Phytoremediation of Petroleum Hydrocarbons Using *Jatropha curcas* in Soils Contaminated with Spent Engine Oil

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***Abstract*: Soil contamination with spent engine oil (a petroleum-based product) is a growing concern in many countries, especially in Nigeria. Phytoremediation of soils using a non-edible plant able to grow on tropical soils such as *Jatropha curcas* offers an eco-friendly and cost-effective method of remediating contaminated soils. This study focuses on the Phytoremediation of Petroleum Hydrocarbons in soils contaminated with 0.25, 0.5 and 0.75% (w/w) Spent Engine Oil using *Jatropha curcas*for a period of 80 days. The physiochemical parameters of the soil samples were analyzed. Thereafter the seeds were planted and grown in 2kg of contaminated soils amended with poultry droppings under field conditions including the control samples. The hydrocarbon loss in soils were periodically assessed at 20 days interval for a duration of 80 days. Results showed that the physiochemical parameters of soil samples were significantly impacted due to contamination with Spent Engine Oil. Furthermore, the percentage degradation of Total Petroleum Hydrocarbons (TPH) was higher (52%)insoil samples amended withpoultry droppings compared to the non-amended soils (45%). The Translocation factor (TF) of *Jatropha curcas* was greater than one. This suggests that *Jatropha curcas* is suitable for the Phytoremediation of Petroleum Hydrocarbons in soils contaminated with Spent Engine Oil at 0.25,0.5 and 0.75% contamination levels and organic amendments enhanced the phytoremediation potential of *Jatropha curcas*.**

***Key words*: Phytoremediation, Spent Engine Oil, *Jatropha curcas*. Petroleum Hydrocarbons, Soil.**

I. INTRODUCTION

The soil is a very important natural resource that is used for agricultural purposes, building and infrastructural development. It harbors various ecosystems such as forest reserves, wetlands, vegetative areas with shrubs and grasses and a bed for various water bodies. It also serves as a habitat for various organisms, a reservoir for underground water and a major component of various biogeochemical cycles.

Petroleum products is one of the major sources of soil contamination, however,Spent Engine Oil contamination is a common phenomenon in major cities across the globe which could pose as a very significant threat to our soils (Dadrasnia and Agamuthu, 2016).Spent engine oil gets into the environment through discharge by motor and generator mechanics (Onwusiri*et al*., 2017), from car exhaust systems during engine use, engine leakages and due to indiscriminate disposal into drainage systems by users (Maduka, 2014 and Onwusiri*et al*., 2017). Since it is liquid, it easily leaches into the environment and eventually pollutes either water or soil (Onwusiri*et al*., 2017).

Phytoremediation Technology

Phytoremediation is an emerging technology that has recently being favored as a good option for the remediation of petroleum hydrocarbons compared to physiochemical methods such as land fill, cap and contain incineration, ozonation and surfactant washing . Its techniques employs the use of various plants to degrade, extract, contain or immobilize contaminants from soil and water (Agmuthu*et al*., 2010 and Waziri *et al*., 2016) .

Jatropha curcas L. is a perennial shrub/small tree belonging to the *Euphorbiaceae* family, a native of Central America and is now common in tropical and subtropical regions of the world such as India, Africa and North America. It has the ability to grow on tropical soils. Its hardiness and the fact that it is a non-edible plant make it a suitable option for the phytoremediation of polluted soils (Agmuthu*et al*., 2010; Balasubramaniyam, 2015; Waziri *et al*., 2016).

The aim of this study was to assess the phytoremediation potential of *Jatropha curcas* in soils contaminated with spent engine oil.

Objectives

i. To assess the physiochemical and heavy metal parameters of soil samples.
ii. To plant *Jatropha curcas* seeds in poultry droppings amended and un-amended soil samples.
iii. To determine the percentage degradation of total petroleum hydrocarbons in soil samples.
iv. To determine the phytoremediation suitability of *Jatropha curcas* by calculating the translocation factor (TF).

II. MATERIALS AND METHODS

Sample Collection

Soil samples were collected at random points from an open farm land adjacent TividOrphanage Home, Northbank, Makurdi using a metal auger at about 0cm- 15cm depths (Luter*et al.,* 2011).The geographical coordinates are latitude

N 07° 45′ 11.088″ of the equator, longitude E 08° 32′ 46.8″ and an altitude of 103.0m of the meridian.

