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Research Article

Preliminary Thermo-Remediation of Crude-Oil Polluted Soil using Cowpea (*vigna sinensis*) as an Indicator

[1]Walter, C. and [2]Inengite, A. K.

[1]Department of Chemistry, Rivers State College of Arts and Science' Port Harcourt, Rivers State, Nigeria

*[2]Department of Chemical Sciences, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria

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Abstract: This study investigates the application of heat in the remediation of crude oil polluted soil. Various percentages pollution of soil by crude oil (0.4, 0.8, 1.2, 1.6, 2.0, 2.4, 2.8 and 3.2) % were prepared and heated at six different temperatures (105, 110, 125, 130, 140 and 160) ^{o}C. The growth rate of cowpea (*vigna sinensis*) was used as an indicator to determine the level of remediation of the polluted soil to its original state. The most effective temperature for the remediation was 105^{o}C while the remediation was highest at the 3.2% crude oil pollution. This method of remediation has good prospects due to its cost and time effectiveness.

Key words: Soil; Crude oil pollution; Thermoremediation; Cowpea

INTRODUCTION

In recent times, there has been an upsurge of public interest in the environmental impact of large-scale industrial projects in Nigeria. One of such large-scale industrial projects that is responsible for most environmental degradation is the exploration and exploitation of crude oil[1-4] Associated with the exploration and exploitation of crude oil operations is the release of sometimes large quantities of crude oil into the environment, leading to deterioration of the quality of the soil and water bodies for life to thrive. Against this backdrop, research interests have developed in the area of remediation of crude oil polluted segments of the environment. Urum *et al*[5] studied the use of surfactants in the remediation of crude oil polluted soils. Also, the use of mycoremediation have been experimented by Okparanma *et al*[6] . Their findings revealed that these methods could be applied in the remediation of crude oil polluted soils; however, they have the challenges of high cost and long process time,

respectively. In this study, the focus is the use of heat to remediate lightly polluted soil. This method and its applications are very simplified and should be more convenient and affordable by developing countries. The germination of cowpea (*vigna sinensis*) used as an indicator, to measure the extent of recovery of the polluted soil.

MATERIALS AND METHODS

Sweet Crude obtained from Shell Petroleum Development Company of Nigeria Limited (SPDC) flow station at Bomu Base was used for the experiments. Its properties are as follows:

Type: Bonny Light***;*** ***Pour Point:*** -15 ^{o}C;

Sulphur Content: 0.122mg/Kg; ***Specific Gravity:*** 0.8623;

API Gravity: 32.6; ***Water and Sediment:*** 0.0%.

The germination rate of cowpea was used as an indicator in the measurement of the extent of remediation or re-instatement of the polluted soil to its original quality. Cowpea is a dicotyledenous, which germinates in approximately two days after planting in good condition.

Garden soil obtained from the agricultural farm of the Rivers State University of Science and Technology, Port Harcourt was used for the experiments. The physic-chemical parameters of the soil are as stated below:

Soil Depth (cm)	pH	Available Phosphorus (mg/Kg)	Total Hydrocarbon Content (mg/Kg)	Organic Carbon (%)	Total Nitrogen (%)	K^+ (mg/Kg)
0-15	5.2	17.65	-	0.8	0.05	0.77
Na^{2+} (mg/Kg)	Ca^{2+} (mg/Kg)	Mg^{2+} (mg/Kg)	Sand (%)	Silt (%)	Clay (%)	Textural Class
0.22	1.85	o.72	87	7.0	6.0	Humus Sand

Fifty-seven identical experimental set-up containers filled with 0.625Kg of soil.

Percentage pollution ranges of 0.0; 0.4; 0.8; 1.2; 1.6; 2.0; 2.4; 2.8 and 3.2 were prepared by homogenising the soil with specific volumes of crude oil, which calculated by the formula:

Volume of Crude Oil = (Mass of Crude Oil) / (Density of Crude Oil)

$$API\ gravity = \left\{\frac{141.5}{\rho_{15}^{15}}\right\} - 131.5$$

Where API gravity for the Crude Oil used is 32.6

$$\rho_{15}^{15} = specific\ gravity\ of\ crude\ oil\ used = 0.8623$$

$$\frac{Density\ of\ Crude}{Density\ of\ water} = 0.8623$$

$$Density\ of\ Crude = 0.8623 * 1000\frac{kg}{m^3} = 862.3\ kg/m^3$$

$$Volume\ of\ Crude = \frac{Mass\ of\ Crude}{862.3\ kg/m^3}$$

For 1.0% pollution, mass of crude oil needed is 1kg of crude in 99kg of soil; therefore, 0.625Kg of soil will need 0.00625 Kg of crude oil, which is equivalent to 7.31cm^3 of crude oil.

