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# Remediation of crude oil polluted soils: Effect of organic and inorganic nutrient source on the performance of sweet potato

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**Abstract** An experiment to remediate crude oil polluted soil and sweet potato (*Ipomea batata*) performance was conducted at the Faculty of Agriculture Teaching and Research Farm of Ambrose Alli University, Ekpoma, southwestern Nigeria. The soil was polluted with crude oil prior to planting. The treatments consisted of three levels of NPK 15:15:15 fertilizer (0, 50 and 100 kg $ha^{-1}$) and three levels of poultry manure (0, 4 and 8 t $ha^{-1}$). The experiment was a 3 x 3 factorial with nine treatment combinations fitted into randomised complete block design and replicated three times. Results showed that application of 50 kg $ha^{-1}$ NPK plus 8 t $ha^{-1}$ PM increased soil organic carbon, total N, calcium and K; the effect was significant with total N. Application of 100 kg $ha^{-1}$ plus 8 t $ha^{-1}$ PM increased ECEC, P and vine length significantly at 3 weeks after planting. Applying poultry manure alone significantly increased $Mg^{2+}$ and total N contents, and P was significantly increased with NPK fertilizer application. Inorganic and organic fertilizer mixtures are effective in the restoration of crude oil contaminated soils and are, therefore, recommended.

Key words: Contamination, crude oil, NPK fertilizer, pollution, poultry manure

## Introduction

Exploration and production of crude oil in Nigeria is carried out in the oil-rich Niger Delta region. Over 80% of the country's oil comes from this ecological zone and its surrounding offshore areas (Okpokwasili & Odokuma, 1994; Odokuma & Dickson, 2003). Within the Delta, the numerous oil fields, tank farms, flow stations, pipelines, tankers and loading jetties constantly provide potential sources of oil pollution (Chikere & Chijioke-Osuji, 2006). Oil spillage hydrocarbons can contaminate soils; these hydrocarbons will inhibit seed germination and plant growth, but most plants do not appear to accumulate the hydrocarbons (Chaineau *et al*., 1998). Ijah & Antai (2003) found that the quantity of crude oil spilled in soil and the age of the contamination influence the rate and total extent of disappearance of oil in the environment. Growth parameters such as plant height, stem girth, ear height, leaf area, length of primary roots and grain yield were reduced compared to the control following crude oil spillage (Ekundayo *et al*., 2001). They also reported high concentrations of heavy metals that were above critical levels in plant tissue as a result of crude oil contamination; 26.24 mg $kg^{-1}$ Fe, 10.84 mg $kg^{-1}$ $Mn^{2+}$, 2.96 mg $kg^{-1}$ Pb, 6.18 mg $kg^{-1}$ Zn and 3.88 mg $kg^{-1}$ Co.

It has been indicated that the application of poultry manure, piggery manure, goat manure, and chemical fertilizer could enhance petroleum hydrocarbon degradation with poultry manure, showing a greater effectiveness and thus could be one of the severally sought environmentally friendly ways of remediating natural ecosystem contaminated with crude oil (Agarry *et al*., 2010). The effectiveness of poultry manure plus NPK fertilizer over the use of NPK fertilizer alone on remediation of crude oil polluted soil has been reported (Isitekhale *et al*., 2013a). Combined use of poultry manure and NPK fertilizer has been adjudged more effective compared to phytoremediation in hydrocarbon removal in crude oil polluted soil (Isitekhale *et al*., 2013a, 2013b).

Optimum N application rates, increased plant root growth and extended rhizosphere influence which lead to enhanced phytoremediation of crude-oil–contaminated soil (Kirkpatrick *et al*., 2006). Chikere *et al*. (2009) reported the effectiveness of poultry manure, NPK and urea fertilizer. Composting is also considered as a remediation method for handling contaminated soil, sediment, and organic wastes (Williams & Keehan, 1993). Barker & Bryson (2002) asserted that composting degrades or binds pollutants to innocuous levels or into innocuous compounds in the finished product. This effect is similar to other organic sources. Soil physicochemical parameters, such as moisture content, pH value, electrical conductivity as well as organic carbon and total-nitrogen contents, showed distinct variations with time in oil polluted soil when treated with NPK fertilizer. This was attributed to lead to greater rates of biodegradation of petroleum polluted in the soils (Ayotamuno *et al*., 2006).

