysis of soil data generated from above laboratory analysis in triplicate were subjected to determination of variance, mean and proportion with least significant difference at 5 % level of probability [16]. Correlation was carried out to determine the relationships between soils parameters and heavy metals studied. Results were and subsequently represented by means ± standard deviation (SD) using Microsoft Excel 2013.

Results and Discussion

3.1. Physical analysis

The result of the physical analysis is shown in Table 1. Clay mean values for LI to L4 ranged from 8.05 - 17.10 and 6.05 - 21.05 top soil and sub soil respectively. The mean values for the control (C) are 10.55 and 16.4 g/kg. The mean values of silt and clay for all the locations did not vary significantly from each other. Sand dominates the particle size distribution followed by clay and lastly silt. The reason why sand dominates the particle size could be due to the nature of parent materials from which the soils were formed. Soil formations accumulated by sand is prone to erosion and excessive leaching. However, in crude oil spilled areas, accumulation by sand could be because of degradation of soil organic matter by toxic and concentrated crude constituents which remove the binding elements in soil. Low clay and silt content may also be because of this. The textural class sandy soil (SS) signifies increased infiltration and less percolation as reported by [4]. This will lead to increased contamination of groundwater. According to [17], once in soil, aromatic hydrocarbons are poorly mobile and can have a long-term effect on soil. It could be observed that sand; silt and clay increased with depth in all locations except for the control location for sand which decreased with increase in depth at 15 — 30cm. This may be because of organic pollution from crude oil spillage pollution as reported by [8]. This soil is prone to erosion because [18] has earlier reported that soils dominated by sand are prone to erosion and low fertility status due to leaching or percolation and hardly support plant roots. Clay content is important in soil, this is apparent because clay particles unlike the sand particles have substantial exchange surface areas and therefore and adsorb and stabilize organic matter and soil nutrient [11]. However, most crude oil spilled areas have low content of clay. A study by [8] reported that organic crude oil constituents degrade clay mineral content.

Table 1 - Physical Properties

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Sample	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Texture	BD (g/cm³)	MC (g/kgl)
FIELDN2	80.4	4	15.6	SL	1.4	3.9
L1TSA	82.38	5	16.3	SL	1.5	4.3
L1TSB	81.39	4.5	15.95	-	1.45	4.1
MEAN	72.4	6	21.6	SCL	1.65	2.77
L1SSA	71.39	5	20.5	SCL	1.5	2.5
L1SSB	71.9	5.5	21.05	-	1.58	2.64
MEAN	82.4	4	13.6	SL	1.3	3.75
L2TSA	83.5	3	14.5	SL	1.2	4.2
L2TSB	82.95	3.5	14.05	-	1.25	3.98
MEAN	80.4	2	17.6	SL	1.3	7.73
LTSSA	82.35	3	18.5	SL	2	7.5
LTSSB	81.38	2.5	18.05	-	1.65	7.62
MEAN	78.4	4	17.6	SL	1.02	6.35
L3TSA	76.5	3	16.6	SL	1	5.45
L3TSB	77.45	3.5	17.1	-	1.01	5.9
MEAN	78.4	6	15.6	SL	1.1	6.35
L3SSA	80.38	5	16.5	SL	1.3	7.5
L3SSB	79.39	5.5	16.05	-	1.2	6.93
MEAN	90.4	2	7.6	SS	1.18	15.25
UTSA	88.35	4	8.5	SS	1.19	13.35
UTSB	89.38	3	8.05	-	1.19	14.3
MEAN	90.4	4	5.6	SS	1.47	9.23
L4SSA	92.25	3.5	6.5	SS	1.5	7.5
L4SSB	91.33	3.75	6.05	-	1.49	8.37
MEAN	86.4	2	11.6	SS	1.12	9.67
CTSA CTSB	84.5	3	9.5	SS	2.02	7.18
MEAN	85.45	2.5	10.55	-	1.57	8.43
CSSA	76.4	6	17.6	SL	1.49	5.25
CSSB	75.28	4	15.25	SL	1.65	6.5
MEAN	75.84	5	16.425	-	1.57	5.875
LSD(0.05)	35.69087	1.30625	22.111674	-	0.05	10.7002
VARIANCE	-	-	-	-	-	

3.1.2. Bulk density and moisture content

Bulk Density mean values of the topsoil and sub soil ranged from 1.01 -1.45 g/cm^3 and 1.20 - 1.65 g/cm^3. The control recorded a value of 1.57 and 1.57 g/cm^3. The bulk density increased with increase with depth except in the control where values remained stable. The mean value for both top soil and sub soil of the locations including the control location significantly varied ($p<0.05$). Also, bulk density followed the regular trend that is the sub soil having higher values than topsoil [19]. However, the bulk density of the control location remained the same for both topsoil and sub soil. Bulk density recorded a very high value of 2.00 g/m sub soil in Location 2 (L2). This could be because of infiltration or percolation downward the soil strata by crude oil. This will hinder plant growth through reduction of pore spaces hindering aeration and root penetration [4]. The lowest bulk density was at Location 3 (L3) topsoil at 1.00 g/cm^3 at a mean of 1.01 which shows a favourable total porosity of the soil. Therefore, the presence of crude oil in this soil could be minimal. In their work [8] observed that low bulk density in oil spilled areas may be because of the ability of soil crops to phytoextract or bioremediate crude oils; this is in line with the work of [20] who gave crop examples as Thlapsi and Indian mustard which also phytoextract heavy metals. These plants roots can increase porosity and thereby enhance soil treatment. Moisture Content means values of the topsoil and sub soil ranged from 3.98 - 14.30 g/kg and 2.64 - 8.37 g/kg respectively. The mean values for the Control Location (C) are 8.43 and 5.88 g/kg. The moisture content of the soil generally followed a non-uniform pattern. It did not significantly vary ($p<0.05$). The topsoil having higher moisture content is strongly believed to be as a result of percolation of crude oil on the surface soil which decreases infiltration and increases run off co-efficient. The highest moisture content is 15.25 kg and lowest at 2.50 g/kg from

Location 4 (L4) topsoil and Location 1 (LI) sub soil. This invariably proves that the soil is heavily polluted by crude oil; according to [17]. The reason for this trend could be due to compaction of soils by the presence of crude oil which affect porosity and reduce the proportion of soil water available for plant use. However, [21] reported that this could enhance bioremediation, soil treatment, and prevent groundwater pollution. Therefore, moisture content has a positive correlation with bulk density.

3.2. Chemical properties

3.2.1. pH

Table shows the chemical properties. The mean values of the topsoil and sub soil ranged from 4.44 - 4.86 and 3.85 - 4.81 all in KC1. The mean values for the Control location are 4.90 and 4.42 for top and subsoil respectively. The pH values especially from the sub soil of LI to L4 are strongly acidic conforming to previous values by other researchers in the area such as [17]. The resultant pH recorded lowest value of 3.76 at location (LI) sub soil and highest value at the Control (C) of 4.92. This significantly shows that while the crude oil polluted locations are strongly acidic, the control location is slightly acidic. The deviation of this trend might be due to formation of Carbonic acid accumulation as result of pollution from crude oil. However, [22] contradicted this and reported that carbonates in crude oil spilled soils may be unavailable for acidification processes in the soils. Most plant nutrients are always available for plant at pH range values of 5.5 - 5.7 below or above this could hinder sustainable production. Based on the above pH values, the soils cannot support plant growth. According to [11], this makes phytoremediation and phytoextraction very difficult. pH did not significantly vary. pH plays important roles in soil fertility. It affects the microorganisms such as actinomycetes, bacteria and fungi which help in the mineralization of organic materials into soluble usable forms for plant up take; it influences the presence of plant nutrient elements such as Cu, Fe, and Zn which are found in the soil having pH less than 5. Elements like Mg^{2+}, Ca $^{2+,}$ K+, and Na^{+} prefer slightly acidic to mid alkaline soils [23].

