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Full Length Research Paper

Amelioration of chemical properties of crude oil contaminated soil using compost from *Calapoigonium mucunoides* and poultry manure

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Abstract

A study was carried out in the green house and laboratory of Soil Science and Meteorology Department in Michael Okpara University of Agriculture, Umudike to compare the effect of a plant; *Calapoigonium mucunoides* and poultry manure at different rates (0%, 0.5%, 1%, and 2%) on crude oil polluted soil. Samples were moistened to 50% field capacity water content, amended with organic materials singly and in combination in pots laid out in Completely Randomized Design (CRD). The polluted and amended soils were incubated for a total of three weeks before soil analysis, standard laboratory techniques were use to analyze the following soil chemical properties; soil pH, total nitrogen, organic carbon, available phosphorus, exchangeable cations (Na, K, Ca, and Mg). The results after pollution and amendments revealed that the 1% and 2% of the amendments applied singly or in combination enhanced chemical properties of oil polluted soil than 0.5% applied rates. The amendments applied singly or in combination increased the values obtained for soil properties such as pH from 4.85 to 6.83 pH units, total nitrogen from 0.09 to 0.13, available P from 8.73 to 31.60 mg/kg. *Calapogonium mucunoides,* a green manure plant better improved soil fertility indices of the polluted soil as indicated by its effects on soil reactivity (pH) and exchangeable cations; the effect was highest when combined with poultry manure.

Keywords: Crude oil pollution, available P, exchangeable cations, poultry manure, *Calapogonium mucunoides.*

INTRODUCTION

The soil is a primary recipient by design or accident of a myriad of waste products and chemicals used in modern society. Pollution caused by petroleum and its derivatives is the most prevalent problem in the 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.

The agricultural lands have become less productive (Dabbs, 1996) and the creeks and the fishing waters have become more or less dead (Okpokwasili and Odokuma, 1990; Odokuma and Ibor, 2002). Several civil unrests due to environmental degradation from oil exploration is reported in the tropics, especially, in the Niger Delta region of Nigeria (Inoni *et al*., 2006), therefore the release of crude oil into the environment by oil spill is receiving world wide attention.

In most cases interest is in identifying the most effective method of remediating crude oil polluted soils and releasing such land for agricultural productivity. Of the many techniques developed to clean up petroleum contaminated soil, the physical, chemical and thermal processes are the common techniques reported to have achieved varying levels of cleaning up of oil contaminated sites (Frick *et al*., 1999). These techniques

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however have some adverse effects on the environment and are also expensive (Frick *et al*., 1999; Lundstedt, 2003). Recently, biological techniques like phytoremediation are being evaluated for the remediation of sites contaminated with petroleum.

Phytoremediation is the use of plants and/or associated microorganisms to remove or render harmful material harmless (Cunningham *et al*., 1996; Schwab and Banks, 1999; Merkl, 2005). It has been shown to be effective for different kinds of pollutants (contaminants) like heavy metals, radionuclide and broad range of organic pollutants (Schroder *et al*., 2002; Schnoor, 2002). According to Pivetz (2001), plants for phytoremediation should be appropriate for the climatic and soil conditions of the contaminated sites. *Calapogonium muccunoides* is a leguminous green manure plant. However, its ability to degrade hydrocarbon from crude oil contaminated soil, has not been studied especially for the Niger Delta soils in Nigeria.

Therefore, the objective of this study is to access the effect of single and combined application of green manure from *Callapogonium muccunoides* and poultry manure on the chemical properties of crude oil contaminated soils in south eastern Nigeria.

MATERIALS AND METHODS

Experimental site

The study was conducted with field soils collected from the Michael Okpara University of Agriculture Umudike, Eastern farm. Umudike is located on latitude 5^o 28' N and longitude 7^o 32' E, with an elevation of 122m above sea level. The area is characterized by uniform mean temperature ranging from 27^{o}C to 30 ^{0}C all through the year, with annual rainfall of 2200 mm per annum. The rainfall pattern is bimodal; a long wet season from April to July is interrupted by a short "August brake". This is followed by another short rainy season from September to October or early November, dry season stretches from early November to March, (NRCRI, 2005). The crude oil used for the experiment was collected from a crude oil spill site at Azuzuama in Southern Ijaw Local Government Area of Bayelsa State.

