POST CLEAN-UP ASSESSMENT OF CRUDE OIL POLLUTED SOILS OF IKOT ADA UDO IN IKOT ABASI LOCAL GOVERNMENT AREA OF AKWA IBOM STATE

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ABSTRACT
Environmental pollution through oil spills has reportedly caused serious damage to both aquatic and terrestrial ecosystems, destruction of forests and farmlands and severely affects the characteristics and management of agricultural soils. Ikot Ada Udo is an agrarian community of about 20,000 people. Since the 2007 crude oil pollution of their agricultural lands, the people of the community, particularly those whose plots were affected, have continued to abandon those lands to seek non-existent alternative means of livelihood. Consequently, hunger, malnutrition, poverty and premature deaths have jointly dealt a deadly blow on the community. The objectives of this study were to assess total petroleum hydrocarbon (TPH) and associated heavy metal (Fe, Cr, Cu, Ni, Pb and Cd) levels in soils affected by the 2007 soil spillage at Ikot Ada Udo in Ikot Abasi Local Government Area following cleanup (August 2008 – March 2009). Two composite soil samples collected from the crude oil affected site at 0 – 15 cm and 15 30 cm depth intervals were analyzed using routine methods and presented in a tabular form. Results showed that TPH was low (14.21 mgkg^{-1}); Fe was high (42.98 mgkg^{-1}); while Cr (12.12 mgkg^{-1}), Cu (9.43 mgkg^{-1}), Ni (11.44 mgkg^{-1}), Pb (1.40 mgkg^{-1}) and Cd (4.16 mgkg^{-1}) were within permissible ranges for agricultural soils. The soils were predominantly loamy sand in texture; low in electrical conductivity (0.0475 dsm^{-1}), total N (0.12 %), exchangeable Ca (3.0 cmolkg^{-1}), exchangeable K (0.11 cmolkg^{-1}) and ECEC (6.01 cmolkg^{-1}); moderate in available P (15.87 mgkg^{-1}) and exchangeable Mg (1.35 cmolkg^{-1}) and high in organic C (4.68 %) and base saturation (66.7 %). The soil samples indicated strong acidity (pH 5.5 in the surface and 5.4 in the subsurface). Nutrient deficiencies (especially N, K and Ca), strong acidity and Fe toxicity were identified as possible problems of the soils. Application of appropriate fertilizers, liming and mulching are management measures recommended for improved soil and crop productivity.

Keywords: *post clean-up assessment, crude oil-polluted soils, soil characteristics, Ikot Abasi, Akwa Ibom State*

INTRODUCTION
Man's technological and scientific advances have caused environmental changes with serious socio-economic consequences. Environmental pollution is one of the major effects of man's technological development. Pollution results when a change in the environment due to the presence in a significant amount of an extraneous material (solid, liquid or gas) harmfully affects the quality of human life including the effects on animals, micro-organisms and plants (Marinescu *et al.*, 2010). The contamination of the environment (mainly terrestrial and aquatic) by crude oil is referred to as oil pollution. Environmental pollution through oil spills has caused serious damage to both aquatic and

terrestrial ecosystems, and destruction of forests and farmlands, and also severely affects the characteristics and management of agricultural soils (Mishra *et al.*, 2015). Oil pollution alters both chemical and physical properties of soil and degrades soil fertility (Dambo, 2000).

Different scholars have reported the effects of crude oil pollution on soil properties, growth and yields of crop plants, particularly if the concentration is above 3 % (Osuji *et al*., 2005; Udo, 2008; Chukwu and Udoh, 2014). Soils contaminated with oil have characteristics that render them less useful to humans. Also, the heavy metals associated with crude oil have some deleterious effects on soil and crop productivity (Barakat *et al*., 2016). Although, some of them are essential micronutrients for plants at low concentrations, they may cause metabolic disorders and become growth inhibitors to most plant species at high concentrations (Li *et al*., 2014). Contamination of soils by crude oil spills is a wide spread environmental problem that requires clean-up. Unfortunately, available data to manage the agricultural soils in the country (Niger Delta region in particular) are inadequate. Although, these data have found various uses in post-spill management programs of the affected ecosystems and communities, recent advances have shown that such data are specific to particular sites and incidents due to the nature of the crude oil contaminants and possible environmental modifications (Osuji *et al.*, 2006).

Ikot Abasi Local Government Area in Southern Akwa Ibom State, Niger Delta region of Nigeria, is a major oil producing area which has both on-shore and off-shore fields (Udo, 2008). Oil exploration in Ikot Abasi by Shell Petroleum Development Company (SPDC) started in the nineteen forties (Udo, 2008). Ikot Ada Udo village in the area was one of the on-shore areas where oil was discovered in commercial quantities but had been preserved within a corked well codenamed IBIBIO-I well, for more than 50 years. Over the years, oil has spilled from the corked well several times, the most devastating occurring between August and November 2007, when a large volume of oil from the corked well spilled and spread over an extensive area of land causing serious environmental damage (Udo, 2008).

Ikot Ada Udo is an agrarian community but since the 2007 crude oil pollution of their agricultural lands, the people of the community, particularly those whose farmlands were affected, have abandoned their lands to seek alternative means of livelihood. Consequently, hunger, malnutrition, poverty and premature deaths have impacted negatively on the community. Reports from earlier studies (Osuji *et al*., 2005; Udo, 2008; Chukwu and Udoh, 2014) on the problem have raised serious ecological concerns considering the magnitude of environmental degradation, loss of farmlands and heavy metals toxicity. Oil spill had severely degraded most agricultural lands in the community and turned hitherto productive areas into wastelands given that the physico-chemical characteristics of the soils were highly affected and there were high concentrations of heavy metals as well as nutrient imbalances. The people would not still believe that the lands could still be put to meaningful agricultural use after some years because they did not believe that the clean-up exercise would restore the soil. This has made life increasingly difficult for the community.

It is expected that this study would generate information that could help encourage the community to return to the abandoned lands for meaningful agricultural production and tips on proper management of the affected soils for increased agricultural productivity in the community. Also, findings of the study would serve as a guide in taking decisions on effective remediation approach to adopt in similar occurrence in the future.

Consequently, the objectives of this study were to:

1) Assess the total petroleum hydrocarbon (TPH) level, heavy metal levels and the physico-chemical properties in the crude oil affected soils at Ikot Ada Udo, Ikot Abasi Local Government Area of Akwa Ibom State.
2) Determine the fertility status and constraints of the soils.
3) Suggest management measures that could be adopted to improve the agricultural productivity of the soils.

MATERIALS AND METHODS

Description of the study area

This research was conducted at Ikot Ada Udo in Ikot Abasi Local Government Area of Akwa Ibom State, Nigeria. Ikot Abasi lies between latitude 4^o 28^I and 4^o 43^I N and longitudes 7^o 30^I and 7^o 50^IE (Udo *et al.*, 2001). The climate of the area is humid tropical marked by dry and wet seasons. The dry season starts from November and ends in March, while the wet season starts from April and ends in October, though there is a short break in August generally known as "August Break" during the long rainy season. Rainfall is usually heavy with mean annual value of over 3000 mm and mean annual temperature of about 27 ^oC. Relative humidity (about 80 %) and cloud covers are high resulting in low incipient solar radiation (Udo, 2008).

The soils in the area are formed on Tertiary coastal plain sands. The soils are deep with loamy sand to sandy loam texture. Because of their sandy nature, they are fragile and highly susceptible to erosion. Soil reaction ranges from 4.5 to 5.2, thus generally, referred to as 'Acid Sands' since they are both acidic and sandy (Udo *et al.*, 2001). The topography of the area is low-lying coastal plain (Udo, 2008). The original rain forest has virtually disappeared because of clearing for farming activities. Major crops grown in the area include maize, cassava, yam, cocoyam, fluted pumpkin, plantain, banana and oil palm (Udo *et al.*, 2001).

Field studies

Two composite soil samples were collected from crude oil affected site at 0-15 cm and 15-30 cm depths. To obtain a composite soil sample, ten soil samples were randomly collected with a soil auger from each sampling depth and were thoroughly mixed together. Each composite soil sample was collected into a clean and well labeled polythene bag, sealed and taken to the laboratory, where it was prepared for total petroleum hydrocarbon and physico-chemical analyses.

Laboratory analysis

The collected samples were air-dried, crushed and passed through a 2mm-mesh sieve preparatory for laboratory analyses.

Total Petroleum Hydrocarbon (TPH) was extracted with 20 ml of xylene and measured using Atomic Absorption Spectrophotometer, as described by Osuji and Nwoye (2007).

Heavy Metals Analysis: The processed soil samples were digested with perchloric acid and nitric acid and Fe, Cr, Cu, Ni, Pb and Cd were read using the Atomic Absorption Spectrophotometer (UNICA 936 Model) (AOAC, 1990).

The physico-chemical properties determined were particle size distribution, soil pH, organic carbon, total nitrogen, available phosphorus, exchangeable acidity, exchangeable bases, effective cation exchange capacity and base saturation.

Particle size distribution was determined by hydrometer method according to the procedure of Gee and Or (2002).

Soil pH was determined using pH meter and read at a soil: water ratio of 1:2.5.

Available phosphorus: Available phosphorus was determined by Bray P-1 extractant as described by Udo *et al*. (2009).

Exchangeable acidity (H^+ and Al^{3+}) was extracted with 1NKCl and titrated against 0.02N NaOH (AOAC, 1990).

Organic carbon was measured by Walkley and Black Wet digestion method (Nelson and Sommers, 1982) while total nitrogen (N) was estimated from organic carbon.

Exchangeable bases were extracted with neutral normal ammonium acetate (at pH 7), K^+ and Na^+ contents were read with the aid of flame photometer while Ca^{2+} and Mg^{2+} were determined by EDTA complexiometric titration method (Jackson, 1962).

Effective Cation Exchange Capacity (ECEC) was determined by summation of exchangeable acidity and exchangeable bases (AOAC, 1990).

Base saturation was calculated as percentage of ECEC occupied by calcium, magnesium, sodium and potassium (AOAC, 1990).

RESULTS AND DISCUSSION

The results of the soil analyses for total petroleum hydrogen (TPH), heavy metals (iron, chromium, copper, lead, cadmium and nickel) and physico-chemical properties are presented in Tables 1 – 3

From Table 1 below, it was shown that the total petroleum hydrocarbon content was 14.21 mgkg^{-1} (0.0014 %) in the surface layer of the soil (0–15 cm), while that of the sub-surface soil layer (15 – 30 cm) was 13.28 mgkg^{-1} (0.0013 %). The TPH in each of the sampled layers was found to be reduced and would not pose any serious threat to growing crops when compared with the pre-clean-up TPH levels of 1372 – 4800 mgkg^{-1} reported by Udo (2008) or the 198.18 mgkg^{-1} reported by the Federal Government Monetary Agency as the TPH level in the soils after completion of clean-up (JIT, 2010). The TPH level reported in this study might therefore not pose any serious threats to growing crops. From the findings of this study, it was observed that TPH content in the soil decreased following the clean-up by RENA method. Hydrocarbon metabolism by natural populations of micro-organisms represents one of the primary mechanisms by which petroleum and other hydrocarbon pollutants are eliminated from the soil environment, although some phyto-oxidation also occurs. The ease of decomposition usually follows the order: N-alkanes > Branched alkanes > Low molecular weight aromatics > cyclic alkanes (Paul and Clark, 1996). The resistant and toxic components in crude oil, few nutrients (P, K, N and S), scarcity of hydrocarbon metabolizers, low temperatures and limited oxygen availability are some of the major factors limiting petroleum decomposition in the soil environment (Atlas and Bartha, 1993).

Table 1: Post cleanup total petroleum hydrocarbon (TPH) of the crude oil affected soils under study

Soil layer	Value (mgkg^{-1})
Surface soil (0 – 15 cm)	14.21
Sub-surface soil (15 – 30 cm)	13.28

Table 2 shows that, iron, chromium, copper, nickel, lead and cadmium levels were 42.98, 12.12, 9.43, 11.44, 1.40 and 4.16 mgkg^{-1} respectively in the 0–15 cm soil layer and 45.85, 11.94, 10.47, 11.73, 1.32 and 4.15 mgkg^{-1} in the 15–30 cm soil layer respectively. Iron was very high compared with other metals. Iron usually accumulates in crude oil-polluted soils (Ufot 2012). Given mean value of 21,412.5 mgkg^{-1} reported by Udo (2008) before the clean-up, the iron content of the soils was found to reduce by 99.8 % in both soil layers. Despite this reduction, iron content of the soil was still very high as the values from both soil layers were greater than the 4.5 – 10.0 mgkg^{-1} medium level reported by Ufot (2012). Such levels of iron in agricultural soils are not good because they can be injurious to most crop plants and even microorganisms.

Table 2: Post clean-up heavy metals of the crude oil affected soils under study (2015)

Heavy Metal (mgkg^{-1})	Surface soil (0 – 15 cm)	Subsurface soil (15 – 30 cm)
Fe	42.98	45.85
Cr	12.12	11.94
Cu	9.43	10.47
Ni	11.44	11.73
Pb	1.40	1.32
Cd	4.16	4.15

Fe = Iron, Cr = Chromium, Cu= Copper, Ni = Nickel, Pb = Lead and Cd = Cadmium

Chromium levels in both soil layers were within the permissible range of 5–1000 mgkg^{-1} for normal soils (Isirimah, 2004). Lead content of the soil (of both layers) was below the 10–30 mgkg^{-1} permissible range for agricultural soils (Chukwu and Udoh, 2014). The cadmium and nickel levels in both layers of the soil were within the permissible ranges of 0.01–7.00 mgkg^{-1} and 10–1000 mgkg^{-1} for normal soils respectively (Isirimah, 2004; Udo, 2008). The values of copper for both soil layers were also found to be within the permissible levels of 7–80 mgkg^{-1} for normal soils (European Commission, 1986).

Post clean-up physicochemical properties of crude oil affected soils of the study area

Results presented in Table 3 indicates that, particle size distribution showed 90.20 % sand, 4.00 % silt and 5.80 % clay in the surface (0–15 cm) soil layer, while the sub-surface (15–30 cm) layer had 89.20 % sand, 5.00 % silt and 5.80 % clay. The particle size distribution, gave the soil a loamy sand texture in the two soil layers. The sandy nature of the soil was attributed to the parent material from which it developed. According to NGSA (2009) and Peters *et al.* (1989), soils of the area are developed from the coastal plain sands. Such soils favour entry and drainage of crude oil and other liquids through them due to the existence of macro-pores. Besides, aeration and microbial activities are also favoured. However, crude oil pollution usually introduces conditions by excluding air from the soil.

The electrical conductivities of the soil which are at the levels of 0.0475 and 0.0421 dsm^{-1} in the two layers respectively indicated no problems of salinity, as the two values were much lower than the 2.00 dsm^{-1} critical level for agricultural soils.

Soil reaction (pH) indicated strong acidity (pH 5.5 in the 0–15 cm layer and 5.4 in the 15–30 cm layer). Udo (2008) reported pH range of 6.7–7.1. One of the chemical changes brought about by crude oil pollution of an acid soil is increased pH, up to 7.0 (Brady and Weil, 1999). The pH levels observed during the study indicated tremendous decomposition of crude oil in the soil. Decomposition of organic materials usually releases some acids and other substances that may affect the soil pH over time, either positively or negatively. Chukwu and Udoh (2014) reported a mean pH of 5.5 (similar to the one of this report). The pH observed was within the normal range of pH of similar soils (coastal plain soils) in Akwa Ibom State.

The organic carbon content was 4.68 and 4.64 % in the 0–15 cm and 15–30 cm layers respectively, indicating very high content (>2 %) (FDALR, 1990). Udo (2008) reported a mean value of 201.4 $mgkg^{-1}$ (20.14 %) of organic carbon for the same soil when mean TPH content was 3294.9 $mgkg^{-1}$. The high reduction (about 98 %) in the organic carbon content of the soil indicated decomposition of the crude oil in the soil. The organic carbon value of the soil was within the normal range obtained for most agricultural soils in Akwa Ibom State. Also, the high content of organic carbon was attributed to microbial mineralization of the crude oil in soil (Ogboghodo *et al*., 2004).

The Total nitrogen content was moderately low as the 0–15 cm layer value (0.12 %) and the 15–30 cm layer value (0.11 %) were below the critical level of 0.15 % for agricultural soils in the southeast agro-ecological zone of the country (FPDD, 1989). Crude oil polluted soil is usually faced with the problem of total nitrogen depletion due to denitrification and immobilization of nitrogen by micro-organisms as a result of the high C/N ratio of crude oil. When soils are polluted with serious amounts of crude oil such as in the study area in 2007, anaerobic conditions will set in following exclusion of oxygen. Consequently, some anaerobes obtain oxygen from NO_2^- and NO_3^- with accompanying release of N_2 and N_2O into the atmosphere. Such losses, coupled with plant removal, might be responsible for the low nitrogen status of the soil. To use the soil for meaningful crop production, farmers have to augment it through the application of appropriate mineral fertilizer(s), as application requires nitrogen in large quantities for protein formation, high photosynthetic activity and vigorous vegetative growth (Havlin *et al*., 2009). The findings agreed with that of Chukwu and Udoh (2014).

The available phosphorus content of the 0–15 cm soil layer was 15.89 $mgkg^{-1}$, while that of the 15- 30 cm was 18.99 $mgkg^{-1}$, indicating moderate status (Ufot, 2012). The main source of available phosphorus content of the soil might be the soil's parent material and the level of available phosphorus before the crude oil pollution might be higher, considering that micro-organisms need phosphorus in addition to other nutrients to decompose crude oil in the soil. Such utilization plus plant removal could have reduced the available phosphorus status of the soil which therefore has to be augmented through the application of phosphorus-rich fertilizers if crop productivity of the soil has to be improved. Udo (2008) reported low mean available phosphorus level of 6.1 $mgkg^{-1}$. The present finding therefore shows a significant improvement in available phosphorus content of the soil which might be due to the significant reduction in the TPH content of the soil over the years following massive decomposition by soil micro-organisms.

The exchangeable calcium, magnesium and potassium levels in the 0 – 15 cm layer of the soil were 3.00, 1.35 and 0.11 cmolkg^{-1} while those in the 15 – 30 cm soil layer were 3.16, 1.20 and 0.09 cmolkg^{-1} respectively.

Based on the ratings of FDALR (1990), for soils of southeast agro-ecological zone, the exchangeable calcium and potassium were low and very low respectively. While the exchangeable magnesium levels for both layers were moderate. The low and very low status of the exchangeable calcium and potassium could be due to microbial utilization for decomposition, plant removal and leaching due to high rainfall. Chukwu and Udoh (2014) reported similar results.

The exchangeable acidity was 2.01 and 2.15 cmolkg^{-1} in the 0–15 cm and 15–30 cm soil layers respectively. The values fell within the range (1.0 – 2.5 cmolkg^{-1}) reported by Chukwu and Udoh (2014) for soils in the area.

The effective cation exchange capacity (ECEC) was low (6.52 and 6.65 cmolkg^{-1} in the 0 – 15 cm and 15 – 30 cm layers respectively). Strong soil acidity decreases soil ECEC due to its effects. Besides, the low clay content of the soil also contributes to the low ECEC. Most of the exchangeable bases were low, hence the low ECEC. Chukwu and Udoh (2014) reported similar results. Low soil ECEC shows that the soil has low ability to attract and hold cationic plant nutrients resulting in low soil fertility (Havlin *et al.*, 2009). The ECEC of most Nigerian soils are low because of the dominance of low activity clay and rapid leaching of humus and basic nutrient elements (Ufot, 2012).

The base saturation was 66.7 and 67.1 % in the 0 – 15 cm and 15 – 30 cm layers respectively, indicating high status (FDALR, 1990) and the ease with which the soil provides basic nutrients to growing plants (Havlin *et al.*, 2009). The availability of calcium, magnesium and potassium to plants increases with increasing base saturation. High base saturation status depicts high potential fertility and this is good for agricultural soils because it denotes greater availability of some basic and ammonium ions, which are important macro and secondary plant nutrients (Udoh *et al.*, 2009).

Table 3: Post clean-up physicochemical properties of crude oil affected soils of the study area

Soil properties	Surface soil (0 – 15 cm)	Subsurface soil (15 – 30 cm)
Sand (%)	90.2	89.2
Silt(%)	4.1	5.0
Clay (%)	5.8	5.8
Textural class	LS	LS
pH	5.5	5.4
EC	0.0475	0.0421
Org. C	4.68	4.64
Total N	0.12	0.11
Av. P (mgkg^{-1})	15.87	18.99
Ca (cmolkg^{-1})	3.00	3.16
Mg (cmolkg^{-1})	1.35	1.20
K (cmolkg^{-1})	0.11	0.09
Na (cmolkg^{-1})	0.050	0.045
EA (cmolkg^{-1})	2.01	2.15
ECEC (cmolkg^{-1})	6.52	6.65
B. sat (%)	66.7	67.1

LS= Loamy Sand; EC = electrical conductivity; Org. C = organic carbon; Total N = total nitrogen; Av. P = available phosphorus; Ca, Mg, Na, K = calcium, magnesium, sodium, potassium, respectively; EA = exchangeable acidity; ECEC = effective cation exchange capacity; B. sat = base saturation

SUMMARY AND RECOMMENDATION

The post clean-up total petroleum hydrocarbon (TPH), heavy metals and the physico-chemical properties of crude oil affected soils of Ikot Ada Udo in Ikot Abasi Local Government Area of Akwa Ibom State were assessed. From the results shown, it was observed that the impact of oil spill on the soils has diminished compared to the impact it posed as at 2008 following the massive oil spillage, on TPH, heavy metals and physico-chemical properties of the soils.

The results showed that TPH, chromium, copper, nickel, lead, cadmium and exchangeable acidity were within the permissible ranges for normal agricultural soils. Exchangeable potassium and calcium, total nitrogen and effective cation exchange capacity were low. While iron, organic carbon and base saturation were high. The soils were very strongly/strongly acidic. The results also showed that the soils were predominantly loamy sand in texture. Multi-nutrient deficiencies (especially N, K and Ca), very strong/strong acidity and Fe toxicity were identified as the main problems of the soils.

These soils can therefore be recommended for agricultural purposes. However, to improve soil fertility and obtain high yield of agricultural crops, the following recommendations are made;

i) Application of appropriate fertilizers (especially organic fertilizers) to increase the soil microbial population of the area,
ii) Liming (lime) should be applied to the soils in order to reduce the acidity and to increase the effectiveness of fertilizers and growth of crops,
iii) Mulching should be done to prevent excessive evaporation of soil moisture and encourage biodiversity,
iv) Planting of acid-tolerant crops especially where liming is not possible should be done to promote and encourage the biodiversity of the land that will be able to withstand the stress occasioned by the impact of the pollution.

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