3.2.2. Organic matter (OM) and total nitrogen (TN)

The mean values for both top and sub soils range from 1.91 - 4.85g/kg and 0.86 - 4.50g/kg respectively. Control (C) mean values varied between 0.03 g/kg topsoil and 1.78g/kg sub soil. The crude oil spilled soils of LI to L4 significantly varied ($p<0.05$) from the control (C) location. While the OM is high in polluted areas, it was found to be significantly low in the control location. The reason for this value might be because of the over-cultivation of the limited non-polluted soils by crude oil exploration. The recorded highest Organic Matter is 4.91g/kg topsoil and lowest 0.03 at the control (c) location. This high Organic Matter content in spilled areas might be because of accumulation of organic carbon in high rates. [24] however stated that this organic content may be unavailable for plant. The mean difference between the top and sub soil for each pollution location (LI - L4) do not vary significantly. Total Nitrogen (TN) followed the same pattern with the organic matter. The total nitrogen value in crude oil polluted soils is in line with some other researchers such as [17] and [25]. According to them, soils treated with crude oil usually have high organic carbon and invariably high organic matter.

3.2.3. Available phosphorus

Available phosphorus is the amount of soil phosphorus available to the soil for plants uptake [26]. Phosphorus is one of the major plant nutrients alongside with Nitrogen (N) and Potassium (k). The available phosphorus of the sample locations is relatively low when compared to the critical value of 15ppm according to WHO standards for soil, 2006 [27], but the worst level was recorded in sub soils. The mean values for topsoil significantly varied ($p<0.05$). Tropical soils usually have low available phosphorus sufficient for plant growth hence needs to apply additional fertilizers is always being encouraged. This unavailability may be because P has been converted to insoluble forms by crude oil through adsorption and absorption. The reason for the shortage of available phosphorus (P) in the soil includes the nature of parent material and intensity of soil weathering. Crude oil significantly affected available phosphorus, can affect phosphorus-fixation, and reduce fertility.

3.2.4. Base saturation

Base Saturation (BS) is the mathematical summation of Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}. It represents the percentage of basic cations that occupied the exchange site of a soil. The higher it is the higher its ability to provide these basic cations. The mean values range from 74.79% - 90.90% topsoil and 62.75 - 88.80% sub soil. There is no statistical variation of base saturation in all the polluted locations. The higher base saturation recorded at the topsoils especially for location 4 (L4) can be attributed to high Organic matter Content [21] because of crude oil.

3.2.5. Cation exchange capacity (CEC)

The value for the topsoil is not very statistically opposite for sub soil. Topsoil ranged from 4.46 - 7.68Cmol/kg while sub soil ranged from 4.60 - 7.36Cmol/kg. This result is in agreement with [5] who reported that soils from low land ecosystem i.e., inland valley and flood plains in 13 countries including Nigeria are generally low in fertility and was associated with mineralogical composition suggesting that the low land soils in the region have low nutrient capacity and limited potential nutrient supply. However, crude oil spillage could degrade clay particles which will make cations unavailable [28].

3.2.6. C/N, K/Mg and Ca/Mg values

The value for the topsoil and sub soil for C/N, K/Mg and Ca/Mg are 11.86 - 12.15 g/kg and 11.91 - 12.09 g/kg; 0.09 - 0.19 g/kg and 0.09-0.17g/kg and 1.31 - 2.16g/kg and 1.08 - 1.75g/kg respectively. The control mean values are 1.00 and 12.12g/kg C/N, 0.17 and 0.12g/kg K/Mg, lastly 1.84 and 1.53 g/kg Ca/Mg for top and sub soil respectively. Low C/N, K/Mg and Ca/Mg are respectively low in the control locations which show significant fertility. The polluted sites however varied significantly ($P<0.05$). The variance for C/N and Ca/Mg was negative. The balancing of nitrogen mineralization is strongly influenced by C/N ratio of decomposing organic matter [4]. C/N ratio above 30:1 makes decomposition very difficult as observed in oil spilled soils. K is needed more by plant than Mg, so the lower the value, the better it favours soil fertility. There are not well-defined critical levels for this value especially in southern soils, Nigeria [17]. Finally, if Ca/Mg is so high, it could influence soil structure to hinder root penetration. K/Mg varied significantly.

3.3. Physical vs chemical properties

The mean value for sand, silt and clay did not vary significantly (P<0.05). Sand is relatively high because of the parent material which is coastal plain sand. However, the values for bulk density were relatively within limits but moisture content is high at the topsoil signifying compaction of the soil from percolation of crude oil. Organic Matter and Total Nitrogen had a significant variation showing increased fertility status, but organic content is unavailable for plant use due to crude oil pollution. Available phosphorus did not vary significantly (P<0.05) and was below critical limits of 15ppm [29], which could be because of crude oil pollution. Base saturation was relatively high which means it can supply nutrients. CEC showed low fertility because of poor mineralogical composition. The soil fertility status was significantly high because of high presence of organic matter; however, the nutrients are unavailable because of crude oil spillage.

3.4. Correlation of fertility index with selected soil properties

Table 2 shows correlation of fertility index with some selected soil properties. C/N positively correlated significantly with moisture content at (p=0.05, r=0.58). Ca/Mg: it significantly correlated positively with caution exchange capacity and exchangeable Ca at (p=0.05, r=0.783) respectively. K/Mg: significantly correlated positively with exchangeable K and negative correlation with exchangeable Mg at (p=0.01, r=0.81) and (p=0.05, r=-0.67). OM (organic matter) was significantly positively correlated with available phosphorus, Cation Exchange Capacity, Exchangeable Mg and total nitrogen at (p=0.05, r=0.63), (p=0.05, r=0.54), (p=0.05, r=0.68) and (p=0.01, r=0.92).

Table 2 - Chemical properties

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Sample	(H_20)	OM	Avail. P	(Cmol/kg)	Soil
FIELD NO		(g/kg)	(ppg)		(kg)
L1TSA	5.76 4.86	1.07 1.85	0.09 1.10	2.07	1.6
L1TSB	5.76 4.86	1.09 1.96	0.08 1.11	2.09	1.8
MEAN	5.76 4.86	1.08 1.91	0.09 1.11	2.08	1.7
L1SSA	5.83 3.94	2.61 4.50	0.22 0.55	1.3	1.2
L1SSB	4.98 3.76	2.78 4.50	0.24 0.56	1.4	1.4
MEAN	5.41 3.85	2.70 4.50	0.23 0.56	1.35	1.3
L2TSA	6.12 4.87	1.45 2.51	0.12 2.06	1.8	1.2
L2TSB	6.56 4.45	1.56 2.62	0.14 2.10	1.9	1.2
MEAN	6.34 4.66	1.51 2.57	0.13 2.08	1.85	1.2
LTSSA	5.47 4.83	0.99 1.71	0.08 1.67	3.4	2
LTSSB	5.49 4.78	0.95 1.79	0.10 1.72	3.6	2.2
MEAN	5.48 4.81	0.97 1.75	0.09 1.70	3.5	2.1
L3TSA	5.42 4.53	2.85 4.91	0.24 1.87	2.6	1.2
L3TSB	5.46 4.49	2.45 4.78	0.22 2.08	2.8	1.2
MEAN	5.44 4.51	2.65 4.85	0.23 1.98	2.7	1.2
L3SSA	5.54 4.4	2.29 3.95	0.19 0.57	2.2	1.6
L3SSB	5.55 4.28	2.28 3.87	0.18 0.63	3.6	1.8
MEAN	5.55 4.34	2.29 3.91	0.19 0.60	2.9	1.7
UTSA	6.83 4.42	2.49 4.29	0.21 0.70	4.1	2.6
UTSB	6.78 4.46	2.50 4.34	0.22 0.72	3.8	2.4
MEAN	6.81 4.44	2.50 4.32	0.22 0.71	3.95	2.5
L4SSA	5.86 4.12	0.49 0.85	0.04 0.16	2.3	1.6
L4SSB	5.78 4.14	0.48 0.87	0.06 0.15	2.4	1.8
MEAN	5.82 4.13	0.49 0.86	0.05 0.16	2.35	1.7
CTSA	5.57 4.92	0.01 0.03	0.01 0.56	1.9	1
CTSB	5.56 4.88	0.01 0.03	0.01 0.68	2	1.4
MEAN	5.57 4.90	0.01 0.03	0.01 0.62	1.95	1.2
CSSA	5.22 4.41	1.10 1.89	0.09 1.77	2.2	1.6
CSSB	5.24 4.43	1.09 1.67	0.08 1.76	2.4	1.6
MEAN	5.23 4.42	1.095 1.78	0.085 1.765	2.3	1.6
LSD (0.05)	0.233288 0.1114	0.913462 2.75532	0.0063 0.482	0.620934	0.18
Variance	-	-	-	-	

