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Full Length Research Paper

Influence of nitrogenous fertilizer plant effluents on growth of selected farm crops in soils polluted with crude petroleum hydrocarbons

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Nitrogenous fertilizer (NPK) plant effluents from NAFCON were used in amending plots of land experimentally polluted with crude oil. Results obtained showed that NPK served as a good soil for the natural removal of contaminating crude from soils. Crude oil disappearance in untreated plots ranged between 8.70 and 34.80% and 20.90 and 60.50% for treated plots; cumulative loss was 73.0%. The disappearance was influenced by the N/P ratio in the supplementing fertilizer effluent. Crops grown on the experimental plots at the end of the study period indicated good soil recovery. The study revealed that fertilizer factory effluents, a cheap source of NPK can be applied to petroleum hydrocarbon contaminated soils in a controlled manner to improve crop germination recovery on such soils

Key words: Nitrogenous, fertilizer, effluents, farm, crops, pollution, petroleum.

INTRODUCTION

The growing demand and supply of fuel oil and new chemicals by the industrialized society of the twenty-first century has placed increasingly higher stress on the natural environment (Jaffe, 1991). Large amounts of diverse chemicals enter the environment via industrial discharges and other anthropogenic activities. Of particular concern are the hydrophobic organic compounds, because of their toxicological characteristics and their ability to accumulate in the environment.

Soil and water represent the first lines of recipients of oil pollution. Surface and ground water contamination by crude oil therefore is becoming an increasing sensitive issue in Nigeria because most of the water supply is derived from streams, shallow and unconfined aquifers. Furthermore, contamination of land is of paramount importance of man in that it is on this portion that man's existence depends. The oil mineral producing areas in Nigeria are in danger because the land is damaged and made infertile due to oil spill and other factors and this prevents growth of crops for varying periods of time. The damageing effects are due to suffocation and toxicity of the crude oil (Odu, 1978). Apart from this, it has been reported that Nitrate formation was reduced. Even 0.1% (v/w) of oil when mixed with soil practically checked nitrate formation and this is inimical to soil fertility (Odu et al., 1985).

Currently, physical and chemical methods, the most widely used procedures for clean-up, are not simple or favourable to the environment. For example, the use of chemical sorbents and dispersants are all regarded as fail-safe because they further introduce poisonous contaminants to the environment (Stevens, 1991).

Bacteria, which exist ubiquitously in the environment, have a great potential to degrade crude oil (Lee and Levy, 1991). Bioremediation is a new intervention method for post clean up whereby the natural biodegradable capabilities of the soil are enhanced by nutrient addition and/or cultured micro-organisms with advantages as cost effectiveness and without causing any environmental damage. Odu (1978) reported an increase in bioremediation of oil-polluted soil after supplying paraffin supplemented nitrogenous fertilizer (PSF) to the soil. Similarly, Odu (1978), Atlas and Bartha (1973c) reported that nitrogen and phosphorous are the most limiting nutrients to oil degrading bacteria. Thus, it would be interesting to study the relative importance of indigenous soil bacteria in bio-

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Table 1. Physico-chemical characteristics of NAFCON fertilizer plant effluent.

Parameter	Value
pH	8.4
Conductivity	1.5µs cm^{-1}
Turbidity	4.0 NTU
Salinity	0.1%
Dissolved Oxygen (DO)	7.8mg l^{-1}
NO_3	1.7mg l^{-1}
PO_4	5.2mg l^{-1}
SO_4	97.5mg l^{-1}

bioremediation in the presence of Nitrogenous fertilizer plant effluent. Generally, the concept of fitness of microorganisms as agents of geochemical transformation depends on three factors such as ubiquity of microorganisms, their metabolic potential and as well as their metabolic versatility which enables them to degrade a vast variety of naturally occurring organic materials (Lee and Levy, 1991).