Sample collection

Soil samples were collected from four depths (0-15cm, 15-30cm, 30-45cm, 45-60cm), sieved through a 2mm mesh sieve and weighed out into perforated containers. Samples were polluted with crude oil at the rate of 30 ml/kg (Amadi, 1992), and moistened to 50% field capacity water content and were allowed to equilibrate in the soil for one week before the application of amendments.

Amendment application

The amendments used for remediation of the polluted soils were poultry manure and green manure (*Callapogonium mucunoides*) applied singly or as mixture in concentrations of 0%, 0.5%, 1% and 2% that were equivalent to 0g, 5g, 10g and 20g per kg soil respectively. The amendments were mixed thoroughly with the soil, and applied in triplicate giving a total of 144 observable units. The polluted and amended soils were randomly placed in bench in the green house and allowed to incubate for a total of three weeks before soil analysis.

Soil analysis

Soil chemical properties analyzed include: soil pH measured electronically using a glass electrode pH meter in water and in KCl_2 using a soil: liquid suspension ratio of 1: 2.5 as modified by Jones (2001). Soil organic carbon was determined using dichromate wet oxidation method as modified by Eno et al., (2009). Exchangeable cations were determined by extracting soil samples in 1N NH_4OAC, and the filtrate collected for elemental determination (Jones, 2001). The amount of K, Ca, Na, and Mg in the filtrate was determined using a flame photometer and magnesium was determined using an atomic absorption spectrophotometer. Total nitrogen in the soil was determined using the macro Kjeidahl method (Bremner and Mulvaney 1982). Available phosphorus was determined using Bray II method as described by Bray and Kurtz (1945). The soil texture was determined using the Bouyoucos method (1962).

Statistical analysis

Laboratory results were analyzed in a CRD, and the significant differences between the means were separated by Fishers Least Significant Difference (F_{LSD}) at 5% probability level.

RESULTS AND DISCUSSIONS

The characterization of the amendments used for the study, indicate that the poultry manure was higher in percent nitrogen (108%) than the green manure (97%), similarly, Ca and Na values in (Cmo l(+)kg$^-$) were higher in the poultry manure (1.23 and 0.79 respectively) than in the green manure (1.01 and 0.28 respectively) while the magnesium content of the green manure was higher as compared to the poultry manure. The characterization of the soil before crude oil pollution (Table 1) indicated that the soil was of sandy loam texture except at sampling depth 0-15cm. The lower depths had higher content of

Table 1. Physiochemical characteristics of the soils sample used before crude oil pollution

Properties	Depth(cm)			
	0-15	15-30	30-45	45-60
Sand (%)	81.80	77.80	71.80	68.80
Silt (%)	7.80	10.80	14.80	15.80
Clay (%)	10.40	11.40	13.40	15.40
Textural class	Loamy-sand	Sandy-loam	Sandy-loam	Sandy-loam
PH	5.64	5.64	5.16	4.83
Total nitrogen (%)	0.14	0.12	0.13	0.13
Organic carbon (%)	1.54	1.65	1.5	1.45
Ca (Cmol(+)kg^-)	10	12	11.6	14
Mg (Cmol(+)kg^-)	7.4	8.24	7.2	8.8
K^+ (Cmol(+)kg^-)	0.1	0.12	0.15	0.14
Na (Cmol(+)kg^-)	0.44	0.46	0.5	0.6
Available. P (mg/kg)	26.24	25.14	25.54	23.54

Mg but lower content in Na and available P.