## Materials and methods

**Study area.** The experimental site was located at the Faculty of Agriculture Teaching and Research Farm of Ambrose Alli University, Epkoma. Edo State, Nigeria The site lies within latitude 06. $42^0$ N and 06.$09^0$ E with an annual rainfall of 1,300 mm and a mean temperature range of 26 - $32^0$C. It is located in the forest derived savannah transitional zone of Edo State. Soils of the area have earlier been classified as Rhodic Kandiudult (Obazuaye, 2009).

**Soil sample collection.** A composite soil sample was collected prior to field studies from the study area at a depth of 0-15cm according to Anderson & Ingram (1993) and then analyzed for its physicochemical properties. Composite soil samples were collected from crude oil contaminated and treated plots in the experimental layout after harvesting. A total of 27 soil samples were collected based on the treatment combinations and replication. The soil samples were air dried, crushed, sieved using a 2mm mesh sieve and bagged for laboratory analysis.

**Crude oil, poultry manure and NPK fertilizer.** Crude oil used for the soil contamination was collected from Bornu well F2 belonging to Shell Petroleum Development Company of Nigeria (SPDC) Limited. The chemical properties of the crude oil are given in Table 1.

Poultry manure used for the experiment was collected from a poultry farm located in Ekpoma, Edo State. Raw poultry droppings (layers manure) were collected from birds raised in battery cage system. The raw poultry droppings were spread under a roof to air-dry. This was achieved when there was no longer a pungent odour. The layer manure about a year old was fully decayed, and free from other contaminants that may influence its properties. The NPK 15:15:15 fertilizer used was whitish and of grain sizes, manufactured by Springfield and was sourced from a commercial outlet in Ekpoma.

**Planting material.** Sweet potato (*Ipomoea batatas*) cuttings used for planting consisted of two nodes and were sourced locally from Ekpoma.

**Field studies.** The field experiment was carried out in the rainy season. The experimental site was delineated into plots; each plot was 1.5 m x 1.5 m (2.25 m$^2$), the entire experimental area was 113.75 m$^2$ (0.01 ha). Each plot was polluted with crude oil at the rate of 1 litre per plot and allowed to equilibrate for a month. The treatments consisted of three levels of NPK 15:15:15 fertilizer (0, 50 and 100 kg ha$^{-1}$) and three levels of poultry manure (0, 4 and 8 t ha$^{-1}$). The experiment was a 3 x 3 factorial with nine treatment combinations fitted into randomised complete block design and replicated three times. Sweet potato *Ipomoea batatas* was planted at a spacing of 50 cm x 50 cm. Poultry manure levels were applied to the plots by broadcasting a month before planting in order to equilibrate with the soil. The manure was fully spread on the entire surface of each plot treated. While the NPK fertilizer was applied to the soil immediately after planting by band placement. Weeds were manually controlled with the use of hoes and cutlasses as the need arose.

Plant growth performance was determined by measuring the vine length at 3, 6 and 9 weeks after planting. Vine length was measured with the aid of a Tape rule graduated in centimetres.

**Laboratory studies.** The composite soil sample collected from the location before field experiment was air-dried at room temperature, crushed and sieved through 2 mm sieve to remove debris and other materials and kept in plastic containers with cover for routine analysis. Soil samples after field experiment, were also collected from individual plots that received different treatment combinations and prepared for laboratory studies according to Anderson and Ingram (1993) procedures. Plant leaf and shoot samples were also collected for analysis.

**Soil chemical and physical properties.** Soil pH was measured in a 1:1 soil-water suspension using glass electrode pH meter (MaClean, 1982). Exchangeable acidity ($AI^{3+}$, $H^+$) were extracted with IN KCl (Thomas, 1982) and determined by titration with 0.05 Na0H using phenolphthalein as indicator. Organic carbon was determined by wet dichromate acid oxidation method (Nelson & Sommers, 1982). Total nitrogen was determined by the Micro-Kjedahi method (Bremner, 1982). Available phosphorus was extracted with Bray-P1 solution and measured by the molybdenum blue method on the technician auto analyzer as modified by Olsen & Sommers (1982). Exchangeable cations ($Ca^{2+}$, $Mg^{2+}$, $Na^+$ and $K^+$) were extracted within 1N $NH_4OAc$. pH 7.0 (ammonium acetate), $K^+$ and $Na^+$ were determined with flame emission photometer while Ca and Mg were determined with atomic absorption spectrophotometer (Anderson and Ingram, 1993). Effective cation exchange capacity (ECEC) was calculated by the summation of exchangeable bases and exchangeable acidity (Anderson & Ingram 1993; Okalebo *et al.*, 2002).