Sufficient supply of nutrients and their influence on the ability of petroleum oxidizers to degrade crude oil products have remained controversial since crude oil is a mixture of hydrogen and carbon. Therefore, a spill in an area will result in an imbalance in the carbon-nitrogen ratio since more of the carbon will be added from the oil. Basically, bacteria require about 10 parts of carbon to 1 part of nitrogen for efficient growth (Jobson et al., 1974). If the ratio becomes greater as a result of oil spillage for instance 100:1, or 1000:1, growth of bacteria and utilization of carbon source will be retarded and also there will be nitrogen deficiency in such oil-soaked soil. Atlas and Bartha (1972) reported that nutrients are the main factors limiting the occurrence of petroleum degrading microorganisms. The availability of nitrogen and phosphorous in both seawater and soils were limiting to the occurrence of microorganisms that utilize petroleum and their subsequent degradation of crude oil (Odu, 1978; Floodgate, 1972; Athrendy, 1973). In contrast, Kinney et al. (1969) and Atlas (1981) observed that nitrogen and phosphorous were not limiting factors to petroleum degrading microoganisms in oil contaminated soil. It was concluded that nitrogen and phosphorous are both limiting only with respect to rates of hydrocarbon degradation considering solubility, and that they are in no way limiting factors in the sense that the solubility of hydrocarbon is so low as to preclude establishment of any unfavourable carbon / nitrogen or carbon/phosphorous ratio.

The objective of this study was to ascertain the potential for enhancement of crude oil removal from contaminated soils of the Niger delta region by controlled addition of nitrogenous fertilizer factory plant effluents.

MATERIALS AND METHODS

Sources of materials

The crude oil used was fresh "Bonny Light" obtained from Shell Petroleum Development Company of Nigerian Ltd (SPDC), Port Harcourt. The nitrogenous fertilizer plant factory effluent (characteristics in Table 1) was obtained from National Fertilizer Company Nigeria (NAFCON), Onne, Rivers State. All chemical reagents used in this study were of analytical grade.

Location of experimental plot

The experimental plot was located at the front entrance of Institute of Pollution Studies (IPS), Rivers State University of Science and Technology Nkpolu, Port Harcourt, Nigeria. It is an area characterized by typical grassland vegetation. The area was cleared and mapped out into four (4) plots of equal dimension (1m x 1m x m depth). The edges were elevated up to about 15 cm above the soil level to ensure proper demarcation and also to prevent run-off when it rains. The textural class of the soil is sandy, loamy (75% sand 14% silt and 11% clay).

Experimental design

The work involved field experiment and laboratory simulation. Experiment was designed to involve a laboratory stage of isolation by first exposing microorganisms from the field test soils to the effluent and hydrocarbon source in 2-litre flasks mounted on rotary shakers. Field-testing or experiment lasted for about five (5) months and employing three (3) separate treatment options and a control, each aimed at assessing the enhancement of bioremediation of crude oil polluted soils. After each treatment, the following parameters were determined: pH, moisture content, total organic carbon, total nitrogen and available phosphorous. The levels of exchangeable cation (potassium, calcium, magnesium and sodium) Total organic carbon /nitrogen 'C/N' ratio and Total hydrocarbon (THC) – (crude oil) level were also determined.

Recovery of the soil as indicated by growth of selected farm crops (okra, maize and fluted pumpkin) was also investigated. The test plot out lay is as shown below (Figure 1): The soil in plots 3 and 4 were polluted with three litres of crude oil each and plots 2 and 4 were sprayed with (2) two litres of Nitrogenous Fertilizer Plant effluent every other day for one month. Samples were then collected on appropriate days for testing in the laboratory. Table 1 shows the chemical and physical properties of the treated and untreated soils.

Soil sample collection

Top soil samples (0 – 3 cm) deep were collected at random from each test plot into a labelled sterile plastic bag using sterile auger. It was mixed very well (bulked) for uniformity. The samples were then taken to the laboratory immediately for microbiological analysis. The rest were left in open air (room temperature) to air dry for physico-chemical analysis. Sample collection was done weekly.

Measurement of total hydrocarbon (THC) in the soil samples

The residual hydrocarbon remaining in soil after experimental period was determined according to the method described by Odu et al. (1985).

