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**PHYTODEGRADATION OF PETROLEUM HYDROCARBON CONTAMINATED SOIL USING CARPET GRASS (*AXONOPUS FISSIFOLIUS*)**

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**Abstract**

Environmental pollution with petroleum and petrochemical products has been recognized as one of the most important serious current problem. Phytoremediation is an effective treatment in terms of efficacy, cost effective, environmentally friendly on long term use, simplicity of administration. The aim of this research was to study the effectiveness of Carpet grass (*Axonopus fissifolius*) in the remediation of soil contaminated by Total petroleum hydrocarbon (TPH). The result revealed that there are irregular variations in the level of the physiochemical properties of the soil before, during and after the experiment. There was increase in the height of the plants every 10 days for all the plants. Also, a decrease in the values of TPH for all samples considered after the phytodegradation was observed. The relative potential or efficiency (percentage reduction) of the grasses remediating the TPH contaminated soils are in the order 5g> 15g> 25g>35g. Generally, the phytoremediation of the TPH contaminated soil is lower when amended with the cow dung than unamended. Therefore, the study suggests that carpet grass (with average of 76% percentage reduction) is having a high efficient in the degradation of TPH polluted soil.

**Keywords:** *Phytodegradation, