academicJournals

Vol. 7(6), pp. 67-75, July, 2013
DOI: 10.5897/AJBR11.113
ISSN 1996-0778 ©2013 AcademicJournals
http://www.academicjournals.org/AJBR

African Journal of Biochemistry Research

Full Length Research Paper

Effects of organic manures on the physicochemical properties of crude oil polluted soils

N. A. Obasi[1]*, Eberechukwu Eze[2], D. I. Anyanwu[2] and U. C. Okorie[1]

[1]Department of Science Laboratory Technology, Akanu Ibiam Federal Polytechnic, Unwana, Afikpo, Ebonyi State, Nigeria.
[2]Department of Plant Science and Biotechnology, University of Port Harcourt, Port Harcourt, Rivers State, Nigeria.

Accepted 13 June, 2013

The impact of crude oil pollution on the edaphic physicochemical parameters and the influence of incorporation of different types of organic manures in the polluted soils were investigated. The factorial set of treatments were six levels of crude oil pollution (0, 30, 60, 90, 120 and 150 ml), while amendment treatments were done after two weeks of pollution treatment, using the following organic manures: poultry manure (PM), cow dung manure (CM), saw dust manure (SM), poultry + cow dung manure (PM + CM), poultry + saw dust manure (PM + SM) and cow dung + saw dust manure (CM + SM) with two sets of control: pollution + no amendment and no pollution + no amendment. Results indicated that crude oil pollution significantly affected the edaphic physicochemical parameters at $P \leq 0.05$. The percentage total organic carbon, total organic matter and total hydrocarbon content (THC) significantly increased two weeks after crude oil pollution while the pH, percentage total nitrogen, phosphorus and exchangeable bases (Ca, K and Mg) significantly decreased. The results also showed that the different amendment treatments significantly decreased crude oil toxicity at different degrees by improving the nutrient content and decreasing the total hydrocarbon content of the soil. The results indicated the order of their remediation potential as PM > PM+CM > CM > PM+SM > CM + SM > SM. Thus, PM followed by PM + CM are highly recommended for amendment of crude oil polluted soil for enhanced agronomic performance due to their narrowing effect on carbon : nitrogen (C:N) ratio which is an index of improved soil fertility.

Key words: Crude oil, organic manures, amendment, physicochemical parameters, toxicity.

INTRODUCTION

Soil is the key component of natural ecosystem and environmental sustainability depends largely on sustainable ecosystem (Adenipekun, 2008; Onuh et al., 2008a; Adedokun and Ataga, 2007). Crude oil pollution adversely affects the soil ecosystem through adsorption to soil particles, provision of an excess carbon that might be unavailable for microbial use and an induction of a limitation in soil nitrogen and phosphorus (Baker and Herson, 1994; Atlas, 1981). These processes which affect drastically soil enzymatic activities result in a very slow biodegradation of crude oil polluted soils (Ijah et al., 2008; Okolo et al., 2005). Consequently, various soil amendments have been used in bioremediation strategies to hasten the process for the actualization of sustainable ecosystem.

The effects of crude oil pollution on the properties of soil have been the subjects of many studies. Okolo et al. (2005) reported that oil pollution increase carbon and reduces soil nitrates and phosphorus. Similarly, Adedokun and Ataga (2007) reported that any contact of

*Corresponding author. E-mail: naobasi@yahoo.com.

soil with crude oil results in damage to the soil micro-organisms and plants while Onuha et al. (2003) among others have shown that crude oil pollution prevents oxygen exchange between soil and the atmosphere due to hydrophobic properties of oil.

In Nigeria, most of the terrestrial ecosystem and shore-lines in oil producing communities are important agricultural land under continuous cultivation. The adverse effects of crude oil pollution on these arable agricultural lands have given rise to various soil treatment options such as the use of surfactants, alternate carbon substrates, organic and inorganic manures and bioremediation plants as bioremediation strategies (Ijah et al., 2008; Onuh et al., 2008a, b; Okolo et al., 2005; Burd et al., 2000; Raskin et al., 1997).

Organic manures as well as plants have over time been used to improve soil fertility (Ijah et al., 2008; Onuh et al., 2008a, b; Okolo et al., 2005; Raskin, 1997). Their efficacy in promoting plant growth in crude oil polluted Nigerians soils has also been well documented (Ogbogholo et al., 2005; Amadi and Uebari, 1992).

The effectiveness of these treatments has however been conflicting (Lee et al., 2002; Lindstrom and Braddock, 2002; Cunningham and Philip, 2000; Brown et al., 1986). This might be attributed to the heterogeneity of soils and crude oil samples as well as possible interact-tions between the soil amendments and the natural soil constituents (Knaebel et al., 1994). The effectiveness of each treatment in any soil therefore needs to be evaluated on a case specific basis. This study therefore is aimed at investigating the potentials of using organic manures as bioremediants in crude oil polluted soils.

MATERIALS AND METHODS

Study area description

The study was conducted at the University of Port Harcourt Botanic Garden, Port Harcourt, Rivers State of Nigeria. The study site is about 26 km North-West of the city of Port Harcourt, along the East-west road between Latitude 4° 00N and 5° 00N, and longitude 6° 30′ and 7° E of the tropical rainforest belt of southern Nigeria.

Sample collection

Soil samples for the experiment were collected randomly with a metal soil auger at the surface soil (loamy clay) between the depths of 0 to 15 cm from an old agricultural garden in the Botanic Garden, University of Port Harcourt, Rivers state. The soil samples were bulked together, homogenized and 5.0 kg was put into perforated labelled bags (Onuh et al., 2008a). This perforation allows for proper drainage (avoid water logging) and better aeration of the experimental soil. A total of 168 bags filled with experimental soil were used for the experiment. The soil parameters (pH, organic carbon, organic matter, phosphate, total nitrogen, total hydrocarbon content, potassium, calcium and magnesium) were also determined. The poultry manure was collected from poultry farm at Aluu, cow dung manure from Aluu slaughter and sawdust manure from a milling factory at Aluu, all in Obio-Akpo LGA, Rivers State, Nigeria. The poultry manure and cow dung were composted and crushed before use. The crude oil was obtained from Nigerian National Petroleum Corporation (NNPC), Eleme, Port-Harcourt, Rivers State and was applied as pollutant.

Pollution treatment

Crude oil was added to the soil in the bags at various levels (0, 30, 60, 90, 120 and 150 ml) and thoroughly mixed with the soil. The polluted and unpolluted soils were allowed to stand under natural environment for 14 days before application of organic manure amendments. During this period, the soil samples were watered at intervals of two days. A total of 140 bags with soil were polluted with crude oil and 28 bags without crude oil pollution.