With the above calculations, the following values were obtained:

% Pollution	0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2
Volume of Crude (cm^3)	o.o	2.9	5.8	8.7	11.6	14.5	17.4	20.3	23.2

Forty-eight of the soil samples, homogenised with specific amounts of crude oil were then subjected to heat at six different temperatures (105, 110, 125, 130, 140 and 160) ^oC on a regulated hot plate, with continuous stirring during the heating process for uniform heating. The 0.0% pollution served as a control.

All the containers were left to cool to ambient temperature, afterwards, 20 uniform viable cowpea seeds were planted in each container. The seeds were equally spaced from one another, uniformly, in the containers and watered uniformly on daily basis. After 2 days, the best performing seedlings were singled out from all the 59 experimental set-ups and the shoots measured. This continued on daily basis for the next 10 days, at 12pm daily.

Considering effectiveness of the remediation at 105^{o}C, the comparisons of the rates of germination in the thermoremediated soil and the non-thermo remediated soil were done at this temperature, using the formula:

$$Rg = \left(\frac{Fo - Fp}{Fp}\right) * 100\%$$

Rg = % reduction in the rate of germination

Fo = Final Reading of 0% pollution

Fp = Final Reading of polluted soil/ thermoremediated soil.

RESULTS AND DISCUSSION

The shoot lengths of the measured seedlings for the thermo-remediated, the non-thermoremediated, and the control, for all the 11 days are as stated in **Table 1-3.** The results show that there is an inverse relationship between the quantities of crude oil and the germination rate of cowpea**. Figure 1** shows the growth with respect to time. The greater the dose or quantity of crude oil in the soil, the lesser the rate of growth. This finding is similar to the work done by Amakiri and Onofeghara[2].

Table -1: Lengths of Cowpea Shoot in Centimeters for 0.4-1.6 % Crude oil Pollution after Themoremediation

% CRUDE OIL	0.4						0.8						1.2						1.6					
TEMP(^{o}C)	105	110	125	130	140	160	105	110	125	130	140	160	105	110	125	130	140	160	105	110	125	130	140	160
DAY1	7.7	7.5	7.4	7.2	7.0	6.6	6.4	6.2	5.6	5.2	4.8	4.6	6.2	6.0	5.8	5.2	5.0	4.1	5.6	5.3	5.0	4.8	4.4	4.2
DAY2	12.9	12.5	12.2	12.0	11.8	11.8	9.7	9.5	8.0	7.5	4.8	4.6	8.6	8.4	7.5	7.2	6.7	6.1	7.6	7.1	6.6	6.0	5.4	5.2
DAY3	17.0	16.7	16.5	16.5	16.0	15.7	13.5	11.9	11.4	10.1	9.6	8.4	10.7	9.5	8.8	8.5	7.0	6.6	9.6	9.5	8.7	8.3	7.0	6.8
DAY4	21.1	20.0	18.8	18.8	18.2	18.0	15.3	14.0	13.6	13.1	12.6	11.0	13.4	12.8	10.4	10.0	9.2	8.1	12.8	12.7	9.8	9.3	8.2	8.0
DAY5	22.1	21.8	21.5	21.5	21.2	21.0	17.0	16.6	15.8	15.6	13.7	13.0	15.0	14.6	13.0	12.8	12.2	10.2	14.9	13.9	10.1	10.0	9.7	9.2
DAY6	22.9	22.5	19.8	19.8	19.3	19.0	19.4	19.1	18.8	17.4	15.4	15.1	17.4	17.2	15.8	14.3	14.0	12.9	15.7	15.0	13.9	13.4	13.0	12.4
DAY7	23.2	23.0	21.5	21.5	21.2	20.4	20.1	20.0	19.6	18.8	17.5	16.8	18.5	18.3	17.5	17.0	16.2	14.0	16.4	16.4	14.6	14.4	14.1	13.3
DAY8	23.0	21.9	19.5	21.4	19.5	19.3	21.9	22.6	22.1	21.8	21.4	19.1	19.6	19.0	18.5	18.2	17.1	15.0	17.8	17.3	15.8	15.3	14.1	14.0
DAY9	24.7	23.3	21.8	22.2	21.8	21.5	22.8	22.6	22.1	21.8	21.4	19.1	20.9	20.6	20.1	20.0	19.1	17.0	18.9	18.5	18.0	17.6	15.8	15.0
DAY10	25.9	24.7	22.0	22.3	22.0	21.8	23.0	22.7	22.4	22.0	21.8	20.0	21.3	21.0	21.0	20.6	20.2	19.6	19.9	19.3	19.0	18.7	17.1	16.5
DAY11	27.4	26.0	23.7	24.6	23.7	22.6	25.1	24.4	24.0	23.7	23.2	21.1	24.1	22.4	22.1	21.7	21.1	20.1	22.5	20.0	20.0	19.7	18.2	18.0

