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Remediation of Crude Oil Contaminated Soil with Inorganic and Organic Fertilizer Using Sweet Potato as a Test Crop

Isitekhale, H.H.E[1]; Aboh, S. I[2*]; Edion, R. I[1] and Abhanzioya, M. I[1].
1. Department of Soil Science, Ambrose Alli University, P. M. B 14 Ekpoma, Edo State, Nigeria.
2. Department of Agriculture, College of Education, Agbor, Delta State, Nigeria.
*corresponding author (isitekharri2000@yahoo.com).

ABSTRACT
Experiment was conducted in Faculty of Agriculture Teaching and Research Farm, Ambrose Alli University, Ekpoma to remediate crude oil contaminated soil with organic and inorganic fertilizers. Thirty six pots were filled with 5 kg surface soils (0-15cm).The soils were contaminated with 300 ml crude oil and amended with six rates of poultry manure and NPK fertilizer mixture. Potato vine with 2 nodes was planted in each pot. The pots were laid out using completely randomized design replicated thrice. Results showed that application of 6 t pm/ha + 400 kg NPK/ha and 4 t pm/ha + 200 kg NPK/ha reduced soil THC from 300 mg/kg to 39.08 and 70.00 mg/kg i.e. net remediation of 86.97 and 76.42 % respectively. Inorganic and organic fertilizer mixtures are effective in the restoration of crude oil contaminated soils.
Keywords: contamination, crude oil, NPK fertilizer, poultry manure, remediation, sweet potato.

Introduction

The soil is a primary recipient by design or accident of farmyard of waste products and chemicals used in modern society. Pollution caused by petroleum and its derivatives is the most prevalent problem in the Nigeria Niger delta environment. Since commercial exploration of petroleum started in Nigeria in 1958 (Okoh, 2003), petroleum has continuously grown to be mainstay of the Nigerian economy. However, the exploration of petroleum has led to the pollution of land and water ways. Petroleum is a complex mixture of aliphatic, alicyclic, aromatic hydrocarbons, and smaller proportions of heteroatom compounds, such as sulfur, nitrogen, and oxygen. Crude oil also contains organometallic complexes containing nickel and vanadium in much smaller proportions compared to the other constituents; however these organometallic compounds are problematic during crude oil refining (Head et al., 2003).Invariably, oil spillage damages the soil, water and both plants and animals. Consequent upon its contents of lead, oil pollution renders soils unproductive for years after spillage, reducing the growth performance of plants (Dale et al., 2006). Therefore, plant growth and establishment, and re-vegetation of polluted sites can serve as indicators for soil recovery (Obilo and Ogunyemi, 2005).
Several methods can be employed to remove oil wastes and derivatives from soil and water. These include physical (spray, vapor extraction, stabilization, solidification), chemical (photo-oxidation, dissolution, detergent use), and biological methods (bioremediation). All these methods can be used in the treatment of contaminated sites depending on the priorities and circumstances of each case. Phytoremediation is the use of plants and/or associated microorganisms to remove or render harmful material harmless (Merkl, 2005).The application of plant for remediation of soil contaminated with petroleum hydrocarbon is one of the promising cost and environmental effective approach (Eman, 2008). Schnoor (2002) reported that phytoextraction is more effective with vigorously growing plants that are easily harvested and which accumulate large concentration of contaminants in harvestable form.Tithonia seedlings were able to absorb lead and cadmium in polluted soils, and contents in the root were more than contents in the shoot. The lead and cadmium contents in the shoot compared to the root were about 54% and 30% respectively (Egberongbe, 2010). Isitekhale, et al. (2013) reported net remediation of 75.45 % and 77.51 % using vigorously growing sweet potato variety on crude oil contaminated soil in Nigeria; even with higher concentrations, growth was further sustained. Transformation of contaminants may occur outside the plant in the rhizosphere, inside the plant or sorbed to the leaf surface (photolysis) (Trapp and Karlson, 2001). Sweet potato (*Ipomeabatata* L.) originated from central and parts of South America where it has been grown for many centuries. It has vigorous growth, one of the most efficient tuber crops in Nigeria in terms of tuber yield and days of maturity (Nwinyi*et al.,* 1987).
Ogboghodo et al. (2004) reported that adding chicken manure to soil contaminated with crude oil triggered degradation of 75% of hydrocarbon in the soil within two weeks, and suggested that the use of chicken manure to stimulate crude oil degradation in the soil could be one of the several sought-after environmentally friendly ways of combating petroleum hydrocarbon pollution in the natural ecosystem.
Eneje et al. (2012) reported that addition of organic materials such as poultry and green manure singly or in combination to improve the chemical properties (pH, OC, total nitrogen, available P, Ca, K, and Mg) of the oil polluted soil will enhance the solubility and removal of these contaminants, improving oil biodegradation rates. Fertilizer (NPK) served as a good supplement for the growth of the petroleum utilizing bacteria in oil – polluted

soils (Adoki*et al.,* 2007). Leo and Iruka (2007) reported that with the application of appropriate and sufficient inorganic NPK fertilizer on the oil spill site at Owaza in the Niger-Delta region of Southern Nigeria, it aids in the restoration of the carbon to nutrient ratios to the optimum required to stimulate and sustain microbial activity, adjustment of the soil pH to 6.0 – 6.5 by the addition of lime and also the stimulation.
Obire and Akinde (2006) reported that nutrient supplementation of oil – polluted with poultry droppings as organic nutrient source in particular is beneficial for maize growth and it also enhances both biodegradation of oil and soil recovery. In Nigeria Niger Delta, oil exploration is on the increase, the magnitude of oil spillages is also very high. This is due to technical failures, sabotage, leaks, etc. Simultaneously, environmental impact assessments (EIA) are been carried out frequently to determine levels of contamination as well as remediation efforts. However, ways of remediating crude oil polluted soils are inexhaustible. Poultry manure additions to soil has yielded very positive results in plant nutrients addition, enhancement of soil biological, physical properties and enhancement of crop growth and yield (Isitekhale and Osemwota, 2010 a and 2010 b; Isitekhale et al., 2013). Therefore the objective of the experiment therefore was to employ poultry manure and /or N: P: K (16:16:16) fertilizer for the remediation of crude oil contaminated soil in order to enhance plant growth and yield.

Study Area
The experiment was conducted at the Ambrose Alli University Teaching and Research Farm, Ekpoma, Edo State, Nigeria. Ekpoma is situated in latitude 6^0 $30^!$ and 6^0 $30^!$ N and longitude 6^0 $00^!$ and 6^0 $30^!$ N. Edo state has a tropical climate characterized by one rainy season between April and October and one dry season lasting from November to March. The state has a mean rainfall ranging from about 1300mm to about 2300 mm (EADP, 1995). The temperature of Edo state is characterized of tropical climate with mean daily temperature of about 26.7^0C. Relative humility is fairly high especially during the months of March to November. Even in the dry season, the mean daily relative humidity is around 70%. The state has northern belt of derived savanna. To the south lies an area of rain forest, although in many places, the latter has been degraded to secondary forest as a result of shifting cultivation.

Materials and Methods
Pot Experiment
The experiment was conducted by employing completely randomized design (CRD). Soil sample (5 kg) from the study area was weighed into perforated polyethylene bags (6 kg capacity). The experiment consisted of twelve polyethylene bags per replicate, giving a total of thirty six bags for the experiment. The soils were contaminated with 300 ml crude oil obtained from SPDC, Port Harcourt. The soils were then allowed to equilibrate for 2 weeks; sweet potato vine with two nodes was planted in each polyethylene bag. Poultry manure was sourced from layers kept in cages, the droppings were collected raw and was void of any foreign contaminants or other materials. The droppings were air dried for 6 months in order to ensure complete breakdown. Poultry manure and NPK fertilizer mixture 0 t Pm/h a + 0 kg NPK/ha, 4 t pm/ha + 200 kg NPK/ha, 6 t pm/ha + 200 kg NPK/ha, 6 t pm/ha + 0 kg/ha, 4 t pm/ha + 400 kg NPK/ha and 6 t pm/ha + 400 kg NPK/ha were applied respectively after equilibration. The growth of potato was monitored to 12^{th} week.