Amendment treatments

After 14 days of pollution treatments, organic manures which included poultry manure (PM), cow dung manure (CM), sawdust manure (SM) and a combination of these: poultry manure + cow dung manure (PM + CM), poultry manure + sawdust manure (PM + SM) and cow dung manure + sawdust manure (CM + SM) were carefully weighed into the bags containing the crude oil treated and un-treated soils in the ratio of 1:3 of soil contents. The experimental design is shown in Table 1.

Sampling

Soil samples were collected from the bag at three different times. First was before crude oil application to ascertain the physico-chemical nature of the unpolluted soil. Second was at 14 days after crude oil pollution and third was at 28 days after amendments of crude oil polluted soil.

Determination of physiochemical parameters

The pH were determined by the method outlined by Bates (1954) using an electronically Jenway 3015 pH meter at ratio of 1:2.5 soil/water. The rapid titrimetric method as outlined by Osuji and Adesiyan (2005) was used to determine the organic carbon and organic matter. The ascorbic acid method as outlined by AOAC (1999) was used for phosphate determination. Total nitrogen was determined by Kjaldahl method as outlined by AOAC (1999). Total hydrocarbon contents was determined according to the method as outlined in Osuji and Uduetok (2008) while the determination of calcium, potassium and magnesium were done by mixed acid digestion method as outlined by AOAC (1999).

Statistical analysis

The results were expressed as mean ± standard deviation of four replicates. Analyses of variance (ANOVA) were carried out using SPSS version15.0 and mean values were separated using the Ducans multiple range test (DMRT) at $P \leq 0.05$ as outlined in Kerr et al. (2002).

RESULTS

Effect of crude oil level on the physicochemical properties of the soil

The result of the physicochemical properties of the soil before and two weeks after different level of crude oil

Table 1. Experimental treatment design.

Control	Treatments with organic manures					
Bag 1A + 5.0 kg soil+ 0 ml crude oil	Bag 1B + 5.0kg soil+ 0ml crude oil + 1.67kg PM	Bag 1C + 5.0kg soil+ 0ml crude oil + 1.67kg CM	Bag 1D + 5.0kg soil+ 0ml crude oil + 1.67kg SM	Bag 1E + 5.0 kg soil+ 0 ml crude oil + 0.83 kg PM + 0.83kg CM	Bag 1F + 5.0 kg soil+ 0 ml crude oil + 0.83 kg PM+ 0.83 kg SM	Bag 1G + 5.0 kg soil+ 0 ml crude oil + 0.83kg CM + 0.83kg SM
Bag 2A + 5.0 kg soil+ 30 ml crude oil	Bag 2B + 5.0kg soil+ 30ml crude oil + 1.67kg PM	Bag 2C + 5.0kg soil+ 30ml crude oil + 1.67kg CM	Bag 2D + 5.0kg soil+ 30ml crude oil + 1.67kg SM	Bag 2E + 5.0 kg soil+ 30 ml crude oil + 0.83 kg PM + 0.83 kg CM	Bag 2F + 5.0 kg soil + 30 ml crude oil + 0.83 kg PM + 0.83 kg SM	Bag 2G + 5.0 kg soil+ 30 ml crude oil + 0.83kg CM+ 0.83 kg SM
Bag 3A + 5.0 kg soil+ 60 ml crude oil	Bag 3B + 5.0kg soil+ 60ml crude oil + 1.67kg PM	Bag 3C + 5.0kg soil+ 60ml crude oil + 1.67kg CM	Bag 3D + 5.0kg soil+ 60ml crude oil + 1.67kg SM	Bag 3E + 5.0 kg soil+ 60 ml crude oil + 0.83 kg PM+ 0.83 kg CM	Bag 3F + 5.0 kg soil+ 60 ml crude oil + 0.83 kg PM + 0.83 kg SM	Bag 3G + 5.0 kg soil+ 60 ml crude oil + 0.83 kg CM+ 0.83 kg SM
Bag 4A + 5.0 kg soil+ 90 ml crude oil	Bag 4B + 5.0kg soil+ 90ml crude oil + 1.67kg PM	Bag 4C + 5.0kg soil+ 90ml crude oil + 1.67kg CM	Bag 4D + 5.0kg soil+ 90ml crude oil + 1.67kg SM	Bag 4E + 5.0 kg soil + 90 ml crude oil + 0.83 kg PM + 0.83 kg CM	Bag 4F + 5.0 kg soil+ 90 ml crude oil + 0.83 kg PM + 0.83 kg SM	Bag 4G + 5.0 kg soil+ 90 ml crude oil + 0.83 kg CM+ 0.83 kg SM
Bag 5A + 5.0 kg soil+ 120 ml crude oil	Bag 5B + 5.0kg soil+ 120ml crude oil + 1.67kg PM	Bag 5C + 5.0kg soil+ 120ml crude oil + 1.67kg CM	Bag 5D + 5.0kg soil+ 120ml crude oil + 1.67kg SM	Bag 5E + 5.0 kg soil + 120 ml crude oil + 0.83 kg PM + 0.83 kg CM	Bag 5F + 5.0 kg soil+ 120 ml crude oil + 0.83 kg PM + 0.83 kg SM	Bag 5G + 5.0kg soil + 120 ml crude oil + 0.83 kg CM+ 0.83 kg SM
Bag 6A + 5.0 kg soil+ 150 ml crude oil	Bag 6B + 5.0kg soil+ 150ml crude oil + 1.67kg PM	Bag 6C + 5.0kg soil+ 150ml crude oil + 1.67kg CM	Bag 6D + 5.0kg soil+ 150ml crude oil + 1.67kg SM	Bag 6E + 5.0 kg soil + 150 ml crude oil + 0.83 kg PM + 0.83 kg CM	Bag 6F + 5.0 kg soil+ 150 ml crude oil + 0.83 kg PM + 0.83 kg SM	Bag 6G + 5.0 kg soil + 150 ml crude oil + 0.83 kg CM + 0.83 kg SM

PM = Poultry manure, CM = cow dung manure, SM = saw dust manure.

pollution is shown in Table 2. The pH ranges (4.98 to 5.45) of the unpolluted and the crude oil-polluted soils indicated acidity. The results also showed significant increases in organic carbon and organic matter as the level of crude oil pollution increased. Table 2 also showed that the total nitrogen and phosphorus significantly decreased correspondingly as pollution levels increased. The results (Table 2) also showed a significant decrease ($P \leq 0.05$) in the calcium, potassium and magnesium content as the levels of crude oil pollution increased but a corresponding significant increase ($P \leq 0.05$) in total hydrocarbon (THC) and carbon : nitrogen (C: N) ratio as the crude oil pollution levels increased.