Particle size distribution was determined by the hydrometer method according to Okalebo *et al.* (2002). The soils were dispersed with sodium hexamethaphosphate solution.

**Plant tissue analysis.** Plant dry matter yield (leaf and shoot) was determined at the 6$^{th}$ week by harvesting a single growing plant in the middle row in each plot to eliminate cross feeding. Harvested parts were dried at 70 $^0$C for 48 hours to a constant weight in an oven.

**Statistical analysis.** Field and laboratory data collected were subjected to statistical analysis using analysis of variance (ANOVA) according to Frank and Althoen (1995). Mean comparison was carried out using Duncan multiple range test at 5% probability level.

## Results

The chemical properties of the crude oil are presented in Table 1. The poultry manure used for the study was found to be high in exchangeable cations, organic carbon, total N and ECEC (Table 2). The experimental soil was very low in exchangeable cations, organic carbon, total N but with adequate P and favourable pH (Table 2).

Poultry manure and NPK fertilizer application to the crude oil contaminated soil had no significant effect on soil pH and organic carbon contents (Table 3). Application of 50 kg ha$^{-1}$ NPK plus 4 t ha$^{-1}$ PM slightly raised soil pH to 5.80 compared to 5.50 of the contaminated but untreated soil, while application of 50 kg ha$^{-1}$ NPK plus 8 t ha$^{-1}$ PM increased soil organic carbon to 14.1 g kg$^{-1}$ compared to

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

| Parameters | Values |
|---|---|
| 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$^{-1}$)** | |
| 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. Properties of the experimental soil and poultry manure used for the experiment.

| Parameters | Soil | Poultry manure |
|---|---|---|
| pH ($H_2O$) | 6.50 | 6.00 |
| Total N (g kg$^{-1}$) | 1.21 | 3.17 |
| Total C (g kg$^{-1}$) | ‘16.30 | 2.20 |
| **Exh. Cations (cmol kg$^{-1}$)** | | |
| Exch. Ca | 2.48 | 38.08 |
| Exch. Mg | 0.24 | 4.16 |
| Exch. Na | 0.24 | 1.18 |
| Exch. K | 0.05 | 2.28 |
| Exch. $H^+$ | 0.20 | 0.60 |
| Exch. $Al^{3+}$ | - | 0.30 |
| ECEC | 3.21 | 47.60 |
| P (mg kg$^{-1}$) | 26.47 | 61.29 |
| **Particle size (g kg$^{-1}$)** | | |
| Sand | 933.00 | |
| Silt | 22.00 | |
| Clay | 45.00 | |
| Texture | Sand | |

Table 3. Effects of poultry manure and NPK fertilizer on soil pH, organic carbon and nitrogen in crude oil polluted soil.

| Soil pH<br>NPK (kg ha$^{-1}$) | Poultry manure (t ha$^{-1}$) | | | Means |
|---|---|---|---|---|
| | 0 | 4 | 8 | |
| 0 | 5.55$^{a}$ | 5.50$^{a}$ | 5.80$^{a}$ | 5.61$^{ns}$ |
| 50 | 5.40$^{a}$ | 5.80$^{a}$ | 5.50$^{a}$ | 5.56$^{ns}$ |
| 100 | 5.35$^{a}$ | 5.75$^{a}$ | 5.70$^{a}$ | 5.60$^{ns}$ |
| Means | 5.43$^{ns}$ | 5.68$^{ns}$ | 5.66$^{ns}$ | |
| **Percent organic carbon<br>NPK (kg ha$^{-1}$)** | | | | |
| 0 | 8.5 | 10.6 | 13 | 10.70$^{ns}$ |
| 50 | 10.3 | 11.5 | 14.1 | 12.00$^{ns}$ |
| 100 | 9.6 | 12.7 | 10.6 | 10.90$^{ns}$ |
| Means | 9.50$^{ns}$ | 11.60$^{ns}$ | 12.50$^{ns}$ | |
| **Percent nitrogen<br>NPK (kg ha$^{-1}$)** | | | | |
| 0 | 0.60$^{c}$ | 0.80b$^{c}$ | 0.90$^{abc}$ | 0.80$^{ns}$ |
| 50 | 0.70$^{bc}$ | 0.80$^{abc}$ | 1.20$^{a}$ | 0.90$^{ns}$ |
| 100 | 0.70$^{bc}$ | 0.90$^{ab}$ | 0.80$^{abc}$ | 0.80$^{ns}$ |
| Means | 0.70$^{b}$ | 0.90$^{ab}$ | 1.00$^{a}$ | |

DMRT = 0.30 (NPK+PM), 0.20 (PM). Means followed by the same letter(s) in the same column are not different at 5% level.