Monitoring recovery of soil as indicated by growth parameters

The soil recovery potential was monitored by planting farm crops such as okra, maize and fluted pumpkin on the test plots and observing the growth parameters as it responded to the various

Table 2. Chemical content of untreated and oil treated soil.

Sampling Week	Treatment	pH	Exchangeable cations (Meg $100g^{-1}$soil)				Available PO_4 (ppm)	%		C/N
			Ca^{2+}	Mg^{2+}	K^+	Na^+		Org C*	TN*	
T_1	Control (Untreated)	4.80	2.05	0.01	0.04	0.27	18.60	1.53	0.12	12.75
	Effluent only	5.00	2.30	0.35	1.13	0.35	20.19	1.71	0.14	12.21
	Crude Oil only	5.40	2.15	0.45	0.02	2.43	19.47	3.90	0.11	35.45
	Crude Oil + Effluent	5.60	3.10	0.40	0.03	2.55	19.77	3.86	0.16	24.13
T_2	Control (Untreated)	4.80	1.90	0.05	0.04	0.21	18.60	1.50	0.12	12.50
	Effluent only	5.20	2.45	0.10	0.08	0.30	19.18	1.57	0.13	12.07
	Crude Oil only	5.00	2.15	0.35	0.05	4.06	7.02	3.80	0.06	63.33
	Crude Oil + Effluent	5.90	2.25	0.45	0.06	4.35	12.28	3.30	0.08	41.25
Note:	T_1 – First week of Treatment									
	T_2 – After Eight weeks of Treatment									

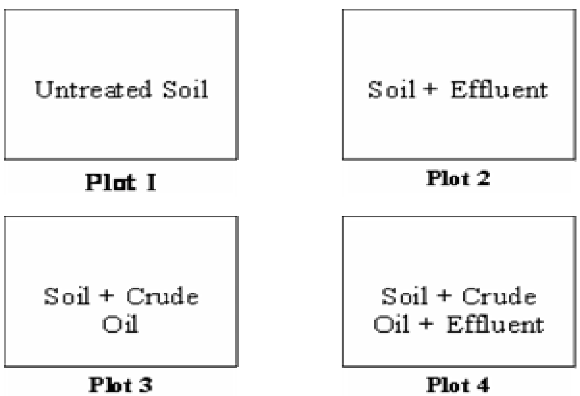

Figure 1. Test plot outlay.

treatments. How were these farm crops and planting methods standardised? The parameters are: observing the germination capacity of the seedling by noting day and number of plumules, measuring length or height of growth and foliage colour.

RESULTS AND DISCUSSION

Physicochemical characteristics of soils

Physicochemical properties of the nitrogenous fertilizer plant effluent are presented in Table 1. The physicochemical properties of untreated and treated soil samples are presented in Table 2. The pH value for pre-treatment (the control) was within the acidic range 4.80 and changed slightly after the application of crude oil and NPK effluent. A pH range of 6.0 - 6.8 was observed in week 4 for plots 2, 3 and 4. It later changed to the acidic range in week 8; 5.00 - 5.90. Similarly, Atlas (1981), Bossert and Bartha (1984) reported that neutral pH enable bioremediation activity of bacteria in the soil. However, a pH range of 6.5 - 8.0 has been reported for optimal mineralization of hydrocarbons (Dibble and Bartha, 1979; Greenfield, 1991). Thus, pH values recorded throughout the study period in all test plots were suitable for bioremediation.

Exchangeable cations at the end of the investigation increased in all treated soil as compared to the untreated (control) at the outset of the investigation. However, magnesium and sodium values were low in plot 2 the effluent treated soil than in the control soil after week 8. The reason for this low value may be attributed to either masking of these cations by some effluent anions or dilution. The values obtained for calcium, magnesium, potassium and sodium in the control at the beginning of investigation were 2.05mg $100g^{-1}$ soil, 0.10meg $100g^{-1}$, 0.04 and 0.27 meg $100g^{-1}$ soil respectively. These values increased slightly at the end of the investigation in the oil treated soils, but values obtained are below values obtained by Odu et al. (1985) as being good enough to maintain adequate soil fertility in Nigeria soil. The result obtained is similar to that presented by Amadi et al. (1993) who reported an increase in exchangeable cation in crude oil contaminated soil.