Spent Engine Oil was obtained as pooled used engine oil from vehicles, at an auto-mechanic workshop beside AYM shafa filling station and poultry droppings were collected from a local poultry farm in Northbank.*Jatropha curcas* seeds were collected from Sam Agro Global Services and a local selling outlet at yangev village, behind Modern Market, Makurdi.

Physiochemical and Heavy Metal Parameters

Soil pH was determined in a soil/water (1:1 ratio) suspension method using a glass electrode (Maduka,2014 and Omoni*et al*,2015). Organic Carbon was determined by Walkley-Black(1934) method of wet oxidation using chromic acid as adapted by Nanda and Abraham(2011). Total nitrogen was determined using Micro-kheldal digestion and distillation technique (Maduka,2014 and Omoni*et al*,2015).

Available Phosphoruswas determined using Bray-1 extraction followed by Molebdenum blue colorimetric technique by Maduka(2014) and Onwu*et al*. (2018). Calcium (Ca) and Magnesium (Mg)concentrations were determined by titration methods as described by (Nwite and Alu, 2015). Sodium (Na) and potassium (K) were extracted with 1N ammonium acetate solution (NH_4OAC), and determined using flame photometer (Nwite and Alu, 2015).

Effective cation exchange capacity was calculated by the sum of exchangeable bases (Ca, Mg, K,Na) and exchangeable Al and H expressed in cmol/kg.

Organic matter content of the soil was determined by the weight loss on ignition in a muffle furnace at 500°C for1hour (Awhange*et al*., 2012). Organic matter content of the soil was determined by the weight loss on ignition in a muffle furnace at 500°C for1hour (Awhange*et al*., 2012).Heavy metals in soil samples were determined using Atomic Absorption Spectrophotometer, Perkin-Elmer Model 403.

Soil Preparation

Soil samples were air-dried (for seven days), pulverized and filtered through a 2mm mesh sieve (Luter*et al*., 2011 and Omoni*et al*., 2015). Two kilograms each were then weighed into separate plastic buckets (20cm by 30cm) and treated with 5ml, 10ml, and 15ml of spent oil to obtain 0.25, 0.5, and 0.75% contamination levels respectively. Poultry droppings (25g) were added to treatments that were to be amended and thoroughly mixed. Three (3) viable *Jatropha curcas* seeds were planted in each bucket (including the control samples) laid out in the field and were moderately watered every 2 days with tap water to prevent leaching from the plastic buckets. The design of theexperiment is as shown in Figure 1 below.

Fig.1: Details of the Experimental Design

Sample	Details of the sample	Status
A	Soil (2kg) +P.D (25g)+SEO (5ml) +*Jatropha* seeds	Treatment
B	Soil (2kg) +P.D (25g)+SEO (10ml) +*Jatropha* seeds	Treatment
C	Soil (2kg) +P.D (25g)+SEO (15ml) +*Jatropha* seeds	Treatment
D	Soil (2kg) + SEO (5ml) +*Jatropha* seeds	Treatment
E	Soil (2kg) + SEO (10ml) +*Jatropha* seeds	Treatment
F	Soil (2kg) + SEO (15ml) +*Jatropha* seeds	Treatment
G	Soil (2kg) +P.D (25g)+*Jatropha* seeds	Control
H	Soil (2kg) +*Jatropha* seeds	Control

Key: SEO (Spent Engine Oil), P.D(Poultry Droppings).

Periodic Sampling

Soil samples were taken within the rhizosphere zone of *Jatrophacurcas* from each plastic buckets every 20 days for Total Petroleum Hydrocarbon (TPH) analysis, pH, and temperature. Total Aerobic Heterotrophic Bacteria (TAHB) enumeration was also carried out.

Determination of Total Petroleum Hydrocarbon (TPH) in Soil Samples

Spectrophometric procedures (a modified version of the U.S Environmental Protection Agency) outlined by Adesodun and Mbagwu (2008) was used to determine the initial and final concentrations of TPH in soil samples and plant parts. The percentage degradation of TPH in soil samples was calculated using Ogu and Odo (2015). The equation is as follows;

$$\%\ Degradation = \frac{T_i - T_f}{T_i} \times 100$$

Where; Ti = Initial concentration of TPH in soil.

T_f = Final concentration of TPH in soil.

%Degradation = percentage degradation.

(VI) *Enumeration of Total Aerobic Heterotrophic Bacteria (TAHB)*

Soil samples from the rhizosphere of oil Amended and Non-amended soils were taken at the end of the study for the enumeration of Total Aerobic Heterotrophic Bacteria (TAHB) using methods described by Agamuthu*et al*. (2013).

Determination of the Phytoremediation Potential of Jatropha curcas

In order to determine the phytoremediation potential of *Jatropha curcas*plant in soils contaminated with petroleum hydrocarbons, the Translocation Factor was deduced as follows;

$$TF = \frac{C_{arial\ parts}}{C_{roots}}$$

Where;

TF= Translocation Factor.

$\mathbf{C_{root}}$=Concentration (mg/kg) in roots.

$\mathbf{C_{arialparts}}$=Concentration (mg/kg) in shoots or leaves.

III. STATISTICAL ANALYSIS

Data was collected and recorded.The means of five replicates per sample was subjected to one-way Analysis of Variance (ANOVA) with Statistical Package for Social Sciences (SPSS) version 20.0 at 95% or 0.05 P-value.

IV. RESULTS AND DISCUSSION

Physiochemical and Heavy Metal Parameters of Soil Samples

From the results, soil pH, Total Nitrogen, Potassium and %sand significantly decreased ($P \leq 0.05$) by 3%, 68%, 7% and 3% respectively while organic carbon(O.C), organic matter(O.M), available phosphate, exchangeable bases(EB), Cation Exchange Capacity(CEC), %Silt and %Clay significantly ($P \leq 0.05$) increased by 200%, 200%, 2%, 2%, 1%, 9% and 6% respectively after contamination with spent engine oil (*see appendix I*). This agrees with the findings of Marinescu*et al.* (2010), Agbogidi and Enujeke (2012), Nwite and Alu(2015) and Onwusiri*et al.* (2017).

On the contrary, Okonokhua*et al.* (2007) documented that SEO had no effect on both the pH of the soil but Organic Carbon and Total Nitrogen in the contaminated soils increased compared to the control while phosphate decreased due to contamination with spent engine oil.

Results also showed that there was a significant increase in the concentrations of heavy metals after contaminating soil samples with spent engine oil. For instance, Copper (Cu) increased from 0.21 - 2.01mg/kg, Lead (Pb) from 1.2 - 3.5mg/kg and Iron (Fe) from 0.03 - 1.5mg/kg (*see appendix II*). This agrees with the findings of Uchendu and Ogwo (2014) and Nwite and Alu (2015).

More so, Agbogidi and Egbuchua (2010) and Agbogidi and Enujeke (2012) both submitted to the opinion that oil in soil has deleterious effects on the Heavy metal, chemical and physical properties of the soil depending on the dose and type of the oil. These factors (type and dosage of oil) may have attributed to the significant increase in the above mentioned properties of soil samples used in this study.

Concentrations (mg/kg) of Total Petroleum Hydrocarbon (TPH)and Percentage Degradation in soil samples from 0-80 days

Results from Table 4 below showed that TPH concentrations in soil samples decreased as the number of days increased. This supports the findings of Agamuthu*et al.* (2010) with records of TPH percentage loss in soils from11% - 89% and 14% - 96% in all treatments within 180 days.

Results also showed that the percentage degradation of TPH reduced with increase in Spent Engine Oil contamination levels. For instance, 56%, 51% and 48% were recorded in soils contaminated with 5ml, 10ml and 15ml spent engine oil per two kilograms of soils in Treatments A – C respectively. Similarly, 46% and 31% were recorded in treatments D and E except F (59%).

Furthermore, the percentage degradation of TPH in soils amended with poultry droppings was higher (52%) compared to non-amended soils (45%). This might be due to the fact that poultry droppings are biostimulants which contain appreciable amounts of hydrocarbon utilizers readily available to degrade, eliminate or transform TPH and allow growth of the plants (Umanu and Babade, 2013).