8.50 g $kg^{-1}$ of the control. Poultry manure alone was slightly more effective than fertilizer alone in raising soil pH and soil organic carbon. Soil N content was similarly increased significantly with the application of 50 kg $ha^{-1}$ NPK plus 8 t $ha^{-1}$ PM from 0.60 to 1.20 g $kg^{-1}$ compared to 0.60 g $kg^{-1}$ of the control treatment. Poultry manure alone increased soil N content significantly compared to fertilizer alone.

Poultry manure and fertilizer had no significant effect on exchangeable $Ca^{2+}$ and $K^{+}$ contents of the soil (Table 4). However, combined application of 50 kg $ha^{-1}$ NPK plus 8 t $ha^{-1}$ PM and 100 kg $ha^{-1}$ NPK plus 8 t $ha^{-1}$ PM to oil contaminated soil increased $K^{+}$ and $Ca^{2+}$ contents to 0.12 an 4.48 cmol $kg^{-1}$ compared to 0.08 and 2.84 cmol $kg^{-1}$ of the controls, respectively. Manure and fertilizer applied separately (8 t $ha^{-1}$ and 100 kg $ha^{-1}$) increased $Ca^{2+}$ contents in the contaminated soil to 3.82 and 3.85 cmol $kg^{-1}$ that was relatively sufficient for southwestern soils of Nigeria. Exhangeable $Mg^{2+}$ was increased in the contaminated soil by the application of 4 t $ha^{-1}$ PM alone and mixture of 100 kg $ha^{-1}$ NPK plus 4 t $ha^{-1}$ PM; $Mg^{2+}$ content 1.60 and 1.62 cmol $kg^{-1}$ were higher significantly compared to 1.24 and 1.02 cmol $kg^{-1}$ of the controls, respectively. Fertilizer application alone further reduced Mg content in the contaminated soil.

The ECEC of the soil follows similar pattern of exchangeable cations; application of 100 kg $ha^{-1}$ NPK plus 8 t $ha^{-1}$ PM, 100 kg $ha^{-1}$ NPK plus 4 t $ha^{-1}$ PM and 50 kg $ha^{-1}$ NPK plus 4 t $ha^{-1}$a PM increased ECEC contents to 6.05, 6.07 and 6.37 cmol $kg^{-1}$ compared to 4.61 cmol $kg^{-1}$of the control (Table 5). Similarly, fertilizer and manure applied separately had no significant effects on ECEC but slightly increased the content.

Soil P contents of the crude oil contaminated soil was increased significantly by the application of 100 kg $ha^{-1}$ NPK plus 8 t $ha^{-1}$ PM; it increased soil P from 4.76 mg $kg^{-1}$of the control to 44.45 mg $kg^{-1}$ (Table 5). The effects were however, not different from other manure and fertilizer treatment combinations. Fertilizer application at 100 kg $ha^{-1}$ increased soil P in the contaminated soil compared to the control (untreated but contaminated). Though poultry manure increased soil P relative to the control, it had no significant effect.

At 3 weeks after planting (WAP) amending the contaminated soil with 100 kg $ha^{-1}$ NPK plus 8 t $ha^{-1}$ PM increased potato vine length significantly from 10.67 cm of the control treatment to 20.00 cm (Table 6). Amending the soil with fertilizer and manures separately had no significant effect on potato vine length. Similarly at 6 and 9 WAP application of 100 kg $ha^{-1}$NPK plus 8 t $ha^{-1}$ PM and 50 kg $ha^{-1}$ NPK plus 4 t $ha^{-1}$ PM increased potato vine length, respectively, compared to the control. At 9 WAP separate applications of 50 kg $ha^{-1}$ NPK fertilizer and 4 t $ha^{-1}$ PM treatments increased potato vine length relative to the controls. The treatment (50 kg $ha^{-1}$ NPK fertilizer plus 4 t $ha^{-1}$ PM) similarly increased potato leaf and shoot dry matter yield significantly compared to the controls (Table 6). The treatment increased leaf and shoot dry matter yield significantly from 18.83 and 22.13 to 26.17 and 30.63 g, respectively. Similar to potato vine length at 9 WAP, separate applications of 50 kg $ha^{-1}$ and 4 t $ha^{-1}$ PM treatments increased potato leaf and shoot dry matter yield compared to the control.

