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Effects of Phytoremediation on Soil Total Hydrocarbon Content

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Abstract
Experiment was conducted in Faculty of Agriculture Teaching and Research Farm, Ambrose Alli University, Ekpoma to determine soil total hydrocarbon content (THC) after contamination and remediation with sweet potato (*Ipomea batatas*) (phytoremediation). Thirty six plastic pots were filled with 5 kg surface soils (0-15 cm). The potted soils were contaminated with six rates of crude oil: 0, 200, 400, 600, 800 and 1000 ml/pot. Potato vine with 2 nodes was planted in each pot. The pots were laid out using completely randomized design replicated thrice. Results showed that phytoremediation activities reduced soil total hydrocarbon content (THC) from 100 and 200 mg/kg to 22.49 and 49.10 mg/kg i.e. net phytoremediation of 77.51 and 75.45 % respectively. Sweet potato plant is effective in the restoration of crude oil contaminated soils.
Keywords: contamination, crude oil, phytoremediation, remediation, sweet potato.

Introduction

The soil is a primary recipient by design or accident of amyriad 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). 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 (*Ipomea batata* 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. Residual characteristics of poultry manure have been documented (Isitekhale, 2010; Isitekhale and Osemwota, 2010). 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 contaminated soil will enhance the solubility and removal of these contaminants, improving oil biodegradation rates.

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. 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. The objective of the experiment therefore was to employ the use of sweet potato, poultry manure and/or N: P: K (16:16:16) fertilizer for the remediation of crude oil contaminated soil.

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

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) 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.

Pot Experiment

The experiment was laid out in a completely randomized design (CRD) with three replicates. The experiment included six rates of crude oil obtained from Shell Petroleum Development Company (SPDC), Port Harcourt.; 0, 50, 100, 150, 200 and 250 ml respectively. Crude oil rates were applied to 5 kg soil in polyethylene bag and allowed to equilibrate for two weeks before planting. At two weeks after contamination, sweet potato vine was planted, a vine per bag. Filtrate from the polyethylene bags was constantly re-applied to the soil in order to ensure complete effect of the crude oil rate.

Potato whole plant dry matter yield (DYM) was determined at 6 weeks after planting and tuber weight at harvest.

Statistical Studies

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 Propertie

The chemical properties of the crude oil are given in Table 1 and the physico-chemical properties of the soil used for experiment before crude oil contamination are shown in Table 2. The experimental soil was earlier classified as Rhodic Kandiustult (Obazuaye, 2009), the soil is low in phosphorus, nitrogen and potassium but with marginal magnesium and calcium contents. The surface sand texture enables percolation of the crude oil. Table 3 shows the effect of crude oil contamination on potato tuber weight and dry matter yield (DYM). Potato tuber weight and dry matter yield were significantly affected by the different levels of crude oil contamination. Potato DYM ranged from 4.27 to 13.30 g/pot. The highest potato dry matter yield and tuber weight were obtained from soils contaminated with 400 ml/pot crude oil, the lowest was recorded in 1000 ml/pot crude oil contaminated soil. Tuber yield and DYM decreased when crude oil contamination exceeded 400 ml/ha. At this state, effective plant growth and yield of crops are at minimum; however sustenance of growth at 400 ml/pot crude oil contamination depicts the phytoremediation effect of sweet potato after crude oil contamination in soils. The low yield could be attributed to the effect of crude oil contamination when compared to yield reported by Smith (2004) and Mutandwa (2008). Asuquo et al. (2001) observed increases in organic carbon in contaminated soil following an initial scarcity with contamination. This causes nitrogen deficiency in an oil-soaked soil,which retards the growth of bacteria and the utilization of carbon sources, 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 (THC) ranged from nil to 452.13 mg/kg (Table 4). The THC content of the soil contaminated with 200 and 400 ml/pot crude oil fell below the critical level of 50 mg/kg (Department of Petroleum Resources, 2002) while crude oil remained high in soils contaminated with 600, 800 and 1000 ml/pot when compared to the critical level. The reduction of crude oil in the soil after contamination was due to the growth of sweet potato. The highest percent net phytoremediation of 77.51% was obtained in the soil contaminated with 200 ml/pot crude oil while the least percent net phytoremediation of 9.57% was obtained in the soil contaminated with 1000 ml/pot crude oil. There was a steady decline in percent net phytoremediation. Thus, phytoremediation of crude oil polluted soils decreases with increase in the rate of crude oil pollution. Njoku *et al.* (2009) reported that the ability of given crop to reduce the level of crude oil in oil contaminated soil can help to restore polluted soils back for agricultural use.

Conclusion

Sweet potato a vigorously growing plant can reduce the level of crude oil in soils 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.

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

Parameters	Crude oil
Specific gravity (g/cm^3)	0.79
Viscosity at 38^oC	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	Sand

Table 3 Effects of crude oil pollution on potato dry matter yield (DYM) and tuber weight

Crude oil (ml/pot)	DYM (g/pot)	Tuber weight (t/ha)
0	10.80^{ab}	1.57
200	8.83^{abc}	1.52
400	13.30^{a}	1.94
600	7.80^{bc}	0.77
800	4.37^{c}	0.72
1000	4.27^{c}	0.00
LSD (0.05)	5.05	0.75

Means with the same letter(s) in the column are not significantly different

Table 4 TPH content of soil after phytoremediation

Crude oil Treatment before planting (ml/pot)	THC after harvest (mg/kg)	Net phytoremediation (mg/kg)	%Net phytoremediation
0	0	0	0
100	22.49	77.51	77.51
200	49.10	150.90	75.45
300	129.93	170.07	56.67
400	337.33	62.67	15.67
500	452.13	47.87	9.57