The carbon level of the experimental plots increased following the application of crude oil and flooding of fertilizer effluent, ranging from 1.53 - 3.90 %, and this is shown by the difference between the values for week1 (T_1) and the untreated (control). This may be attributed to the crude oil alone since the fertilizer effluent lacked Available phosphorus decreased in all crude oil contaminated soils at the end of the investigation. At the outset of the experiment, the value was 19.47 and 19.77 ppm for plots 3 and 4 respectively, but this dropped dras-tically to 7.02 and 12.28 ppm at the end (T_3). The crude oil enhanced the uptake of P in unremediated plot 3. Soil available phosphorous was below the level considered for soil fertility (Odu et al., 1985). Total nitrogen was depressed in all oil treated soils. Amadi et al. (1993) had also reported nitrogen depression in soils contaminated with petroleum hydrocarbons. The drop in values noticeable at the end of the study period might represent their utilization

Table 3. Growth parameters of crops in experimental soil.

Test plot	Type of seed planted	No	Day of upshoot	Germination count (No. of survival) After 10 days	Length of growth (after 2 weeks) cm	Foliage-colour
	Fluted Pumpkin	6	5 – 6	5	7.3	Green
1	Maize	10	4 – 7	9	4.2	Green
	Okra	10	7 – 9	8	2.5	Green
	Fluted Pumpkin	6	5	6	10.6	Very Green
2	Maize	10	4 – 5	10	5.9	Very Green
	Okra	10	6 – 8	8	3.4	Very Green
	Fluted Pumpkin	6	6	2	4.5	Greenish-Yellow
3	Maize	10	7	3	2.8	Greenish-Yellow
	Okra	10	-	-	-	
	Fluted Pumpkin	6	6	3	5.6	Green
4	Maize	10	7 – 8	6	3.5	Greenish-Yellow
	Okra	10	8 – 10	3	2.0	Greenish-Yellow

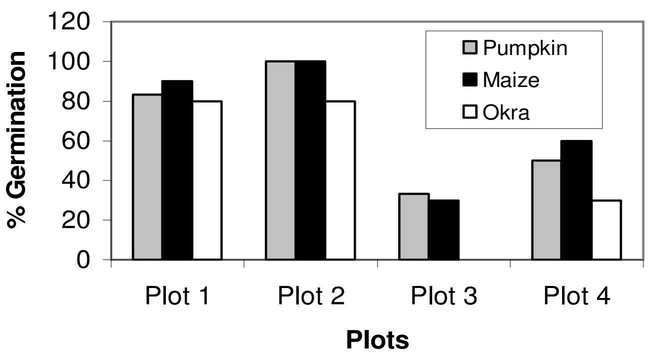

Figure 2. Germination of crops in polluted soils amended with fertilizer effluent

by the microorganisms. Before treatment with the petroleum hydrocarbon, the value obtained for total nitrogen was 0.12%, but by the end of the study (T_3), the values were all below this value (0.06 and 0.08% for plots 3 and 4 respectively). Odu et al. (1985) had reported that a total nitrogen value less than 0.1% is low for soil fertility.

Basically, phosphorous and nitrogen were the main nutrients used for supplementation in this study and their decrease in value as shown at the end of the investigation was due to their essential requirement for bioremediation to take place. Thus, it could be deduced that as petroleum hydrocarbon biodegradation proceeded without exogenous source of P and N, available phosphorous and total nitrogen were being depleted (Atlas et al., 1978). Furthermore, the C/N ratio of the test plot 4 was decreased when compared with plot 3 (41.3 and 63.2 respectively). This suggested that bioremediation activeties were more effective in the effluent supplemented soil plot 4. It conforms to the findings of Sandvik et al. (1986) and Brown et al. (1983); who reported C/N ratios of 9:1 and 200:1 as optimal for bio-treatment of waste oils sludge.