Effect of organic manures on the physicochemical properties of the unpolluted and crude oil polluted soil

The results of the physicochemical properties of the unpolluted and crude oil polluted soil four weeks after amendments with different organic manures are shown in Tables 3 to 8. The results indicated that organic manures significantly influenced the physicochemical properties of the polluted soils.

Bags treated with PM gave the highest pH values followed by those treated with poultry manure and cow dung manure (PM + CM). The increase in pH values on application of these organic manures differed significantly ($P \leq 0.05$) from one organic manure to the other except for bags treated with cow dung manure only which were not significant from those treated with CM + SM manure, respectively, in most cases.

The results also showed that the organic carbon and organic matters contents of the unpolluted and crude oil polluted soil increased significantly ($P \leq 0.05$) on application of the different types of organic manures. Bags treated with poultry manure gave the highest organic carbon and organic matter contents followed by bags treated with PM + CM and then followed by PM + SM and CM in that order and least with SM.

Bags treated with organic manures significantly increased the percentage nitrogen and phosphorus in the unpolluted and crude oil polluted soils ($P \leq 0.05$). Bags amended with PM gave the highest value of nitrogen and phosphorus followed by bags amended with SM and CM + SM had the lowest increased values of nitrogen and phosphorus. However, the increment was all significant ($P \leq 0.05$) using Ducan's multiple range test (DMRT).

Calcium, potassium and magnesium were all influenced by the addition of the various organic manures to the unpolluted and crude oil polluted soils. There were significant increases in these metals on addition of these manures with PM producing the highest values in each case. Addition of saw dust (SM) manures gave the lowest increment in the value of these metals in all the observed cases (Tables 3 to 8). The increment in the values of these metals were however significant ($P \leq 0.05$) in most cases.

The results (Tables 3 to 8) also showed that application of the organic manures significantly decreased the THC

Table 2. Physico-chemical properties of the soil before and two weeks after different levels of crude oil pollution.

Levels of crude oil pollution/parameters	0 ml	30 ml	60 ml	90 ml	120 ml	150 ml
pH	5.45[e] ± 0.03	5.30[d] ± 0.01	5.10[c] ± 0.10	5.08[bc] ± 0.02	5.05[b] ± 0.01	4.98[a] ± 0.01
Organic Carbon (%)	2.48[a] ± 0.01	3.53[b] ± 0.11	5.14[c] ± 0.02	6.97[d] ± 0.01	7.11[e] ± 0.03	7.86[f] ± 0.13
Organic Matter (%)	4.28[a] ± 0.02	6.09[b] ± 0.01	8.86[c] ± 0.11	12.02[d] ± 0.02	12.26[e] ± 0.05	13.55[f] ± 0.01
Nitrogen (%)	0.18[e]± 0.07	0.15[d] ± 0.03	0.12[c] ± 0.01	0.08[b] ± 0.02	0.05[a] ± 0.01	0.03[a] ± 0.01
Calcium (mg/kg)	1.51[e] ± 0.03	1.49[d] ± 0.01	1.36[c] ± 0.01	1.32[b] ± 0.01	1.28[a] ± 0.02	1.27[a] ± 0.01
Potassium (mg/kg)	1.03[e]± 0.01	1.99[d] ± 0.03	0.92[c] ± 0.02	0.88[b] ± 0.01	0.85[a] ± 0.01	0.85[a] ± 0.01
Magnesium (mg/kg)	0.68[de] ± 0.02	0.66[d] ± 0.01	0.63[c] ± 0.05	0.57[b] ± 0.01	0.56[b] ± 0.01	0.51[a] ± 0.01
Phosphorus (mg/kg)	1.37[f] ± 0.03	1.12[e] ± 0.01	1.05[c] ± 0.01	0.86[c] ± 0.03	0.62[b] ± 0.01	0.35[a] ± 0.05
THC (mg/kg)	556.50[a] ± 2.11	4,500.60[b]±1.72	6,798.59[d]±7.08	7,714.29[d]±5.13	8,709.67[e]±11.05	10,800.50[f]±3.75
C:N Ratio	13.78[a] ± 0.05	23.53[b] ± 0.02	42.83[c] ± 0.01	87.13[d] ± 0.07	142.20[e] ± 0.10	262.00[f] ± 0.00

Values are means of four replicates ± standard deviation. Figures followed by the same alphabets in a row are not significantly different at P = 0.05 using Ducans multiple range test. THC = Total hydro carbon content, PM = poultry manure, CM = cow dung manure and SM = saw dust manure.

Table 3. Physico-chemical properties of 0 ml polluted soil four weeks after amendments with different organic manures.

Treatments/parameters	Un-amended	PM	CM	SM	PM + CM	PM +SM	CM +SM
pH	5.48[a] ± 0.01	6.11[f] ±0.03	5.59[c] ± 0.01	5.53[b]± 0.07	6.05[e] ± 0.02	6.00[d] ± 0.00	5.57[c] ± 0.01
Organic carbon (%)	3.00[a] ± 0.00	3.44[f] ± 0.02	3.27[cd]± 0.01	3.15[b] ± 0.05	3.42[e] ± 0.02	3.31[d] ± 0.01	3.22[c] ± 0.06
Organic matter (%)	5.17[a] ± 0.03	5.93[e] ± 0.01	5.64[d]± 0.02	5.43[b] ± 0.11	5.90[f] ± 0.00	5.71[e] ± 0.09	5.55[c] ± 0.17
Nitrogen (%)	0.21[a] ± 0.03	0.30[d] ± 0.05	0.25[c] ± 0.02	0.23[b] ± 0.11	0.28[d] ± 0.02	0.27[d] ± 0.01	0.24[bc] ± 0.02
Calcium (mg/kg)	1.52[a] ± 0.02	1.60[e] ± 0.05	1.57[c] ± 0.11	1.54[b] ± 0.02	1.58[c] ± 0.04	1.57[c] ± 0.03	1.55[b] ± 0.02
Potassium (mg/kg)	1.04[a] ± 0.13	1.11[e] ± 0.23	1.08[cd] ± 0.02	1.06[b] ± 0.03	1.09[d] ± 0.02	1.08[cd] ± 0.02	1.07[bc] ± 0.01
Magnesium (mg/kg)	0.07[a] ± 0.02	0.79[e] ± 0.01	0.77[cd] ± 0.03	0.75[b] ± 0.05	0.78[de] ± 0.02	0.77[cd] ± 0.17	0.76[bc] ± 0.02
Phosphorus (mg/kg)	1.38[a] ± 0.04	1.42[d] ± 0.05	1.40[bc] ± 0.15	1.38[a] ± 0.03	1.41[cd] ± 0.11	1.40[bc] ± 0.02	1.39[ab] ± 0.07
THC (mg/kg)	549.17[c] ± 1.41	193.14[b] ± 1.73	267.18[e]± 1.45	384.93[g] 2.43	102.64[a]± 2.50	217.50[d] ±1.57	296.73[f]± 3.12
C : N ratio	14.29[f] ± 0.11	11.47[a] ± 0.03	13.08[c] ± 0.02	13.70[d] ± 0.10	12.21[d] ± 0.07	12.26[b] ± 0.02	13.42[e] ± 0.08

Values are means of four replicates ± standard deviation. Figures followed by the same alphabets in a row are not significantly different at P = 0.05 using Ducans multiple range test. THC = Total hydrocarbon content, PM = poultry manure, CM = cow dung manure and SM = saw dust manure.

content of the unpolluted and crude oil polluted soil. Bags treated with a mixture of PM + CM gave the lowest THC values followed by bags treated with PM only and PM + SM. The decrease in the THC content was significant (P ≤ 0.05) using Ducan's multiple range test.

There were also decreases in the carbon: nitrogen ratio (Tables 3 to 8) in all the unpolluted and crude oil polluted soils on the application of the organic manures. This ratio however, varied in line with the variation observed for organic carbon and percentage nitrogen content.

DISCUSSION

The results showed a decrease in the pH as the levels of crude oil pollution increased, agreeing with the reports of Amadi et al. (2005) who observed increased soil acidity following increased crude oil pollution. The observed pH, 4.98 to 5.30 in the crude oil polluted samples was acidic and compared favourably with pH values, 4.7 to 5.4 reported by Osuji and Adesiyan (2005).

The decrease in pH as the levels of crude oil pollution increased as observed in this study contradicts the reports of Onuh et al. (2008a) who observed an increase in pH as the levels of crude oil pollution increased. These observed pH values however, do not fall completely within the acceptable standards of 5.5 to 6.5 (DPR, 2002). The pH which is the degree of acidity or alkalinity of soil affects not only the physicochemical properties but also the flora and fauna of soil. Thus, it determines the availability of many nutrients for plant growth and mainte-

Table 4. Physico-chemical properties of 30 ml polluted soil four weeks after amendments with different organic manures.

Treatments/parameters	Un-amended	PM	CM	SM	PM ±CM	PM ±SM	CM ±SM
pH	5.36^{a} ± 0.02	5.62^{e} ± .02	5.53^{a} ± 0.01	5.48^{d} ± 0.03	5.60^{e} ± 0.00	5.57 ^{d} ± 0.10	5.53^{c} ± 0.01
Organic Carbon (%)	3.71^{a}± 0.01	3.84^{f} ± 0.02	3.78^{b} ± 0.05	3.80^{c} ± 0.01	3.80^{e} ± 0.00	3.79 ^{de} ± 0.03	3.73^{b}± 0.02
Organic Matter (%)	6.40^{a} ± 0.02	6.62^{f} ± 0.01	6.52^{d} ± 0.72	6.47^{c} ± 0.15	6.55^{e} ± 0.21	6.53^{d} ± 0.03	6.43^{b} ± 0.25
Nitrogen (%)	0.16^{a} ± 0.01	0.22^{e}± 0.01	0.18^{bc} ± 0.02	0.17^{ab} ± 0.3	0.20^{d}± 0.05	0.19^{cd} ± 0.2	0.18^{bc}± .01
Calcium (mg/kg)	1.50^{a} ± 0.00	1.62^{f} ± 0.02	1.53^{c} ± 0.01	1.51^{ab} ± 0.01	1.58^{e} ± 0.01	1.56^{d} ± 0.01	1.52^{bc} ± 0.03
Potassium (mg/kg)	1.02^{a} ± 0.01	1.10^{f}± 0.05	1.06^{d}± 0.02	1.03^{ab} ± 0.01	1.08^{e} ± 0.02	1.05^{cd} ± 0.01	1.04^{bc} ±0.01
Magnesium (mg/kg)	0.88^{a}±0.03	0.82^{f} ± 0.02	0.75^{c} ± 0.05	0.73^{b} ± 0.02	0.77^{e} ± 0.01	0.75^{cd} ± 0.01	0.76^{de} ± 0.01
Phosphorus (mg/kg)	1.17^{a}±0.11	1.25^{f}±0.01	1.21^{de} ± 0.15	1.19^{bc}± 0.03	1.22^{e}± 0.02	1.20^{cd}± 0.10	1.18^{ab} ± 0.01
THC (mg/kg)	4,096.10^{a}±1.18	1,815.64^{b}±1.52	2,752.34^{d}±1.20	3,610.21^{f}±0.57	1,031^{a}±1.27	2,275.98^{c}±2.18	3,108.82^{e}±1.36
C : N Ratio	23.18^{g} ± 0.12	17.45^{a} ± 0.04	21.00^{e}± 0.05	22.06^{f} ± 0.28	19.00 ^{b}± 0.05	19.95^{c} ± 0.03	20.72^{d}± 0.03

Values are means of four replicates ± standard deviation. Figures followed by the same alphabets in a row are not significantly different at P = 0.05 using Ducans multiple range test. THC = Total hydrocarbon content, PM = poultry manure, CM = cow dung manure and SM = saw dust manure.

maintenance. Strong acidic soils (pH 4 to 5) have been reported to have high concentration of soluble aluminium and manganese salts, which are toxic to plants. Consequently, the lowered pH values observed in the polluted soils can be raised by liming through appropriate application of calcium and magnesium compounds. Also, it is known that carbon mineralization and organic matter breakdown are rapid in neutral-to-slightly alkaline soils (Hunt, 1996).

At two weeks after pollution, percentage organic carbon and organic matter content of the soil samples increased with increase in the concentration of crude oil pollution (Table 4). The increase in the percentage organic carbon and organic matter observed in this study had been observed earlier (Onuh et al., 2008a, b; Amadi et al., 2005; Ogboghodo et al., 2005) and may be attributed to the microbial mineralization of the crude oil.

Available percentage nitrogen and phosphorus of the soil decreased with increase in the levels of crude oil pollution. Onuh et al. (2008a) had also observed a decrease in nitrogen availability with increased levels of crude oil pollution. Similarly, a decrease in phosphorus availability with increased levels of crude oil pollution had been reported (Okolo et al., 2005; Ogboghodo et al., 2005; Isirimah et al., 1989). The decrease in the available nitrogen and phosphorus with increased levels of crude oil pollution may be attributed to the limitation induced by the introduction of excess carbon to the soil since crude oil is a rich source of hydrocarbon (Atlas, 1981). Exchangeable bases (calcium, potassium and magnesium) were observed to have decreased with increased levels of crude oil pollution. This may be attributed to the use of these exchangeable bases by the microbes present in the experimental soil samples.