Table 2: Lengths of Cowpea Shoot in Centimeters for 2.0-3.2 % Crude oil Pollution after Themoremediation

% CRUDE OIL	2.0						2.4						2.8						3.2					
TEMP(oC)	105	110	125	130	140	160	105	110	125	130	140	160	105	110	125	130	140	160	105	110	125	130	140	160
DAY1	5.2	5.0	4.9	4.5	4.4	4.0	5.0	4.8	4.2	4.2	4.0	3.9	4.3	4.0	4.0	5.0	4.1	4.3	4.2	4.0	4.1	3.9	3.6	3.4
DAY2	7.0	6.7	6.4	6.2	5.0	4.6	6.4	5.7	5.3	5.0	4.7	4.0	5.9	4.4	4.6	4.7	3.6	3.0	5.7	5.4	5.3	4.3	4.1	4.0
DAY3	8.6	8.3	8.0	7.3	6.6	5.3	6.9	6.7	6.3	6.0	5.6	5.0	6.8	6.6	6.0	5.6	3.0	2.4	6.6	6.1	6.0	5.5	5.0	5.0
DAY4	11.3	11.3	10.6	10.2	8.3	7.0	7.3	7.0	7.0	7.1	7.0	6.8	8.8	8.0	6.3	7.7	4.6	3.7	8.8	7.7	7.1	7.0	6.7	6.1
DAY5	12.7	12.4	11.7	11.5	10.4	9.6	10.3	8.4	8.0	8.0	7.6	7.0	11.2	11.7	8.6	8.0	7.3	5.0	11.2	10.3	9.1	8.3	7.0	6.3
DAY6	14.0	13.7	12.8	12.4	11.5	10.1	13.0	12.2	12.0	9.3	9.0	8.6	13.2	12.6	10.5	9.6	8.1	6.6	13.2	11.7	10.1	9.6	7.8	7.3
DAY7	15.5	15.1	13.0	13.0	12.6	11.3	14.6	14.7	14.0	13.6	11.3	10.0	14.7	13.3	11.6	11.2	10.1	7.6	14.7	13.0	13.1	11.9	11.6	10.0
DAY8	16.8	16.3	15.0	14.1	13.2	12.0	16.8	15.9	15.0	14.8	14.3	12.8	15.0	14.7	13.5	13.2	12.3	8.1	15.3	14.3	13.1	11.9	11.6	10.0
DAY9	17.6	17.1	16.0	15.3	14.3	13.2	17.9	17.2	16.8	16.0	15.6	14.0	17.8	16.0	14.0	13.0	12.6	7.8	17.7	15.1	15.0	14.7	13.6	12.3
DAY10	18.7	18.4	17.5	16.7	15.0	14.0	18.0	17.9	17.3	17.0	16.7	15.0	19.0	16.6	14.6	13.3	12.3	9.8	18.3	16.3	16.6	15.7	14.1	13.0
DAY11	20.0	19.3	18.2	17.0	16.1	15.6	19.3	18.3	18.0	17.4	17.1	16.3	19.0	18.5	17.3	16.1	14.0	12.3	18.5	17.1	17.1	16.9	15.3	14.0

Table 3: Shoot Lengths in centimetres of Cowpea in Crude Oil Polluted Soils

CRUDE OIL IN SOIL (%)	0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2
DAY1	7.9	5.9	4.2	3.9	3.4	2.6	2.4	1.9	1.5
DAY2	13.0	8.8	7.6	6.9	6.2	5.4	4.0	2.7	2.3
DAY3	17.3	11.5	10.8	9.8	7.8	5.4	4.8	3.1	2.7
DAY4	21.3	14.8	12.2	11.2	11.2	6.3	5.5	4.2	3.4
DAY5	22.3	15.4	14.2	13.6	12.2	7.2	6.7	6.0	5.0
DAY6	23.1	18.4	16.0	14.8	13.2	9.4	7.8	7.0	5.2
DAY7	23.9	19.6	17.2	16.1	14.0	10.2	10.1	7.2	5.5
DAY8	24.4	20.2	17.7	16.6	14.7	10.9	10.6	7.4	5.7
DAY9	25.6	27.7	18.4	17.15	15.4	11.6	11.4	7.6	5.8
DAY10	27.1	21.3	19.2	17.9	16.2	12.3	12.1	7.8	5.9
DAY11	27.6	21.2	20.1	18.8	16.9	15.2	12.9	8.1	6.1

Table-4: Percentage Reduction in Growth rate of Cowpea in Polluted and Thermo remediated Soils

Concentration of Crude oil in soil (%)	% Reduction in Polluted Soil	% Reduction in Thermoremediated Soil
0.4	23.18841	0.724638
0.8	27.17391	9.057971
1.2	31.88406	12.68116
1.6	38.76812	18.47826
2.0	44.92754	27.53623
2.4	53.26087	30.07246
2.8	70.65217	31.15942
3.2	77.89855	32.97101