Laboratory Studies
Soil samples before and after contamination were analyzed for its physico-chemical properties. Particle size distribution was determined by the hydrometer method (Okalabo *et al.,* 2002), soil pH was measured in a 1:1 (soil-water mixture) by glass electrode pH meter (MaClean, 1982), organic carbon was done by wet dichromate acid oxidation method (Nelson and Sommers, 1982), total nitrogen was determined by the micro Kjeldahl method (Bremner, 1982). Available phosphorus was extracted with Bray II solution and determined by the molybdenum blue method on the technicon auto-analyzer as modified by Olsen and Sommers (1982), Al^{3+} and H^+ were extracted with 1N KCl (Thomas, 1982), Ca, Mg, Na and K were extracted with 1N NH_4OAC pH 7.0 (Ammonium acetate). Potassium and sodium were determined with flame emission photometer while calcium and magnesium were determined with automatic adsorption spectrophotometer (Anderson and Ingram, 1993). ECEC was calculated by the summation of exchangeable base and exchangeable acidity (Anderson and Ingram, 1993). Total hydrocarbon content was analyzed by using a methylene chloride extraction; gas chromatography (GC) analyzing technique (Villalobos, 2008) the amount of crude oil lost from the soil was determined as the amount of crude oil added to the soil minus that in the soil at the time of analysis. Potato tubers were harvested at maturity and weight of tubers per pot recorded.

Statistical Studies
All data collected were subjected to statistical analysis using analysis of variance (ANOVA) according to Frank

and Althoen (1985). Least significant difference (LSD) was used for the mean separation.

Results and Discussion

Soil Physico-Chemical Properties

The chemical properties of the crude oil is given in Table 1, the physico-chemical properties of the soil used for experiments before crude oil contamination are shown in Table 2. The experimental soil was earlier classified as Rhodic Kandiustult (Obazuaye, 2009); low in phosphorus, nitrogen and potassium but with marginal contents of magnesium and calcium. The surface sand texture enables percolation of the crude oil.

Sweet potato tuber weight ranged from 0.02 t/ha of the control to 0.10 t/ha obtained from the application of 4 t pm/ha + 200 kg NPK/ha (Table 3). Manure and NPK fertilizer combinations produced potato tubers that were better than that obtained from the control. Potato tuber weight increased significantly with the application of 4 t pm/ha + 200 and 400 kg NPK/ha. The very low yield obtained from the unfertilized soil could be attributed to the harmful effects of crude oil to plants growth and yield. However, yield obtained from treated (manure – fertilizer mixture) soils was below targeted potato yield of 6 t/ha (Smith, 2004; Mutandwa, 2008). Asuquo et al. (2001) observed increases in organic carbon in crude oil contaminated soil following an initial scarcity. This causes nitrogen deficiency in an oil-soaked soil, which retards the growth of bacteria and the utilization of carbon source(s), as well as deficiency in certain nutrients like phosphorus which may be growth-rate limiting (Atlas and Bartha, 2005).

Total Hydrocarbon content

Total hydrocarbon content ranged from nil to 138.96 mg/kg after the soil was contaminated with 300 ml (Table 4). Total petroleum hydrocarbon content of contaminated soil treated with 6 t pm/ha + 200 kg NPK/ha and 6 t pm/ha + 400 kg NPK/ha was below the critical level of 50 mg/kg. Total hydrocarbon in the contaminated soils was above the critical level when treated with 4 t pm/ha + 200 kg NPK/ha, 6 t pm/ha and 4 t pm/ha + 400 kg NPK. This indicates low amount of hydrocarbon in contaminated soils treated with 6 t pm/ha + 200 kg NPK/ha and 6 t pm/ha + 400 kg NPK/ha and the presence of high amount of petroleum hydrocarbon in the soils treated with 4 t pm/ha + 200 kg NPK/ha, 6 t pm/ha and 4 t pm/ha + 400 kg NPK/ha. It was notably noted that the various treatments were effective in hydrocarbon removal. Net hydrocarbon remediation ranged from 111.96 to 262.86 mg/kg (Table 4). The highest hydrocarbon removal was obtained by the application of 6 t pm/ha + 200 kg NPK/ha and 6 t pm/ha + 400 kg NPK/ha. This resulted in 87.62 and 86.97 % net remediation respectively. The observation shows that higher quantity of poultry manure combined with moderate to high NPK fertilizer is more effective for remediation of crude oil contaminated soils. However, treatments administered were good remedies for soils contaminated with crude oil. Residual characteristics of poultry manure could further lead to more hydrocarbon removal. Residual characteristics of poultry manure have been documented (Isitekhale, 2010; Isitekhale and Osemwota, 2010a). Addition of organic materials such as poultry and green manure singly or in combination to improve the chemical properties (pH, organic carbon, total nitrogen, available P, Ca, K, and Mg) of the oil contaminated soil will enhance the solubility and removal of these contaminants. Thus, improve crude oil biodegradation rates.

