

Post-Remediation Assessment of the Quality of Oil Spill Impacted Soils

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Citation: Ihejirika CE, Iheanacho C, Okezie U, Dike MU, Njoku PC, et al. (2019) Post-Remediation Assessment of the Quality of Oil Spill Impacted Soils. *J Environ Pollut Manage* 2: 203

Abstract

This study was carried out to assess the quality of remediated oil spillage impacted soils in Mgbodo Aluu, Ikwerre Local Government Area, Rivers State. Remediated soil samples were collected with the aid of a well calibrated stainless steel hand dug soil auger (2.50 cm in diameter) from six (6) sampling points with a control sample from a non-contaminated site in the same study area, at the depth of 0-30 cm and were immediately transported to the laboratory for standard chemical analyses. Results were compared with established standards and computed with Index of geo-accumulation (I-geo) and Contaminant factor (Cf) models to establish the levels of human impact. All parameters varied significantly ($P < 0.05$) at all sampling points. All values of parameters were significantly above their respective control values. pH ranged between 5.89 ± 0.13 and 5.48 ± 0.08 ; Total Petroleum Hydrocarbon (TPH) from 3015.67 ± 283.93 - 193.67 ± 161.98 mg/kg; Cation Exchange Capacity (CEC) from 3.07 ± 0.05 - 2.74 ± 0.18 Cmol/kg; Cr from 21.66 ± 0.31 - 4.71 ± 0.34 mg/kg; Pb from 3.61 ± 0.49 - 0.21 ± 0.03 mg/kg; Cd from 2.41 ± 0.09 - 0.00 mg/kg; Zn from 12.88 ± 0.27 - 1.79 ± 0.11 mg/kg and Cu from 8.36 ± 0.06 - 3.14 ± 0.13 mg/kg. I-geo for most parameters ranged from very highly polluted to unpolluted, while Cf ranged from very high contamination to low contamination factors. Anthropogenic impact ranged from 99-56.16%. The study established that the remediation of the oil spill contaminated soils were not uniform at all sampling points and varied from location to location. Soil quality ultimately changed on impact by oil spill and remediation was not efficient.

Keywords: Oil Spillage; Pollution; Natural Attenuation; Post-Remediation Assessment; Soil Health

Introduction

According to Inoni, *et al.* [1], all stages of oil exploitation impact negatively on the environment, and the greatest single intractable environmental problem caused by crude oil exploration in the Niger Delta region is oil spillage. According to DPR [2], over 6000 spills had been recorded in the 40 years of oil exploitation in Nigeria, with an average of 150 spills per annum. In the period 1976-1996, 647 incidents occurred resulting in the spillage of 2,369,407.04 barrels of crude oil. With only 549,060.38 barrels recovered, 1,820,410.50 barrels of oil were lost to the ecosystem. The consequences of oil spillage in the environment are the bane of environmental degradation, dwindling ecological diversity, contaminant migration and pollution of ground water systems [1]. According to Achi [3] the impact of oil spillage on the socio-economic life and environment of the host communities of oil exploration companies, has left a record of ecological and socio-physical damage.

Restoration of the contaminated soils in the Niger Delta region of Nigeria has become a major challenge to stakeholders in environmental protection. Periodically, numerous post-impact assessment (PIA) studies are carried out to assess the impact of the effects generated by the oil industry on the general environment. Efforts were made in most cases to remediate the environment using various available techniques. Most of these assessments were focused on comparison of results with established standards but with little or no considerations on the marginal shift in the original environmental quality. Most cases, some areas of the farm land might have received more spills than other. The efficiency of remediation works might not be effectively and uniformly executed on all the contaminated soil, leaving some portions of the farm land non-remediated and physicochemical characteristics above acceptable limits. This study therefore employed post-remediation assessment on previously remediated of oil spill contaminated soils in Aluu community in Rivers State to assess the efficiency of remediation by monitoring physicochemical characteristics of the contaminated area and comparing with uncontaminated (control sites) and established standard limits.

Materials and Methods

Study area

The study area was at crude oil spill remediated soil area of Mgbodo Aluu in Ikwerre Local Government Area, Rivers State, as shown in Figure 1. The area was contaminated with crude oil spillage and was remediated by natural attenuation by Shell Petroleum Development Company.

Sample collection

Remediated soil samples were collected with the aid of a well calibrated stainless steel hand dug soil auger (2.50 cm in diameter) from six (6) sampling points in triplicates (18 samples) at the depth of 0-30 cm. Control soil samples were collected in triplicates (3 samples) at the depth of 0-30cm from a non-contaminated site at Igrita in the same study area. The soil samples were immediately transported to the laboratory for standard chemical analyses.

Chemical analyses

Determination of pH

Twenty grams of air dried soil samples were weighed into a 50mL beaker and 20mL distilled water was added and allowed to stand for 30mins. The solution was filtered and the filtrate used to determine pH of soil sample. Hach pH meter was used to determine the pH. Meter was calibrated using pH calibration buffer solution for pH 4, 7 and 10. The electrode of the meter was dipped into the filtrate and the pH meter readings taken to the nearest 0.05unit.

Determination of conductivity

Twenty grams of air dried soil samples were weighed into a 50 mL beaker and 20 mL distilled water was added and allowed to stand for 30 mins. The solution was filtered and the filtrate used to determine the conductivity of soil sample. Hach conductivity meter was used to determine the conductivity. The conductivity meter was calibrated using conductivity calibration solution. The electrode of the meter was dipped into the filtrate and the conductivity meter readings taken to the nearest 0.05unit.

Determination of heavy metals

One gram of the dried fine soil sample was weighed and transferred into an acid washed, round bottom flask containing 10 cm³ concentrated nitric acid. The mixture was slowly evaporated over a period of 1hour on a hot plate. Each of the solid residues obtained was digested with a 3:1 concentrated HNO₃ and HClO₄ mixture for 10 m at room temperature before heating on a hot plate. The digested mixture was placed on a hot plate and heated intermittently to ensure a steady temperature of 150 °C over 5 hours until the fumes of HClO₄ were completely evaporated [4]. The mixture was allowed to cool to room temperature and then filtered using Whatman No.1 filter paper into a 50 cm³ volumetric flask and made up to the standard mark with deionized water after rinsing the reacting vessels, to recover any residual metal. The filtrate was then stored in pre-cleaned polyethylene storage bottles ready for analysis. Heavy metal concentrations were determined, each with a specific lamp using an Atomic Absorption Spectrophotometer (AAS) AA600 Series.

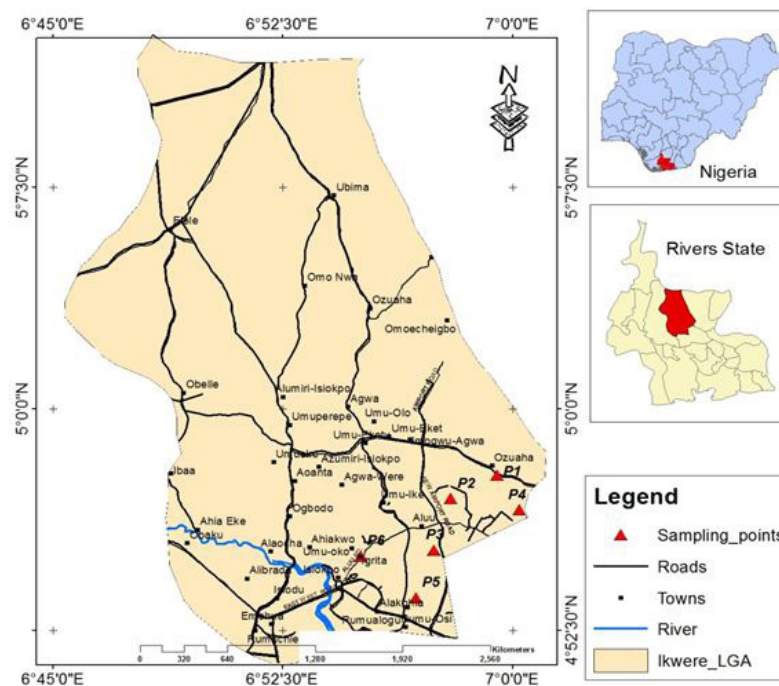


Figure 1: Map of the study area showing the sampling points

Determination of Total Petroleum Hydrocarbon (TPH) in soil

Ten grams (10g) of the sample was weighed into extraction bottle and 20mL of extraction mixture (DCM: Hexane: acetone) in ratio 2:2:1 was added. The mixture was sonicated for 1hr and the organic aqueous layer was decanted. Extracted organic phase was dried using anhydrous sodium sulphate salt and concentrated using vacuum rotary evaporator gas to about 1.0mL. Round bottom flask was rinsed to make the final volume of the extract to 1.0ml. One microlitre (1.0 µL) of the final extract was injected into already calibrated Gas Chromatograph (HP 5890, USA) equipped with capillary column. The peak areas are used in the quantifications. All QA/QC procedures were strictly followed.

Extract was fractionated by using column packing. The column was packed by placing 1g of glass wool into the column and gently packed. One milliliter (1ml) of silica gel was placed on it and 1ml of sodium sulphate was added on top of the silica gel. The column was pre-conditioned by running 10mL of n-hexane through the column. One milliliter (1ml) of the concentrated extract was placed on the column and eluted with 10mL n-hexane. Eight milliliter (8ml) of the eluents was taken and discarded and the remaining 2mL was collected and kept in a 2mL vial for ALIPHATICS. To the same column, 10mL of DCM was allowed to drain through the column and 8mL of the eluent was collected and discarded. The remaining 2mL was collected into a vial and kept for AROMATICS. One microlitre (1.0 µL) of the aromatic and aliphatic extract was injected into already TPH calibrated standard GC and result was expressed in mg/kg.

Determination of Cation Exchange Capacity of the soil samples

The method used by Burt [5] was adopted. Ten (10g) grams of air-dried soil ground to less than 2 mm was weighed and placed into a 250 ml beaker. Twenty five milliliters (25 mL) of NH₄OAc was to the soil. It was covered and let to set overnight. For each sample, a 7 cm Buchner funnel was prepared by fitting it with a 7cm Whatman No. 42 filter paper. The filter was wetted with a minimum amount of NH₄OAc. The funnel was inserted into a 250 ml suction flask. The vacuum pump was turned on to seat the moistened filter. The soil-NH₄OAc mixture was stirred and transferred into the filter. Approximately 75mL NH₄OAc for each sample was measured into a plastic squirt bottle with one bottle for each sample. About was used in the bottle to transfer all of the soil to the Buchner funnel. The soil was covered with a 7.0 cm Whatman No. 1 filter paper to keep the soil moist between leachings. The soil was leached 5 to 7 times with 10 to 15 ml increments of NH₄OAc. The leachate was transferred to a 250 mL volumetric and brought to volume with 1 M NH₄OAc. The solution was analyzed for Ca, Mg, K, and Na using atomic absorption spectrophotometry.

Determination of level of pollution

Calculation of Index of geo-accumulation (I-geo)

The degree of metal and Total Petroleum Hydrocarbon (TPH) pollution at different sites were assessed in terms of seven contamination classes in order of increasing numerical value of the index as shown in Table 1 [6,7]. It was applied to unravel levels of accumulation of heavy metals and Total Petroleum Hydrocarbon (TPH) at the different sites.

$$I\text{-geo} = \log_2(C_n/1.5B_n) \tag{1}$$

Where C_n was the concentration of the heavy metal or Total Petroleum Hydrocarbon (TPH) in the contaminated sample and B_n was the concentration of the metal or Total Petroleum Hydrocarbon (TPH) in the unpolluted (control) samples. The factor 1.5 was introduced to minimize the effect of the possible variations in the background or control values which may be attributed to lithogenic variations in the soil [6].

Category	Value of Soil Quality
<0	Unpolluted
0-1	Unpolluted to moderately polluted
1-2	Moderately polluted
2-3	Moderately polluted to highly polluted
3-4	Highly polluted
4-5	Highly polluted to very highly polluted
>5	Very highly polluted

Table 1: Seven classes of geo-accumulation index

Calculation of Contaminant factor (Cf)

The second approach was the application of Contamination factor (Cf) and the degree of contamination. In calculating Cf, the Equation (2) suggested by Hakanson [8] and Dasaram, *et al.* [9] was used.

$$Cf = C_{0-1}^i / C_n^i \tag{2}$$

Where C_{0-1}^i was the mean content of individual metals or Total Petroleum Hydrocarbon (TPH) from the 6 sample sites and C_{in} was the pre-anthropogenic concentration of individual metals or Total Petroleum Hydrocarbon (TPH). Cf was used to differentiate between the metals or Total Petroleum Hydrocarbon (TPH) originating from anthropogenic activities and those from natural processes and to assess the degree of anthropogenic influence (Table 2).

Contamination factor	Category
$C_f < 1$	Low contamination factor
$1 < C_f < 3$	Moderate contamination factor
$3 < C_f < 6$	Considerable contamination factor
$6 < C_f$	Very high contamination factor
3-4	Highly polluted
4-5	Highly polluted to very highly polluted
>5	Very highly polluted

Table 2: Categories of contamination factors

The third approach used the quantification of anthropogenic concentration of metal or Total Petroleum Hydrocarbon (TPH) by applying the concentration in the control samples to represent the lithogenic metal [10]. This was calculated in accordance with Equation (3):

$$\text{Quantification of anthropogenic metal/TPH} = \frac{X - X_c}{X} \times 100\% \quad (1)$$

Where X = average concentration of the metal in the soil under investigation, and X_c = average concentration of the metal in the control samples [11]. In this study, the concentration of the control samples is taken to represent the pre-anthropogenic concentration as suggested by Victor, *et al.* [11].

Result

Results of Chemical Analysis of Remediated Soil Samples

Table 3 showed the variations of values of the analyzed chemical parameters at different sampling points and comparison with EGASPIN [12] standard. All parameters varied significantly ($P < 0.05$) at all sampling points. pH values ranged between 5.89 ± 0.13 and 5.48 ± 0.08 and close to the control sample value of 5.40. pH varied significantly at all the sampling at $P = 0.015$. Total Petroleum Hydrocarbon (TPH) concentrations ranged from 3015.67 ± 283.93 - 193.67 ± 161.98 mg/kg. TPH values varied significantly at $P < 0.001$. TPH was highest at sampling point B and lowest in sample point E. The values were highly above the control value of 0.01 mg/kg. TPH values were above EGASPIN [12] limit of 1000 mg/kg at sampling points A, B and C while it was below EGASPIN [12] limit at sampling points D, E and F. Cation Exchange Capacity (CEC) varied significantly at different sampling points at $P < 0.003$ and ranged from 3.07 ± 0.05 - 2.74 ± 0.18 Cmol/kg, with highest value at sampling point A and lowest value at sampling point E. The values were below the control value of 5.31 Cmol/kg. Chromium (Cr) ranged from 21.66 ± 0.31 - 4.71 ± 0.34 mg/kg, and varied significantly at $P < 0.001$, with the highest value at sampling point B and lowest value at sampling point F. The values were highly above the control value of 0.01 mg/kg. The values were below the EGASPIN [12] limit of 20 mg/kg. Lead (Pb) ranged from 3.61 ± 0.49 - 0.21 ± 0.03 mg/kg, and varied significantly at $P < 0.001$, with highest value recorded at sampling point C while the lowest value was recorded at sampling point F. The values were highly above the control value of 0.30 mg/kg. Pb values were below the EGASPIN [12] limit of 35 mg/kg. Cadmium (Cd) ranged from 2.41 ± 0.09 - 0.00 mg/kg and varied significantly at $P < 0.001$, with highest value recorded at sampling point F and lowest value at sampling points A and B. The values were highly above the control value of 0.07 mg/kg. Cd values were below the EGASPIN [12] limit of 100 mg/kg. Zinc (Zn) ranged from 12.88 ± 0.27 - 1.79 ± 0.11 mg/kg and varied significantly at $P < 0.001$, with highest value recorded at sampling points E and lowest value at sampling point B. The values were highly above the control value of 3.20 mg/kg. Zn values were below the EGASPIN [12] limits of 140 mg/kg. Copper (Cu) ranged from 8.36 ± 0.06 - 3.14 ± 0.13 mg/kg and varied significantly at $P < 0.001$, with highest value recorded at sampling point B and lowest value at sampling point C. The values were highly above the control value of 0.01 mg/kg. Cu values were above EGASPIN [12] limit of 0.3 mg/kg.