The results showed a significant increase in the THC with increased levels of crude oil pollution. The total hydrocarbon levels of the polluted soils significantly exceeded the compliance limit of 50 ppm set for the petroleum industry in Nigeria for oil and grease contamination (DPR, 2002). Total extractable hydrocarbon content (THC) of soils is frequently used to assess and ascertain the extent of contamination on sites (Osuji and Udoetok, 2008). Several reports have shown that high concentration of THC in soils is detrimental to the growth and productivity of plants and animals (Okolo et al., 2005; Osuji et al., 2004; Salanitro et al., 1997). Thus, the presence of high hydrocarbons of the range obtained in this study creates a clear condition that demands rehabilitation process for a meaningful existence of flora and fauna in crude oil polluted soils.

The results showed that addition of organic manures to the crude oil polluted soils slightly raised the soil pH. The pH of the oil polluted soil amended with PM followed by PM + CM raised the pH higher than those amended with SM which was only slightly raised. The results obtained are in consonance with those obtained by Ijah et al. (2008). The results also confirm earlier findings (Ijah and Antai, 2003) that organic manures (for example, chicken droppings) have buffering effect on crude oil polluted soil. This rise in the pH of the amended soils may favour oil degradation by microorganisms as observed in similar studies

Table 5. Physico-chemical properties of 60 ml polluted soil four weeks after amendments with different organic manures.

Treatments/parameters	Un-amended	PM	CM	SM	PM + CM	PM + SM	CM + SM
pH	5.18^{a} ± 0.01	5.42^{f}± 0.01	5.35^{cd} ± 0.00	5.27^{b} ± 0.12	5.39^{e}± 0.05	5.36^{d} ± 0.07	5.34^{c} ± 0.16
Organic Cabon (%)	5.27^{a} ± 0.03	5.46^{f}± 0.01	5.38^{d} ± 0.11	5.33^{c}± 0.05	5.41^{e} ± 0.02	5.38^{d} ± 0.12	5.30^{b}± 0.05
Organic Matter (%)	9.09^{a} ± 0.06	9.41^{f} ± 031	9.28^{d} ± 0.12	9.19^{c} ± 0.02	9.33^{e} ± 0.17	9.28^{d} ± 0.11	9.14^{d} ± 0.07
Nitrogen (%)	0.14^{a} ± 0.06	0.20^{e} ± 0.10	0.17^{cd} ± 0.11	0.15^{ab} ± 0.05	0.18^{d} ± 0.01	0.16^{bc}± 0.00	0.15^{ab} ± 0.03
Calcuim (mg/kg)	1.40^{a} ± 0.05	1.55^{f} ± 0.02	1.48^{d} ± 0.01	1.43^{c} ± 0.17	1.50^{e} ± 0.05	1.49^{de} ± 0.01	1.4^{ab} ± 0.01
Potassium (mg/kg)	0.95^{a} ± 0.25	1.01^{e} ± 0.05	0.98^{cd} ± 0.01	0.97^{bc} ± 0.03	0.99^{d} ± 0.01	0.98^{cd} ± 0.05	0.96^{ab} ± 0.03
Magnessium (mg/kg)	0.64^{ab} ± 0.02	0.70^{f} ± 0.00	0.67^{de} ± 0.03	0.65^{bc} ± 0.02	0.68^{e} ± 0.11	0.66^{cd}± 0.03	0.63^{a} ± 0.01
Phosphorus (mg/kg)	1.12^{a} ± 0.03	1.21^{f} ± 0.01	1.17^{e} ± 0.11	1.16^{cd} ± 0.05	1.18^{e} ± 0.02	1.15^{c} ± 0.01	1.13^{ab} ± 0.07
THC (mg/kg)	6.186.36^{g} ± 8.15	3,179.77^{c} ±12.5	3,722.01^{e} ±1.27	3,999.8^{f} ±2.10	2,774.8^{a} ±2.10	3,182.06^{b} ±5.3	3,391.64^{d} ±2.45
C : N Ratio	37.64^{e} ± 0.19	27.30^{a}± 0.05	31.65^{b} ± 0.08	35.53^{d} ± 0.7	30.06^{b}± 0.02	33.63^{b} ± 0.05	35.33^{d} ± 0.11

Values are mean of four replicates ± standard deviation. Figures followed by the same alphabets in a row are not significantly different at P = 0.05 using Ducans multiple range test. THC = Total hydrocarbon, PM = Poultry manure, CM = cow dung manure and SM = saw dust manure.

Table 6. Physico-chemical properties of 90 ml polluted soil four weeks after amendments with different organic manures.

Treatments/parameters	Un-amended	PM	CM	SM	PM ± CM	PM ± SM	CM ± SM
pH	5.12^{a} ± 0.02	5.38^{g} ± 0.02	5.29^{e} ± 0.01	5.20^{c} ± 0.15	5.31^{f} ± 0.03	5.26^{d} ±0.02	5.17^{b} ±0.01
Organic Carbon (%)	7.05^{a}± 0.05	7.24^{e} ± 0.06	7.16^{d} ± 0.02	7.09^{b} ± 0.07	7.18^{d} ± 0.11	7.13^{c}± 0.01	7.11^{c} ± 0.03
Organic Matter (%)	12.15^{a}±0.03	12.48^{g} ± 0.02	12.34^{e} ± 0.10	12.22^{b} ± 0.05	12.39^{f} ± 0.07	12.29^{d} ± 0.03	12.26^{c} ± 0.02
Nitrogen (%)	0.10^{a}± 0.01	0.18^{e} ± 0.03	0.15^{c} ± 0.17	0.12^{bc} ± 0.13	0.15^{d} ± 0.05	0.13^{c} ± 0.03	0.11^{ab} ± 0.01
Calcium (mg/kg)	1.35^{a}± 0.04	1.44^{e} ± 0.02	1.39^{cd} ± 0.01	1.37^{b} ± 0.13	1.40^{cd} ± 0.05	1.41^{d} ± 0.01	1.36^{ab} ± 0.05
Potassium (mg/kg)	0.94^{a}± 0.02	1.01^{f} ± 0.17	0.98^{ef} ± 0.09	0.96^{bc} ± 0.02	0.99^{ef} ± 0.03	0.97^{cd} ± 0.01	0.95^{ab} ± 0.02
Magnesium (mg/kg)	0.58^{ab}±0.04	0.62^{d} ± 0.11	0.60^{c} ± 0.05	0.59^{bc} ± 0.03	0.60^{c} ± 0.02	0.58^{ab} ± 0.15	0.57^{a} ± 0.08
Phosphorus (mg/kg)	1.06^{a}± 0.01	1.18^{f} ± 0.02	1.12^{e} ± 0.01	1.10^{b} ± 0.05	1.16^{e} ± 0.02	1.14^{d} ± 0.05	1.13^{cd}± 0.03
THC (mg/kg)	7,105.26^{g}±2.10	4,275.68^{b}±1.35	5,200.42^{e}±1.96	5,636.22^{f}±2.22	3,670.09^{a}±0.15	4,519.42^{c}±1.75	4,861.48^{d}±1.64
C : N Ratio	70.50^{f}±0.10	40.22^{a} ± 0.17	47.73^{b} ± 0.03	59.08^{d} ± 0.02	47.87^{d} ± 0 .11	54.85^{c} ± 0.01	64.64^{e} ± 0.02

Values are means of four replicates ± standard deviation. Figures followed by the same alphabets in a row are not significantly different at P = 0.05 using Ducans multiple range test. THC = Total hydrocarbon content, PM = poultry manure, CM = cow dung manure and SM = saw dust manure.

that higher pH range (6 to 9) provides better conditions for mineralization of hydrocarbons since most bacteria capable of metabolizing hydrocarbons develop best at pH conditions close to neutrality (Tanee and Kinako, 2008; Manuel et al., 1993; Atlas and Bartha, 1992).

The results also showed a significant increase in the percentage organic carbon and organic matter of crude oil polluted soils amended with organic manures. Organic carbon and organic matter affect soil properties such as their water holding capacity, bulk density and mobilizes nutrients for plants (Atlas and Barth, 1973). McGill (1976) also reported that organic carbon and organic matter when present in sufficient quantity have beneficial effect on soil chemical and physical properties. Thus, the signi-

Table 7. Physico-chemical properties of 120 ml polluted soil four weeks after amendments with different organic manures.

Treatments/parameters	Un-amended	PM	CM	SM	PM +CM	PM +SM	CM +SM
pH	5.08^{a} ± 0.01	5.19^{f} ± 0.11	5.13^{cd} ± 0.01	5.11^{b} ± 0.07	5.16^{e}± 0.02	5.14^{d} ± 0.01	5.12^{bc}±0.02
Organic carbon (%)	7.24^{a} ± 0.11	7.36^{f} ± 0.02	7.30^{bc} ± 0.05	7.29^{b} ± 0.13	7.34^{e} + 0.05	7.32^{d} ± 0.02	7.31^{cd}± 0.11
Organic Matter (%)	12.48^{a} ± 0.16	12.69^{f} ± 0.09	12.59^{bc}± 0.03	12.57^{b}± 0.11	12.65^{e}± 0.41	12.62^{d}±0.02	12.60^{cd}±0.05
Nitrogen (%)	0.70^{a} ± 0.01	0.13^{e} ± 0.01	0.09^{bc} ± 0.01	0.08^{ab} ± 0.02	0.11^{d}± 0.07	0.10^{cd} ± 0.00	0.09^{bc} ± 0.01
Calcium (mg/kg)	1.30^{a} ± 0.02	1.45^{d} ± 0.01	1.32^{bc} ± 0.01	1.31^{b}± 0.03	1.33^{c} ± 0.11	1.32^{bc} ± 0.02	1.30^{a}± 0.05
Potassium (mg/kg)	1.02^{a} ± 0.03	1.09^{f} ± 0.01	1.05^{de} ± 0.07	1.03^{bc} ± 0.01	1.06^{e} ± 0.04	1.04^{cd} ± 0.02	1.04^{cd} ± 0.02
Magnesium (mg/kg)	0.62^{a} ± 0.01	0.68^{d} ± 0.02	0.65^{bc} ± 0.02	0.66^{b} ± 0.03	0.66^{c} ± 0.05	0.64^{bc} ± 0.02	0.64^{b} ± 0.02
Phosphorus (mg/kg)	0.71^{a} ± 0.11	0.83^{e} ± 0.31	0.78^{c} ± 0.07	0.75^{b} ± 0.05	0.80^{d} ± 0.02	0.79^{cd} ± 0.11	0.76^{b} ± 0.01
THC (mg/kg)	8,307.69^{g}±1.52	5,420.7^{b}±307	6,679.26^{e}±1.21	7,001.23^{f}±1.75	4.881.28^{a}±2.43	6,373.74^{c}±3.82	6,539.18^{d}±5.43
C: N Ratio	103.42^{f} + 0.11	56.6^{a} ± 0.04	81.11^{d} ± 0.31	91.12^{e} ± 0.05	66.73 ^{b} ± 0.06	73.20^{c} ± 0.05	81.22^{d} ± 0.13

Values are means of four replicates ± standard deviation. Figures followed by the same alphabets in a row are not significantly different at P = 0.05 using. Ducans multiple range test. THC = Total hydrocarbon content, PM = poultry manure, CM = cow dung manure and SM = saw dust manure.

Table 8. Physico-chemical properties of 150 ml polluted soil four weeks after amendments with different organic manures.

Treatments/parameters	Un-amended	PM	CM	SM	PM +CM	PM +SM	CM +SM
pH	5.03^{a} ± 0.11	5.21^{f} ± 0.03	5.15^{d} ± 0.02	5.09^{b}±0.07	5.18^{e} ± 0.02	5.16^{d} ± 0.02	5.13^{c} ± 0.07
Organic Carbon (%)	7.94^{a} ± 0.02	8.01^{e} ± 0.43	7.97^{c} ± 0.28	7.95^{ab}±0.13	7.99^{d} ± 0.07	7.97^{c} ± 0.13	7.96^{bc}± 0.27
Organic Matter (%)	13.69^{a} ± 0.31	13.74^{e} ± 0.01	13.74^{c} ± 0.01	13.77^{b}±0.11	13.77^{d}± 0.09	13.74^{c}±0.08	13.72^{b}± 0.05
Nitrogen (%)	0.05^{a} ± 0.01	0.11^{f} ± 0.01	0.08^{cd} ± 0.02	0.06^{ab}±0.05	0.10^{ef} ± 0.02	0.09^{de} ± 0.03	0.07^{bc}± 0.01
Calcium (mg/kg)	1.29^{a} ± 0.01	1.34^{d} ± 0.02	1.31^{bc} ± 0.07	1.30^{ab}±0.02	1.32^{c}± 0.05	1.31^{bc} ± 0.11	1.30^{ab}± 0.02
Potassium (mg/kg)	0.85^{a} ± 0.05	0.91^{e} ± 0.03	0.89^{cd} ± 0.01	0.86^{a} ± 0.02	0.90^{de} ± 0.05	0.89^{cd} ± 0.11	0.88^{bc} ± 0.02
Magnesium (mg/kg)	0.54^{a} ± 0.02	0.62^{e} ± 0.01	0.58^{c} ± 0.02	0.57^{bc}±0.01	0.60^{d} ± 0.05	0.58^{c} ± 0.02	0.57^{bc} ± 0.01
Phosphorus (mg/kg)	0.41^{a} ± 0.13	0.53^{g} ± 0.07	0.48^{de} ± 0.02	0.45^{b} ± 0.05	0.50^{f} ± 0.10	0.49^{ef} ± 0.06	0.47^{bc}± 0.01
THC (mg/kg)	10,188.68^{g}±3.71	7,430.430^{b}±1.84	8,204.45^{e}±2.17	8,675.18^{f}±3.25	6957.62^{a}±1.05	7,478.45^{c}±1.88	7,943.15^{d}±1.35
C : N Ratio	158.80^{g} ± 1.15	72.82^{a} ± 1.10	99.63^{d}±0.97	132.50^{f} ± 0.05	79.90^{b} ± 0.10	88.56^{c} ± 0.82	113.7^{e}±1.13