Conclusion

Sweet potato a vigorously growing plant can reduce the level of crude oil to tolerable limit as observed in this study. Phytoremediation can be applied at moderate contamination levels or after the application of other remediation measures as a polishing step to further degrade residual hydrocarbons and to improve soil quality. Remediation capacity of the growing potato could also be enhanced through manure and fertilizer mixtures. Thus, application of 4 t pm/ha + 200 kg NPK/ha and 6 t pm/ha + 400 kg NPK/ha to crude oil polluted soils will enhance crude oil remediation, soil nutrient addition and growth of plants. Although manure alone can improve the organic matter of the soil and hence bring about ambient conditions suitable for microorganisms (soil moisture content and retention, humification and nutrient additions). However, combining with NPK fertilizer will further target nutrient increase which may be required immediately by the growing plants or existing vegetation in the contaminated soil. About 40 % of nutrients contained in poultry manure are available in the first year of application.

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Table 1 Chemical properties of the crude oil used for the study

	Crude oil
Specific gravity (g/cm^3)	0.79
Viscosity at 38^{o}C	0.25
Gas oil ratio	88.20
Carbon %	82.50
Hydrogen %	11.80
Sulphur %	1.32
Nitrogen %	0.36
Oxygen %	0.50
Metals (mg/kg)	
Iron	49.60
Nickel	2.80
Vanadium	0.40
Copper	3.00
Zinc	3.15
Lead	0.90
Cadmium	0.30
Cobalt	0.80

Table 2 Physico-chemical properties of the experimental soil.

Parameters	Crude oil
pH (H_2O)	6.80
Total N (g/kg)	1.02
Total C (g/kg)	10.88
Exh. Cations (cmol/kg)	
Exch. Ca	3.84
Exch. Mg	2.40
Exch. Na	0.33
Exch. K	0.08
Exch. H^+	0.02
Exch. Al^{3+}	-
ECEC	6.85
P (mg/kg)	7.49
Particle size (g/kg)	
Sand	941.00
Silt	16.00
Clay	43.00
Texture	

Table 3 Effect of organic and inorganic fertilizer on sweet potato dry matter yield and tuber weight after crude oil contamination (second experiment)

Poultry manure (t/ha) + NPK (kg/ha)	Dry matter yield (g)	Tuber weight (t/ha)
0	3.30	0.02^{c}
4 + 200	4.30	0.10^{a}
6 + 200	4.60	0.04^{bc}
6 + 0	5.90	0.05^{abc}
4 + 400	4.30	0.08^{ab}
6 + 400	5.20	0.06^{abc}
LSD $_{(0.05)}$	Ns	0.04

Table 4 Effect of organic and inorganic fertilizer on crude oil contaminated soil (second experiment).

Poultry manure t/ha +NPK (kg/ha)	Crude oil before planting (mg/kg/)	THC after harvesting (mg/kg)	Net remediation (mg/kg	% Net remediation
0	0	0	0	0
4 + 200	300	70	229.27	76.42
6 + 200	300	137.14	262.86	87.62
6 + 0	300	138.96	161.04	53.68
4 + 400	300	188.04	111.96	37.32
6 + 400	300	39.08	260.92	86.97