Other studies had concluded that moisture content might be a factor of environmental condition than treatment option (Dibble and Bartha, 1979) and in this study, moisture content recorded varied between 10.5 and 42.0 percent. It had been reported that a moisture content range of 20 – 80% is generally optimum for hydrocarbon degradation (Bossert and Bartha, 1984; Lynch, 1983; Dibble and Bartha, 1979). The values obtained for plots 2 and 4 (25 and 30% respectively) in Table 3 after 8 weeks were relatively higher when NPK effluent alone or in combination with crude treatment. These values are an indication of the suitability of this treatment option for enhancement of bioremediation.

Recovery of soil as indicated by growth parameters

The germination count (%) of the crops from fourth day after planting in the various plots 1, 2, 3 and 4 are shown in Figure 2. Germination increased with time with maximum % germination recorded on the 10th day for each treatment.

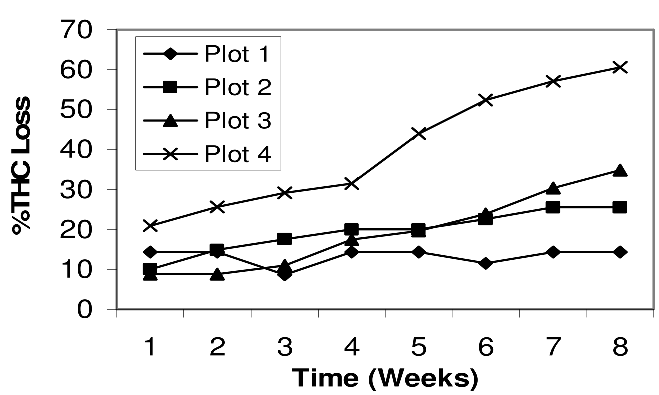

Figure 3. Percent loss of THC in experimental soils.

The non-nutrient supplemented oil polluted soil 3 recorded the lowest percentage germination; for instance, irrespective of its high phosphorus drop, fluted pumpkin had 33.3%, Maize 30.0% and Okra 0% (no growth) on the 10th day compared with the unpolluted plot for the same period which recorded 83.3, 90.3 and 80.0% germination respectively. Also, the addition of fertilizer effluxent to the polluted soil enhanced the percent germination thus, in plot 4, the percentage germination increased more than in the oil polluted, non-nutrient supplemented plot 3; recording 50 60 and 30% as against 33.3, 30 and 0% respectively. (Okra germination was grossly affected). Plot 2, which received NPK effluent without polluting with crude oil performed significantly better for all crops.

Furthermore, the effect of crude oil pollution on growth with respect to crop height or length and foliage colour from Table 3, showed that oil pollution has an adverse effect on growth height and colour of leaf measured 14 days after planting. The difference in crop height (fluted pumpkin, maize and okra) between unpolluted and oil polluted non-nutrient supplemented soil 1 and 3 varied from 7.3, 4.2 and 2.5 to 4.5, 2.8 cm and no growth respectively. There was a remarkable increase in height for crops in plot 4 (oil polluted and NPK supplemented) compared to crop height in plot 3 (oil polluted non-nutrient supplemented). Generally, the foliage colour was grossly affected in plots 3 and 4 -greenish yellow as compared to green and very green colour in plots 1 and 2.

Measurement of hydrocarbon content in treated soils is presented in Figure 3. Plots 1 and 2 with the lowest hydrocarbon (biogenic) removal rates had the best growth parameters (Table 3).

Conclusion

The study reveals that fertilizer factory effluents, a cheap source of NPK can be applied to petroleum hydrocarbon contaminated soils in a controlled manner to aid soil recovery through microbial action (Odu, 1978; Adoki and Orugbani, 2007). This has a very good potential to improve crop germination recovery on such soils.

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