Index of geo-accumulation (I-geo) of parameters at different locations in the remediated soil

The results of computation of I-geo for contaminants were as shown in Table 4. I-geo for TPH ranged from 17.62 to 13.66 for all the sampling points. I-geo TPH was highest at points B and C (17.62) respectively and was lowest at point E (13.66). I-geo TPH was > 5 (Very highly polluted). I-geo for Cr ranged from 10.49 to 8.29 for all the sampling points. I-geo Cr was highest in B (10.49) and lowest in F (8.29). I-geo Cr for all sampling points were > 5 (Very highly polluted). I-geo for Pb ranged from 3.00 to -1.09 for all the sampling points. I-geo Pb was highest in C (3.00) and lowest in F (-1.09). Point A was (2.33 = moderately polluted to highly polluted); point B (1.19 = moderately polluted); point C (3.00 = moderately polluted to highly polluted);

point D (1.55 = moderately polluted); point E (2.65 = moderately polluted to highly polluted) and point F (-1.09 = Unpolluted). I-geo Cd ranged from 4.45 to -0.00 for all the sampling points. I-geo Cd was highest in F (4.45) and lowest in A and B (-0.00) respectively. Point A was (-0.00 = Unpolluted); point B (-0.00 = Unpolluted); point C (3.00 = moderately polluted to highly polluted); point D (-1.47 = Unpolluted); point E (2.32 = moderately polluted to highly polluted) and point F (4.45 = highly polluted to very highly polluted). I-geo Zn ranged from 1.42 to -1.43 for all the sampling points. I-geo Zn was highest in E (1.42) and lowest in B (-1.43). Point A was (-0.59 = Unpolluted); point B (-1.43 = Unpolluted); point C (1.21 = moderately polluted); point D (0.34 = Unpolluted to moderately polluted); point E (1.42 = moderately polluted) and point F (0.89 = Unpolluted to moderately polluted). I-geo Cu ranged from 9.12 to 7.71 for all the sampling points. I-geo Cu was highest in B (9.12) and lowest in C (7.71). I-geo Cu for all sampling points were >5 (Very highly polluted).

Categorization of Contaminant factors (Cf) of parameters and quantification of anthropogenic impact in contaminated soils

The results of the computation of the Contaminant factor (Cf) and quantification of the anthropogenic impact of the oil spillage after remediation of contaminated soils were as shown in Table 5. The mean value of TPH at the different sampling points was 1633.56±1271.76 mg/kg, at a control sample value of 0.01mg/kg. Cf value for TPH was 163355.67 which fell in the category of very high contamination, with an anthropogenic impact of 99.99%. The mean value of Cr at the different sampling points was 11.87±5.20 mg/kg, at a control sample value of 0.01mg/kg. Cf value for Cr was 1186.89 which fell in the category of very high contamination, with an anthropogenic impact of 99.91%. The mean value of Pb at the different sampling points was 1.88±1.22 mg/kg, at a control sample value of 0.30 mg/kg. Cf value for Pb was 6.26 which fell in the category of very high contamination, with an anthropogenic impact of 87.78%. The mean value of Cd at the different sampling points was 0.65±0.89 mg/kg, at a control sample value of 0.07 mg/kg. Cf value for Cd was 9.26 which fell in the category of very high contamination, with an anthropogenic impact of 89.23%. The mean value of Zn at the different sampling points was 7.30±4.16 mg/kg, at a control sample value of 3.20 mg/kg. Cf value for Zn was 2.28 which fell in the category of moderate contamination, with an anthropogenic impact of 56.16%. The mean value of Cu at the different sampling points was 5.67±1.91 mg/kg, at a control sample value of 0.01 mg/kg. Cf value for Cu was 566.67 which fell in the category of very high contamination, with an anthropogenic impact of 99.82%.

Parameters	A	B	C	D	E	F	P-Value	DPR	CS
pH	5.74±0.22	5.89±0.13	5.78±0.03	5.67±0.06	5.48±0.08	5.88±0.14	0.015	-	5.40
TPH mg/kg	2428.33±127.0	3015.67±283.93	3014.67±509.51	700.83±396.6	193.67±161.98	448.67±107.32	<0.001	1000	0.01
CEC Cmol/kg	3.07±0.05	2.99±0.02	2.97±0.07	3.08±0.01	2.74±0.18	3.00±0.01	< 0.003	-	5.31
Cr mg/kg	11.09±0.03	21.66±0.31	10.09±0.23	12.82±0.69	10.84±0.2	4.71±0.34	<0.001	20.00	0.01
Pb mg/kg	2.27±0.04	1.03±0.02	3.61±0.49	1.32±0.7	2.82±0.24	0.21±0.03	<0.001	35.00	0.30
Cd mg/kg	0.00	0.00	0.88±0.29	0.04±0.01	0.55±0.17	2.41±0.09	<0.001	100.00	0.70
Zn mg/kg	3.19±0.12	1.79±0.11	11.08±0.19	6.08±0.84	12.88±0.27	8.88±0.27	<0.001	140.00	3.20
Cu mg/kg	7.86±0.08	8.36±0.06	8.36±0.06	4.65±0.22	4.76±0.25	5.23±0.11	<0.003001	31.00	0.01

Note: A to F are sampling points, CS = Control sample EGASPIN [12]

Table 3: Physicochemical analysis of remediated soil samples compared with DPR standard

Index of geoaccumulation for parameters	A	B	C	D	E	F
I-geo TPH	17.30	17.62	17.62	15.51	13.66	14.87
I-geo Cr	9.53	10.49	9.39	9.74	9.49	8.29
I-geo Pb	2.33	1.19	3.00	1.55	2.65	-1.09
I-geo Cd	-0.00	-0.00	3	-1.47	2.32	4.45
I-geo Zn	-0.59	-1.43	1.21	0.34	1.42	0.89
I-geo Cu	9.03	9.12	7.71	8.28	8.31	8.45

A to F are sampling points

Table 4: Computation of Index of geo-accumulation (I-geo) of Some Parameters at Sampling Points

Parameters	Mean values (mg/kg)	Control values (mg/kg)	(Cf)	Category	% Anthropogenic impact	P- Value
TPH	1633.56±1271.76	0.01	163355.67	Very high contamination	99.99	<0.001
Cr	11.87±5.20	0.01	1186.89	Very high contamination	99.91	<0.001
Pb	1.88±1.22	0.30	6.26	Very high contamination	87.78	<0.001

Parameters	Mean values (mg/kg)	Control values (mg/kg)	(Cf)	Category	% Anthropogenic impact	P- Value
Cd	0.65±0.89	0.07	9.26	Very high contamination	89.23	<0.001
Zn	7.30±4.16	3.20	2.28	Moderate contamination	56.16	56.16 <0.001
Cu	5.67±1.91	0.01	566.67	Very high contamination	99.82	99.82 <0.001

Table 5: Categorization of Cf of Some Parameters and Quantification of Anthropogenic Impact in Six Sampling Points (18 samples)

Discussion

The significant variation ($P < 0.05$) of parameters at different sampling points was confirmative of the fact that the level of remediation was not uniform for all parameters or characteristics of the soil at the different sampling points. Since the soil properties or characteristics might be same within the study area before contamination, the concentrations of the crude oil at the different sites/points before remediation might have varied with the remediation efficiency [13]. The topography of the area might play key role in the velocity of the oil spread and dispersion [14]. Increased velocity of the oil dispersion might reduce the stay time and rate of infiltration of the oil into the soil [15]. Stagnancy of oil spills might be responsible for variations in concentration of contaminated sites [16]. Another major factor responsible for the varying concentrations of parameters at the different sites/points might be the efficiency of oil recovery [17]. Oil recovery before remediation from contaminated sites might not have reduced the concentrations of the oil to uniform concentrations at the varying sites or points.

Though the pH varied significantly ($P < 0.05$) at the different sampling points, it still remained acidic when compared with the pH of the control sample. Though, the Niger Delta soils have been known to be generally acidic, oil spillage might assist the soil in maintaining acidic pH values. Acidic soil pH affects soil microbial activities and nutrient bio-geochemical cycling [18]. Acidic pH of soils can affect the availability of soil nutrients and mobility of heavy metals. Heavy metals might be toxic to soil biota and lead to ground water contamination due to infiltration.