Table 4. Effects of poultry manure and NPK fertilizer on Exchangeable Ca, Mg and K (cmol $kg^{-1}$) in crude oil polluted soil.

| Ca<br>NPK (kg $ha^{-1}$) | Poultry manure (t $ha^{-1}$) | | | Means |
|---|---|---|---|---|
| | 0 | 4 | 8 | |
| 0 | 2.84$^{a}$ | 2.88$^{a}$ | 4.12$^{a}$ | 3.28$^{ns}$ |
| 50 | 3.17$^{a}$ | 4.32$^{a}$ | 2.88$^{a}$ | 3.45$^{ns}$ |
| 100 | 3.24$^{a}$ | 3.84$^{a}$ | 4.48$^{a}$ | 3.85$^{ns}$ |
| Means | 3.08$^{ns}$ | 3.68$^{ns}$ | 3.82$^{ns}$ | |
| **Mg**<br>**NPK (kg $ha^{-1}$)** | | | | |
| 0 | 1.24$^{abc}$ | 1.76$^{a}$ | 1.24$^{abc}$ | 1.41$^{ns}$ |
| 50 | 1.04$^{abc}$ | 1.52$^{abc}$ | 1.28$^{abc}$ | 1.28$^{ns}$ |
| 100 | 0.80$^{c}$ | 1.60$^{ab}$ | 1.00$^{bc}$ | 1.13$^{ns}$ |
| Means | 1.02$^{b}$ | 1.62$^{a}$ | 1.17$^{b}$ | |
| **K**<br>**NPK Fert.(kg $ha^{-1}$)** | | | | |
| 0 | 0.08$^{a}$ | 0.08$^{a}$ | 0.07$^{a}$ | 0.07$^{ns}$ |
| 50 | 0.11$^{a}$ | 0.08$^{a}$ | 0.12$^{a}$ | 0.10$^{ns}$ |
| 100 | 0.08$^{a}$ | 0.09$^{a}$ | 0.07$^{a}$ | 0.08$^{ns}$ |
| Means | 0.09$^{ns}$ | 0.08$^{ns}$ | 0.08$^{ns}$ | |

DMRT = 0.72(NPK+PM), 0.41(PM). Means followed by the same letter(s) in the same column are not different at 5% level.

Table 5. Effects of poultry manure and NPK fertilizer on available P (mg $kg^{-1}$) and ECEC (cmol $kg^{-1}$) in crude oil polluted soil.

| Soil P<br>NPK Fert.(kg $ha^{-1}$) | Poultry manure (t $ha^{-1}$) | | | Means |
|---|---|---|---|---|
| | 0 | 4 | 8 | |
| 0 | 4.76$^{b}$ | 7.82$^{ab}$ | 10.02$^{ab}$ | 7.53$^{b}$ |
| 50 | 18.44$^{ab}$ | 17.10$^{ab}$ | 16.73$^{ab}$ | 17.42$^{b}$ |
| 100 | 32.01$^{ab}$ | 38.16$^{ab}$ | 44.45$^{a}$ | 38.20$^{a}$ |
| Means | 18.40$^{ns}$ | 21.02$^{ns}$ | 23.73$^{ns}$ | |
| **ECEC**<br>**NPK Fert.(kg $ha^{-1}$)** | | | | |
| 0 | 4.61 | 5.16 | 5.93 | 5.23$^{ns}$ |
| 50 | 4.92 | 6.37 | 4.71 | 5.33$^{ns}$ |
| 100 | 4.53 | 6.07 | 6.05 | 5.55$_{ns}$ |
| Means | 4.68$^{ns}$ | 5.86$^{ns}$ | 5.56$^{ns}$ | |

DMRT=3 9.11 (NPK+PM), 22.58 (NPK). Means followed by the same letter(s) in the same column are not different at 5% level.