The effects of compost amendment on soil pH (Tables 2 and 3) was significantly different (P>0.05) and higher for the combination of poultry and green manure at 0.5% rate of application, there were also significant differences (P>0.05) in the pH value of the soils at the other rates (1%, 2%) of application compared to the control. The pH values varied with depth; the pH of soils deeper profile (45-60cm) approached neutrality ranging between 6-7pH unit for the amended soils compared to the values at the shallower depth (0-15cm or 15-30cm) with values ranging from 4-6 pH units.

The low pH value observed in crude oil polluted soil that did not receive the compost amendment (0% amendment) may be attributed to heavy metals and the hydrocarbon contained in the crude oil polluted soil. This is in line with the findings of Osuji and Nwoye (2007) who reported that the soil pH was reduced due to the presence of hydrocarbon that produce organic acids when acted upon by microorganisms.

The effects of organic compost at different rates on available phosphorus (Tables 2 and 3), show that available phosphorus increased as the soil were amended with the composted materials; the level of increase in available phosphorus relative to control was proportional to the rate of compost amendment and varied depending on the amendment type.

This observation is not unassociated with the fact that crude oil pollution adversely affects the soil ecosystem through adsorption to soil particles and provision of an excess carbon that might be unavailable for microbial use. This induces a limitation in soil nitrogen and phosphorus, normally associated with a delay in the natural rehabilitation of crude oil polluted soils. Therefore, the addition of compost manure would negate these effects; however the degree of influence would vary depending on manure type and soil type and microbial population.

In this study, the observed values indicated that the application of poultry manure compost alone was most effective followed by the combination of poultry manure and *Callapogonium mucunoides* (M+CM) relative to control in increasing soil available P in crude oil polluted soil. Changes in total N, following compost application showed the same trend as in available P, relative to control, the total nitrogen increased with increased rate of amendment as shown in the Tables 2 and 3 above. The treatment and rate of amendment were statistically significant in influencing total nitrogen at P<0.05. Researchers (Ogboghodo *et al.,* 2004) also 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 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. Generally poultry manure has been used to improve soil chemical properties (Amadi, 1992) and in promoting plant growth in crude oil polluted soils (Atlas and Bartha, 2005).

Reports, (Millioli *et al.,* 2005), indicate that biological treatments are more efficient and cheaper than chemical and physical ones, thus bioremediation techniques is employed for the degradation of crude oil in soil matrix by using microorganisms able to transform petroleum hydrocarbons into less toxic compounds. However, the low solubility and adsorption capacity of high molecular weight hydrocarbons limit their availability to microorganisms. Hence 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

Table 2. Changes in chemical properties after incubation at shallow depths (0-30cm)