Values are means of four replicates ± standard deviation. Figures followed by the same alphabets in a row are not significantly different at P = 0.05 using Ducans multiple range test. THC = Total hydrocarbon content, PM = poultry manure, CM = cow dung manure and SM = saw dust manure.

ficant increase in the organic carbon and organic matter content of the amended soil observed in this study may have beneficial effect on the soil chemical and physical properties. This is in line with earlier reports (Mbah et al., 2006, 2009; Shimp and Pfender, 1984) which stated that organic carbon and organic matter from wastes can influence the ability of microorganisms to degrade pollutants.

Total nitrogen and phosphorus content of the amended unpolluted and crude oil polluted soils were significantly higher than those of the un-amended soils, respectively. This increase in the percentage nitrogen and phosphorus may be as a result of anthropogenic inputs of these nutrients from the organic manures because organic manures have been reported as being capable of increasing soil nutrients by supplementing the limiting nutrients (Mbah et al, 2009:2006; Tanee and Kinako, 2008). Reports have shown that addition of nitrogen and phosphorus enhances biodegradation of polluted soil presumably by removing the nitrogen and phosphorus limitation resulting from low natural level (Odokuma and Ibor, 2002; Lee et al., 1995). Thus, the increase in the percentage nitrogen and phosphorus content of the amended soils induced by the various organic manures may enhance the biodegradation of the crude oil polluted soil and as such enhance its fertility.

The results showed that there were slight increases in the levels of calcium, potassium and magnesium in the amended unpolluted and crude oil polluted soils relative to the un-amended soils. Mbah et al. (2006, 2009) observed similar results. The increment may well be attributed to the anthropogenic input of the exchangeable bases induced by the organic manure sources. The increase was highest in soils amended with poultry manure (PM) followed by PM + CM and least in those amended with SM. This showed that poultry manure is a rich source of these exchangeable bases than saw dust manure. The addition of these exchangeable bases to soils improves soil fertility. Thus, these amendment options will definitely improve the soil fertility thereby amending the crude oil pollution.

The results showed that there was a marked significant decrease in the total hydrocarbon content of amended unpolluted and crude oil polluted soils relative to the un-amended soils. Highest loss of total hydrocarbon was evident in the PM + CM followed by PM treatments. This reduction in THC of the organic manures amended soils is in line with the reports of Tanee and Kinako (2008) who observed significant loss in the THC of poultry manure and NPK amended crude oil polluted soil. The high hydrocarbon loss in the organic manures amended soils is in line with Lee et al. (1995) who reported that organic manures have effect in stimulating crude oil degradation by increasing the total heterotrophic microbial growth and activity.

The results indicated that C : N ratios were significantly reduced in all the treatments. Highest reduction was recorded in the PM treatment followed by PM+CM treatments. These results compared favourably with those documented by Tanee and Kinako (2008) using inorganic fertilizer, NPK and poultry manure. The fact that lower C : N ratio were recorded with poultry manure and poultry manure and cow dung manure treatments indicated that some nutrients were lacking (Odokuma and Dickson, 2003). This means that hydrocarbon loss increased with smaller C : N ratios justifying the use of organic nitrogenous nutrient sources to aid biodegradation.

Conclusion

The results indicated that crude oil adversely affect soil physicochemical properties. Results from this study also showed improved soil physicochemical properties on crude oil contaminated soils amended with organic manures relative to the un-amended soils. Poultry manure in particular performed significantly better ($P \leq 0.05$) for the improvement of all soil physicochemical parameters, while saw dust manure elaborated the adverse effect of crude oil on the soil nutritional status. In light of the above, the results provided ample evidence that showed that organic manure supplements modify the physical, chemical and biological properties of crude oil polluted soils and improve their nutritional status for enhanced agronomic performances.

Based on this study, therefore, one would suggest that further research be conducted, so as to establish optimal levels of organic manures supplements that are likely to impact maximum economic gains as well as guarantee agricultural sustainability in the oil producing areas of the humid tropics exposed to incessant crude oil pollution.

REFERENCES

Adedokun OM, Ataga AE (2007): Effects of amendments and bioaugmentation of soil polluted with crude oil, automotive gasoline oil and spent engine oil on the growth of cowpea (*Vigna unguiculata*. L Walp). Sci. Res. Essay 2(5): 147-150.

Adenipekun CO (2008). Bioremediation of engine oil polluted soil by *pleurotus tuber-regium* Singer, a Nigerian whole rot fungus. Afr. J. Biotechnol. 7(I): 055-058.

Amadi A, Uebari Y (1992). Use of poultry manure for amendment of oil polluted soils in relation to growth of maize (Zea mays L.). Environ. Int. 18:54-57.

Amadi EN, Okol JC, Odu CTI (2005). Optimising Crude oil degradation in a sandy soil: Effects of urea-nitrogen and phosphoric acid. Phosphorus. J. Niger. Environ. Soc. 2(3):322-329.

AOAC (1999). Methods of Analysis of Association of Official Analytical Chemists (16th ed.). Washington, D.C. 1:600-792.

Atlas RM (1981). Biodegradation of Petroleum hydrocarbon: an environmental perspective. Microb. Rev. 45: 109-190.

Atlas RM, Bartha R (1973). Degradation and Mineralization of Petroleum in Sea Water. Environ. Sci. Technol. 17:5-38.