This is similar to the findings of Maduka (2014) with reports that 68% and 12% TPH degradation were recordedin soil samples amended with poultry droppings and non-amended soils respectively using *Hibiscus cannabinus L.* plant. Agamuthu*et al.* (2010) reported 89.6% and 96.6% in soils contaminated with 2.5% and 1% oil, respectively after amendments with Banana skin (BS) and brewery spent grain (BSG) for about 180 days. ZHUO *et al.* (2011) also opined that the application of soil amendment appears to be a valuable option for the phytoremediation of Petroleum Hydrocarbons contaminated soil because it enables great vegetative coverage and increases the rate of Petroleum Hydrocarbons removal in soil. This suggests that organic amendments enhanced the phytoremediation potential of *Jatropha curcas*.

There was no death of *Jatropha curcas* plants recorded in all the treatments, however soil samples amended with poultry droppings had greenish broad leaves and increased stem height and number of leaves compared to non-amended soils (see appendix IV & V). The control samples showed no symptoms to phyto-toxcity.

V. CONCLUSION

Soil contamination with spent engine oil (a petroleum-based product) is a growing concern in many countries. This may lead to a global environmental threat. However, Phytoremediation is an emerging and promising technology that will be useful in mitigating these effects. Findings from this study could serve as a building block for other researchers and a contributing factor to governments and other experts in the field geared towards the restoration of soil quality and reclamation of degraded lands lost to oil pollution in our society today.

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APPENDICES

APPENDIX I

Table 2: Physio-chemical properties of soil samples prior to and after contamination

S/num.	Parameter	Before contamination	after contamination	Variance
1	pH	6.24	6.02	0.0242
2	OC (%)	0.49	1.58	0.59405
3	OM (%)	0.85	2.72	1.74845
4	TN (%)	0.44	0.14	0.045
5	P(Mg/L)	4.7	4.8	0.005
6	K(g/kg)	0.28	0.26	0.0002
7	E B(cmol/kg)	6.54	6.73	0.01805
8	CEC(cmol/kg)	7.64	7.72	0.0032
9	Silt (%)	11.0	12.0	0.5
10	Sand (%)	73.8	71.8	2.0
11	Clay (%)	15.2	16.2	0.5

Key: pH, O.C (Organic Carbon), O.M (Organic Matte), T.N (Total Nitrogen),

P(Phosphate), K (Potassium), EB (Exchangeable bases) and CEC (Cation Exchange Capacity). ($P \leq 0.05$)

APPENDIX II

Table 3: Mean Concentrations (g/kg) of Lead (Pb), Zinc (Zn), Copper (Cu) and Iron (Fe) in soil samples before and after contamination

S/num.	Heavy metal	Before Contamination M/SD	after contamination M/SD
1	Pb(g/kg)	1.20±0.10	3.5±0.20
2	Fe(g/kg)	0.03±0.01	1.5±0.07
3	Cu(g/kg)	0.21±0.10	2.01±0.10
4	Zn(g/kg)	0.03±0.01	0.03±0.01

Key: Lead (Pb), Iron (Fe), Copper (Cu) and Zinc (Zn).M/SD=Mean/Standard deviation. ($P \leq 0.05$)

APPENDIX III

Table 4: Total Petroleum Hydrocarbon Concentration (mg/kg) in soil samples and Percentage Degradation from 0-80 days

			Days			Perc. Deg.
Treatment	0	20	40	60	80	
A	2.08	1.20	0.98	1.10	0.91	56%
B	2.10	1.52	1.23	1.14	1.02	51%
C	2.11	1.80	1.54	1.36	1.10	48%
D	2.04	1.41	1.27	1.24	1.11	46%
E	2.40	1.50	1.36	1.28	1.66	31%
F	3.01	1.82	1.64	1.48	1.24	59%
G	0.05	0.03	0.02	0.01	0.01	80%
H	0.05	0.03	0.02	0.01	0.01	80%

Key: Deg. Perc.(Degradation Percentage). ($P \leq 0.05$)

APPENDIX IV

Figure 1: Sample of *Jatropha curcas* in soils amended with poultry droppings. Plant has dark- green broad leaves

APPENDIX V

Figure 2: Sample of *Jatropha curcas* in soils without poultry droppings.