Treatment	Rate (t/ha)	Depth (cm)	OC (%)	N (%)	P (mg/kg)	Ca+ (Cmol(+)kg^{-})	pH	Mg+ (Cmol(+)kg^{-})	K+ (Cmol(+)kg^{-})
Manure (M)	0	1	2.2	0.09	8.93	6.40	4.85	4.31	0.11
		2	2.2	0.08	8.45	8.00	5.21	5.20	0.08
Manure	0.5	1	1.9	0.11	13.6	8.25	5.89	4.3	0.42
		2	1.9	0.11	13.49	8.33	5.91	4.4	0.42
Manure	1	1	1.8	0.12	25.38	11.39	6.33	8.1	0.43
		2	2.1	0.13	25.67	11.14	6.39	8.15	0.43
Manure	2	1	1.9	0.14	31.60	21.56	6.83	14.4	0.58
		2	0.7	0.14	30.49	21.25	6.52	14.3	0.60
C. Mucunoides	0	1	2.2	0.09	9.47	6.40	4.85	4.31	0.11
		2	2.0	0.08	8.58	8.00	5.21	5.2	0.08
C. Mucunoides	0.5	1	1.9	0.10	9.80	7.93	6.78	4.32	0.45
		2	1.9	0.12	9.46	8.29	6.30	4.23	0.42
	1	1	1.7	0.12	14.07	11.23	6.50	7.22	0.45
		2	1.6	0.12	13.92	11.03	6.57	8.46	0.43
C. Mucunoides	2	1	1.1	0.13	18.98	21.49	6.52	13.3	0.51
		2	0.8	0.13	18.43	21.54	5.23	14.23	0.54
M+CM	0	1	2.2	0.09	8.70	6.40	4.85	4.31	0.11
		2	2.2	0.08	8.52	8.00	5.21	5.2	0.08
M+CM	0.5	1	2.0	0.12	12.33	8.36	6.90	4.32	0.44
		2	2.0	0.12	12.09	8.45	6.43	4.2	0.43
M+CM	1	1	1.7	0.11	16.61	10.99	6.60	7.7	0.43
		2	1.8	0.13	16.54	10.94	6.68	8.09	0.45
M+CM	2	1	1.5	0.12	23.41	20.13	6.48	15.32	0.56
		2	1.1	0.13	24.08	21.56	5.23	14.3	0.61
FLSD (0.05) at D=1			T=0.01, R=0.01 TR=0.0	T=0.005, R=0.06 RT=0.01	T=0.59, R=0.69, TR=1.189	T=0.19 R=0.22, TR=0.38	T=0.04 R=0.05 TR=0.08	T=0.049, R=0.057, TR=0.099	T=0.343, R=0.039 TR=0.69
FLSD(0.05) at D= 2			T=0.01, R=0.01 TR=0.02		T=0.61, R=0.7, TR=1.214	T=0.16, R=0.188, TR=0.33	T=0.113, R=0.130 TR=0.226	T=0.039,R=0.045,TR=0.078	T=0.028, R=0.032 TR=.056

Note: Depth =1 or 2: 0-15cm or 15-30cm. T= treatment, R =rate, TR= treatment X rate interaction

polluted soil will enhance the solubility and removal of these contaminants, improving oil biodegradation rates. Also studies (Daniel-Kalio et al., 2003; Akonye and Onwudiwe, 2004) indicated that plant sources such as saw dust and *Chromolena odorata* L popularly known as stubborn weed posses those chemical and biological characteristics capable of amending polluted soil.

The effect of type and rate of compost manure on OC, from the results, was not consistent, this could be explained by the observation of Atlas and Bartha (1977) who reported that the effectiveness of these treatments could vary and could be related to the heterogeneity of soils and crude oil samples as well as possible interactions between the soil amendments and the natural soil constituents. This observation indicates that the effectiveness of each treatment in any soil needs to be evaluated on a case specific basis. In this study however, organic carbon content decreased in the compost amended soils relative to the control. This may be as a result of microorganisms in the amendments utilizing the carbon for their cell carbon, thus the high organic carbon content of the control soil (0% compost amendment) is explained by the effect of crude oil contamination which results in initial immobilization of the available C in the soil by surviving microorganism. Asuquo et al., (2001) also observed increases in organic carbon in contaminated soil following an initial scarcity with contamination. This study indicated that crude oil spills result in an imbalance in the carbon-nitrogen ratio at the spill site compared to the control site because crude-oil is essentially a mixture of carbon and hydrogen. This causes a 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). Furthermore, large