Atlas RM, Bartha R (1992). Hydrocarbon biodegradation and oil spill bioremediation. Adv. Microb. Ecol. 12:287-338.

Baker KH, Herson D (1994). Microbiology and Biodegradation. In: Bioremediation. Baker, K.H. and Herson, D. (eds). McGraw Hill Inc., New York. pp. 9-60.

Bates CA (1954). Electronic pH Determinations. John Wiley and Sons Inc New York. pp. 76-88.

Brown EJ, Pignatello J, Martinson M, Crawford R (1986). Pentachlorophenol degradation: A pure bacteria culture and epilithic microbial consortium. Appl. Environ. Microbiol. 52: 92-97.

Burd GI, Dixon DG, Glick BG (2000). Plant growth promoting bacteria that decrease heavy metal toxicity in plants. Can. J. Microbiol. 46: 237-245.

Cunningham CJ, Philip JC (2000). Comparison of biostimulation in ex-*Situ* treatment of diesel contaminated soil. Land Contam. Reclamation 8: 216-269.

DPR (2002). Environmental guidelines and standards for the petroleum industry in Nigeria (Revised edition). Department of Petroleum Resources, Ministry of Petroleum and Mineral Resources, Lagos. pp. 30-58.

Hunt JM (1996). Petroleum Geochemistry and Geology. Freemann, San Francisco. pp. 180-183.

Ijah UJJ, Antai SP (2003). The potential use of chicken drop microorganisms for oil spill remediation. Environmentalist 2(3):89-95.

Ijah UJJ, Safiyanu H, Abioye OP (2008). Comparative study of Biodegradation of Crude oil in soil amended with Chicken droppings and NPK fertilizer. Sci. World J. 3(2):63-67.

Isirimah NO, Zuofa K, Loganathan P (1989). Effect of crude oil on maize performance and soil chemical properties in the humid zone of Nigeria. J. Discov. Innov. 1(3):85-98.
Kerr AW, Hall HK, Kozub SA (2002). Doing Statistics with SPSS. SAGE Publications Ltd, London. pp. 163-174.
Knaebel DB, Federle TW, McAvoy DC, Vertal JR (1994). Effects of mineral and organic soil consistuents on microbial mineralization organic compounds in natural soil. Appl. Environ. Microbiol. 60: 4500-4508.
Lee I, Kin OK, Chang Y, Bae B, Kim HH, Dack KH (2002). Heavy metal concentration and Enzyme activities in soil from a contaminated Korean Shooting Range. J. Biosci. Bioeng. 94(5): 406-411.
Lee K, Tremblay GH, Cobanli SE (1995). Bioremediation of oil beach sediments: Assessment of inorganic and organic fertilizers. Proceedings of 1995 oil spill conference of American Petroleum Institute, Washington DC. pp. 101-119.
Lindstrom JE, Braddock JF (2002). Biodegradation of Petroleum hydrocarbons at low temperature in the presence of the dispersant corexet 9500. Mar. Pollut. Bull. 44: 739-749.
Manuel C, Jorge R, Maximilliano C (1993). Biodegradation experiment conducted at a tropical site in Eastern Venezuela. Waste Manage Res. 11: 97-106.
Mbah CN, Nwite JN, Nweke IA (2009). Amelioration of spent oil contaminated ultisol with organic wastes and its effect on soil properties and maize (*Zea mays* L) yield. World J. Agric. Sci. 5(2): 163-168.
Mbah CN, Nwite JN, Okporie OE (2006). Effect of organic wastes on some chemical properties and productivity of spent oil polluted ultisol in Abakaliki, Nigeria. Niger. J. Trop. Agric. 8:51-56.
McGill WB (1976). An introduction for field personnel to the effect of oil spills on soils and some general restoration and clearing Procedure. Alberta Institute of Pedology, AIP Publication (No.C 76-1). pp.133-141.
Odokuma LO, Dickson AA (2003). Bioremediation of a Crude oil polluted tropical mangrove environment. J. Appl. Sci. Environ. Manage. 7:23-29.
Odokuma LO, Ibor MN (2002). Nitrogen fixing bacteria enhanced bioremediation of a crude oil polluted soil. Glob. J. Pure Appl. Sci. 8(4):455-468.
Ogboghodo IA, Azenabor UF, Osemwota IO (2005). Amelioration of Crude oil polluted soil with poultry manure and the effect on growth of maize and some soil properties. J. Plant Nutr. 28(1): 21-32.
Okolo JC, Amadi EN, Odu CTI (2005). Effects of soil treatments containing poultry manure on crude oil degradation in a sandy loam soil. Appl. Biol. Environ. Res. 3(1): 47-53.
Onuh MO, Madukwe DK, Ohia GU (2008a). Effects of poultry manure and cow dung on the physical and chemical properties of crude oil polluted soil. Sci. World J. 3(2): 45 – 50.
Onuh MO, Ohazurike NC, Maduekwe DK (2008b). Interaction of crude oil and manure treatments and its effects on the agronomic characteristics of maize (*Zea mays* L.). Sci. World J. 3(2): 107 – 111.
Osuji LC, Adesiyan SO, Obute GC (2004). Post impact assessment of oil pollution in the Agbada West plain of Niger Delta Nigeria: Field reconnaissance and total extractable hydrocarbon content. Chem.. Biodivers. 1(10): 1569 – 1577.
Osuji LC, Adesiyan SO (2005). The Isiokpo oil-pipeline leakage: Total organic carbon/organic matter contents of affected soils. Chem. Biodivers. 2: 1079 – 1085.
Osuji LC, Uduetok IA (2008). Impact of contaminable hydrocarbons on soil Physicochemical properties. J. Oil Field Chem. 1(1): 25 – 34.
Raskin I, Smith RD, Salt DE (1997). Phytoremediation of metals: Using plants to remove pollutants from the environment. Curr. Opin. Biotechnol. **8**:221- 226
Salanitro JP, Dorn PB, Huesemann MH, Moore KO, Rhodes IA, Jackson IMR, Vipond TE, Western MM, Wisnieswski HL (1997). Crude oil hydrocarbon bioremediation and Soil Ecotoxicity Assessment. Environ. Sci. Technol. 5:1769-1776.
Shimp RI, Pfeander FK (1984). Influence of naturally occurring carbon substrates on the biodegradation of mono-substituted phenols by bacteria. Annu. Proc. Am. Soc. Microbiol. USA. pp. 212 – 216.
Tanee FBG, Kinako PDS (2008). Comparative Studies of Biostimulation and phytoremediation in the mitigation of crude oil toxicity in tropical soil. J. Appl. Sci. Environ. Manage. 12(2): 143 – 147.