3.5. Lead (Pb) vs. Nickel (Ni) Correlation

The statistical results from correlations of Lead (Pb) and Nickel (Ni) are shown in Table 2. Lead (Pb) concentration levels in the five locations showed that there is no strong relationship with Nickel (Ni) (P<1； Pearson Correlation less than or equal to 1). The Nickel (Ni) to Lead (Pb) relationship in the crude oil polluted soils did not vary significantly (P<0.05). Therefore, the soils are strongly polluted by Lead (Pb) and slightly polluted by Nickel (Ni). Lead (Pb) concentration levels in the soil are above critical limits of O.1ppm while Nickel is slightly above limits of <1.0ppm (WHO, 2006). Therefore, the soil is strongly polluted by Lead (Pb) because of crude oil spillage pollution. According to [30] heavy metals are found in high quantities in most oil spilled soils in southeastern Nigeria. Heavy metals are extremely carcinogenic.

Table 3 - Chemical properties continuation

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Sample	K	Na	AL	H	BS %	C/N	K/Mg	Ca/Mg
FIELD NO	(Cmol/ kg)	(mol/kg)	(Cmol/ kg)	(Cmol/ kg)				
L1TSA	0.25	0.17	0.9	0.4	5.37-75.80	11.88	0.15	1.29
L1TSB	0.24	0.18	0.9	0.5	5.48-73.78	11.84	0.14	1.33
MEAN	0.25	0.18	0.9	0.45	5.43-74.79	11.86	0.15	1.31
L1SSA	0.18	0.12	0.7	1	4.50-62.20	11.86	0.15	1.08
L1SSB	0.19	0.13	0.68	0.9	4.70-63.30	12.03	0.18	1.07
MEAN	0.19	0.13	0.69	0.95	4.60-62.75	11.95	0.17	1.08
L2TSA	0.24	0.13	0.8	0.3	4.47-75.30	12.08	0.2	1.5
L2TSB	0.25	0.14	0.7	0.4	4.45-75.20	12.21	0.17	1.5
MEAN	0.25	0.14	0.75	0.35	4.46-75.25	12.15	0.19	1.5
LTSSA	0.27	0.16	0.8	0.6	7.23-80.60	12.37	0.14	1.7

Conclusion

Conclusively, after comparing the fertility status of the crude oil polluted and nonpolluted areas, it was discovered that there were no significant differences in the fertility status of the soils. Most of the indicators did not vary statistically. Crude oil spilled soils had appreciable values of organic matter, total nitrogen, and cation exchange capacity. However, these organic nutrients are in insoluble forms and therefore unavailable for plant uptake. However, the soil is acidic. In reference to this result, despite the high fertility status of the soil, there is significantly strong pollution by crude oil spillage and heavy metals affecting its potential to support plant growth and enhance sustainable agriculture; and consequently, affecting sustainable environmental development.

Конфликт интересов

Не указан.

Conflict of Interest

None declared.

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