Table 3. Changes in chemical properties after incubation at 30-60cm depth

Treatment	Rate (t/ha)	Depth (cm)	OC (%)	N (%)	P Mg/kg	Ca (Cmol(+)kg^{-})	pH	Mg (Cmol(+)kg^{-})	K (Cmol(+)kg^{-})
Manure (M)	0	3	2.1	0.08	8.46	7.20	5.23	3.56	0.08
		4	2.3	0.08	8.46	8.4	5.00	4.80	0.16
Manure	0.5	3	1.8	0.12	12.51	8.32	6.83	3.86	0.44
		4	1.9	0.12	12.42	8.3	6.00	4.14	0.42
Manure	1	3	1.8	0.12	24.58	11.19	6.71	8.15	0.43
		4	1.2	0.13	24.70	10.97	7.00	8.07	0.48
Manure	2	3	1.5	0.13	31.62	21.06	6.70	14.23	0.54
		4	1.3	0.13	29.57	20.97	7.00	14.10	0.58
C. Mucunoides	0	3	2.1	0.08	8.57	7.20	5.23	3.56	0.08
		4	2.2	0.08	8.78	8.40	5.00	4.80	0.16
C. Mucunoides	0.5	3	2.0	0.11	8.82	8.29	6.33	4.14	0.41
		4	2.1	0.11	9.12	8.31	6.00	4.09	0.41
	1	3	1.4	0.12	13.02	11.14	6.69	8.16	0.41
		4	1.7	0.12	12.20	11.19	7.00	8.08	0.43
C. Mucunoides	2	3	1.2	0.13	17.65	20.54	6.51	14.15	0.52
		4	1.4	0.13	18.01	21.89	7.00	14.07	0.50
M+CM	0	3	2.4	0.08	8.52	7.20	5.23	3.56	0.08
		4	2.33	0.08	8.61	8.40	5.00	4.80	0.16
M+CM	0.5	3	1.6	0.10	12.21	8.37	6.77	3.86	0.41
		4	2.0	0.12	11.40	8.10	6.00	4.12	0.42
M+CM	1	3	1.4	0.13	16.21	11.08	6.61	8.15	0.43
		4	1.9	0.11	15.64	11.00	7.0	8.14	0.43
M+CM	2	3	1.1	0.14	23.09	20.75	6.63	14.27	0.54
		4	1.3	0.13	22.62	23.12	7.00	14.15	0.48
FLSD (0.05) at D=3			T=0.01, R=0.01 TR=0.02	T=0.01 R=0.01 TR=0.02	T=0.53, R=0.61, TR=1.05	T=0.29, R=0.34, TR=0.58	T=0.026,R=0.030,TR=0.052	T=0.05, R=0.06, TR=0.096	T=0.03 R=0.03 TR=0.05
FLSD (0.05) at D=4			T=0.007, R=0.008, TR=0.014	T=0.198, R=0.229, TR=0.014	T=0.544,R=0.629, TR= 1.09	T=0.198, R=0.229, TR=0.396		T=0.036, R=0.041, TR=0.072	T=0.023, R=0.027, TR=0.047

Note: D=3; (30-45cm), D=4- (45-60cm). T= treatment, R =rate, TR= treatment X rate interaction

concentrations of biodegradable organics in the top layer of agricultural soils deplete oxygen reserves in the soil and slow down the rates of oxygen diffusion to deeper layers, hence the effect of and rate and type of compost manure, on Ca content soils varied with depth and was statistically significantly different at $p<0.05$. All compost amendment irrespective of rate of application increased the calcium content of the soil, with the 2% rate of application giving the highest value at different depths. Similar trend was observed with K as shown in Table 2 and 3. However for Mg, the effect of organic compost amendment was significantly different ($P>0.05$) only for the combined compost amendment (M + CM) at 0.5% rate of application, but for the other amendments (M and CM) the other rates (1%, 2%) were significantly different ($P>0.05$) compared to the control.

CONCLUSION

Crude-oil pollution tends to persist in soils until remediation measures, involving the application of nutrients are resorted to, because oxygen and nitrogen are limiting factors in all types of petroleum degradation. Many techniques are being developed to clean up petroleum contaminated soil, as shown in the study; the effect of crude oil pollution on the soils could be ameliorated by the use of poultry and green manure (*Callapogonium mucunoides*). The application of organic materials such as poultry and green manure singly or in combination improved the selected chemical properties (pH, OC, total nitrogen, available P, Ca, K, and Mg) of the soil. The improvement relative to control for the different treatments increased as the rate of application increased. The two compost amendments applied singly or in combination gave the best effect at 1% and 2% rate of application in ameliorating chemical properties of the crude oil polluted soil. The results from this research strongly recommend the use of green manure plants such as *Callapogonium mucunoides* as suitable mulch or manorial material for remediation of crude oil contaminated soil

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