Table 6. Effects of poultry manure and NPK fertilizer on sweet potato vine length (cm) at 3, 6 and 9 WAP after crude oil pollution.

| 3 WAP Vine Length NPK Fert.(kg ha$^{-1}$) | Poultry manure (t ha$^{-1}$) 0 | 4 | 8 | Means |
|---|---|---|---|---|
| 0 | 10.67$^{ab}$ | 12.50$^{ab}$ | 10.33$^{b}$ | 11.17$^{ns}$ |
| 50 | 17.00$^{ab}$ | 15.67$^{ab}$ | 13.33$^{ab}$ | 15.33$^{ns}$ |
| 100 | 14.33$^{ab}$ | 13.67$^{ab}$ | 20.00a | 16.00$^{ns}$ |
| Means | 14.00$^{ns}$ | 13.94$^{ns}$ | 14.56$^{ns}$ | |
| **6 WAP NPK Fert.(kg ha$^{-1}$)** | | | | |
| 0 | 86.17 | 82.03 | 78.53 | 82.24$^{ns}$ |
| 50 | 121.67 | 111.33 | 81.70 | 104.90$^{ns}$ |
| 100 | 97.67 | 92.67 | 140.53 | 110.29$^{ns}$ |
| Means | 101.83$^{ns}$ | 95.34$^{ns}$ | 100.26$^{ns}$ | |
| **9 WAP NPK Fert.(kg ha$^{-1}$)** | | | | |
| 0 | 221.33 | 207.67 | 163.33 | 197.44$^{ns}$ |
| 50 | 206.80 | 261.67 | 207.67 | 225.38$^{ns}$ |
| 100 | 207.67 | 240.33 | 193.37 | 213.79$^{ns}$ |
| Means | 211.93$^{ns}$ | 236.56$^{ns}$ | 188.12$^{ns}$ | |

DMRT = 9.44(NPK+PM). Means followed by the same letter(s) in the same column are not different at 5% level.

## Discussion

Poultry manure and fertilizer mixtures and their separate applications though not significantly different, increased exchangeable Ca in the contaminated soil to sufficient level that was above the critical level of 3.80 cmol kg$^{-1}$ (Agboola & Ayodele, 1987). Increases in exchangeable cations in the contaminated soil compared to the control suggest the remediation capability of poultry manure plus NPK fertilizer treatments (Isitekhale, 2010; Isitekhale *et al.*, 2013b). This further enhances soil chemical and physical properties; poultry manure has been reported to enhance soil physical properties by the improvement of soil organic matter and in turn increased soil moisture holding capacity, water retention and reduced bulk density. Ojeniyi & Adejobi (2001) observed that poultry manure significantly increased exchangeable N, P and Mg and Ca compared to NPK fertilizer.

Addition of organic materials such as poultry manure singly or in combination with fertilizer improved the contaminated soils' pH, organic carbon, total nitrogen, available P, and exchangeable $Ca^{2+}$, $K^{2+}$, $Mg^{2+}$ and $Ca^{2+}$ contents. This enhances the solubility of soil nutrients, biodegradation of crude oil and eventual removal of contaminants. Although manure and fertilizer combinations were very effective in improving soil nutrients, applying manure alone was not significantly effective.

Contaminated soil amended with 100 kg ha$^{-1}$ NPK fertilizer plus 8 t ha$^{-1}$ PM significantly increased potato vine growth, while remediation with 50 kg ha$^{-1}$ NPK fertilizer and 4 t ha$^{-1}$ PM significantly enhanced leaf and shoot dry matter yield compared to untreated soil (control). Poultry manure alone also significantly improved potato growth and dry matter yield. This is agrees with Amadi *et al.* (1993); there is every indication that nutrient supplementation of oil polluted soil especially with organic nutrient sources is beneficial for crop growth, because the C/N ratio is narrowed while the rate of biodegradation of oil and soil recovery is also enhanced. Agarry, *et al.* (2010) found that application of poultry manure, piggery manure, goat manure, and chemical fertilizer could enhance petroleum hydrocarbon degradation but concluded that poultry manure shows greater effectiveness. Growth increase is attributed to hydrocarbon removal by poultry manure and NPK fertilizer treatment. Chikere *et al.* (2009) found that polluted soil which had 3,666 mg kg$^{-1}$ of TPH at day zero was decreased by 95, 89.7 and 84% by NPK fertilizer, poultry manure and urea fertilizer, respectively

## Conclusion

Sweet potato growth can reduce the level of crude oil to some extent. Remediation can be enhanced through manure and fertilizer mixtures. Thus, application of 50 kg ha$^{-1}$ NPK plus 4 t ha$^{-1}$ and 100 kg ha$^{-1}$ NPK plus 8 t ha$^{-1}$ PM to crude oil polluted soils will enhance crude oil remediation, soil nutrient addition and growth of plants. 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 and the other 60% is through residual addition.

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