That the TPH values were above DPR limit of 1000 mg/kg [12] at sampling points A, B and C while it was below EGASPIN [12] at sampling points D, E and F, implied that the remediation was not uniformly carried out at all the sampling points and that some points in the study area were still affected by the oil spill even after remediation. The values were highly above the control value of 0.01 mg/kg. I-geo TPH was >5 which implied that the study area was very highly polluted [6]. Cf value for TPH was 163355.67 which fell in the category of very high contamination [9], with an anthropogenic impact of 99.99% [10]. The high TPH results confirm petroleum hydrocarbon pollution. Measured TPH values suggest the relative potential for human exposure, and therefore, the relative potential for human health effects. According to Agency for Toxic Substance and Disease Registry (ATSDR), [19] the compounds in some TPH fractions can also affect the blood, immune system, liver, spleen, kidney, developing foetus and lungs. Certain TPH compounds can be irritating to the skin and eyes. One TPH compound (benzene) has been shown to cause cancer (leukemia) in people. The International Agency for Research on Cancer [20] has determined that benzene is carcinogenic to humans. Some other TPH compounds or petroleum products such as; benzo(a)pyrene and gasoline are considered to be probably and possibly carcinogenic to humans based on cancer studies in people and animals. One TPH compound (n-hexane) can affect the central nervous system in a different way, causing a nerve disorder called “peripheral neuropathy” characterized by numbness in the feet and legs, and in severe cases, paralysis swallowing. Some petroleum products such as gasoline and kerosene cause irritation of the throat and stomach, central nervous system, depression, difficulty in breathing and pneumonia from breathing liquid into the lungs. However, for the fact that some TPH fractions are persistent pollutants and are present in water and soil, signifies the sure intake of the substances through the roots of plants and presence in the fruits of the plants with higher tendencies for bioaccumulation in aquatic biota spells serious concern. The presence of TPH in the soil serves as a reservoir for PAHs leached into the ground water and as runoff into surface water. Its presence indicates the exposure of humans to health problems. The CEC values were below the control value of 5.31 Cmol/kg. According to Karumam, *et al.* [21], a low value of CEC implied that the soil had a low capacity to hold cations in exchangeable form. In this study, the CEC values obtained may be classified as low [21] and could be attributed to the loss of binding capacity in the soils due to oil spillage. Therefore, retention of metal ion was low in all the sampling points and this could suggest high leachability of heavy metals from soils underneath the wastes into underground water, thereby posing a health hazard to humans and other animals that drink this water. The values of Cr were below the EGASPIN [12] limit of 20 mg/kg and highly above the control value of 0.01 mg/kg. This implied that the remediation was efficient in controlling deposits of Cr below established standards. This did not imply that there was no introduction of Cr in the study area due to the oil spillage. I-geo Cr for all sampling points were >5 , which implied that the study area was very highly polluted [6] when compared with the value of the control sample. The Cf value for Cr was 1186.89 which fell in the category of very high contamination [9], with an anthropogenic impact of 99.91% [10]. Though, Pb varied significantly ($P < 0.05$) at the different sampling points, Pb values were below DPR limit of 35 mg/kg. This implied that the remediation was efficient in controlling deposits of Pb below established standards. This did not imply that there was no introduction of Pb in the study area due to the oil spillage. I-geo for Pb showed that some points were highly polluted, while others were moderately polluted to unpolluted [6] when compared with the value of control sample. The Cf value for Pb was 6.26 which fell in the category of very high contamination [9], with an anthropogenic impact of 87.78% [10].

The values of Cd were below the EGASPIN [12] limit of 100 mg/kg and were highly above the control value of 0.07 mg/kg. This did not imply that there was no introduction of Cd in the study area due to the oil spillage. I-geo for Cd showed that some points were highly polluted, while others were moderately polluted to unpolluted [6] when compared with the value of control sample. The Cf value for Cd was 9.26 which fell in the category of very high contamination [9], with an anthropogenic impact of 89.23% [10].

The values of Zn were below the EGASPIN [12] limits of 140 mg/kg and were highly above the control value of 3.20 mg/kg. This did not imply that there was no introduction of Zn in the study area due to the oil spillage. I-geo for Pb showed that some points were moderately polluted while others were unpolluted [6] when compared with the value of control sample. The Cf value for Zn was 2.28 which fell in the category of moderate contamination [9], with an anthropogenic impact of 56.16% [10].

The values of Cu were above EGASPIN [12] limit of 0.3 mg/kg and were highly above the control value of 0.01 mg/kg. I-geo Cu for all sampling points were >5 which implied that the study area was very highly polluted [6] when compared with the value of the control sample. The Cf value for Cu was 566.67 which fell in the category of very high contamination [9], with an anthropogenic impact of 99.82% [10].

Conclusion

The study showed that the remediation of the oil contaminated farm land was not completely effective and effective. Thus, demands the need for proper post-remediation assessment of oil contaminated agricultural lands to ensure environmental sustainability.

Acknowledgement

We appreciate the cooperation of staff of the National Oil Spill Detection and Response Agency, Nigeria in ensuring the success of this study.

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