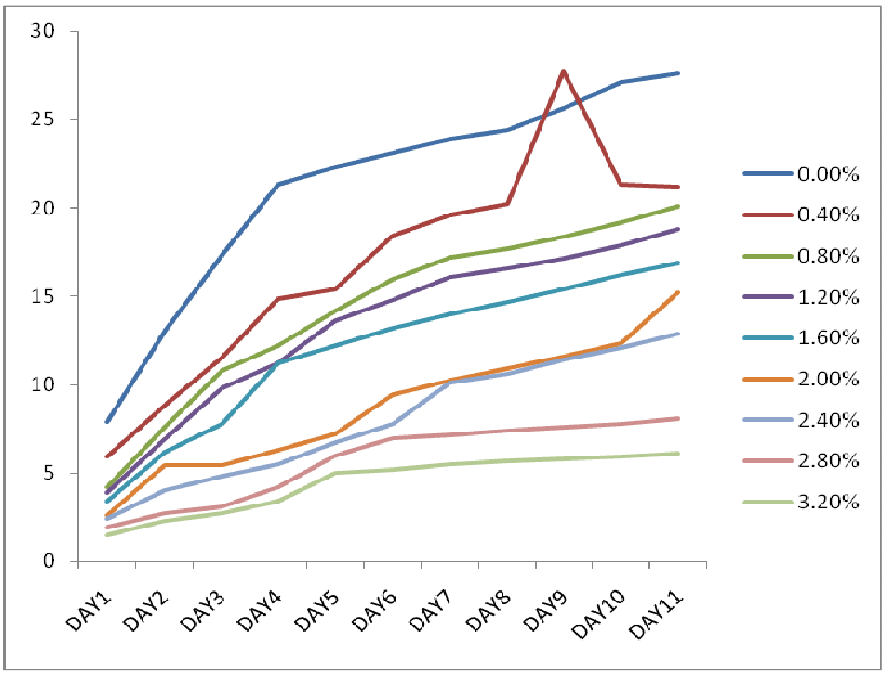

Figure 1. Growth Rate of Cowpea in Polluted and Non-polluted Soils

There was an appreciable improvement in the growth rate of cowpea because of thermoremediation of the polluted soil, within the range of the pollutions worked on. The highest remediation was observed in 3.2% crude oil pollution where the percentage reduction of the growth was improved by about 45%, from 77.90% to 32.97% as illustrated in **Figure 2.**

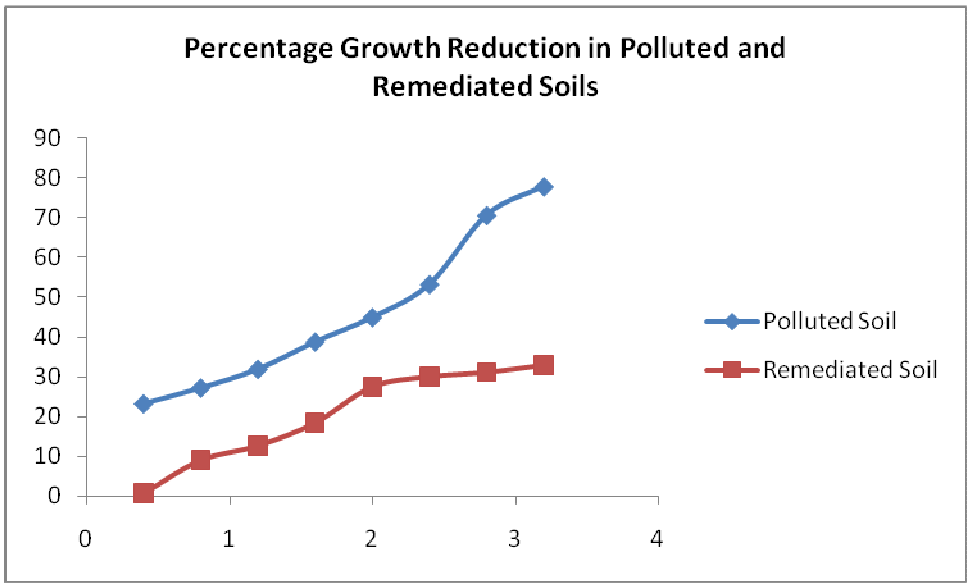

Figure 2. Percentage Growth Reduction in Polluted and Thermoremediated Soils

CONCLUSION

This preliminary study has shown that thermoremediation of crude oil polluted soil has prospects in the remediation of polluted soil especially when high cost and time consumption are challenges.

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Corresponding author: Inengite, A. K.; Department of Chemical Sciences, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria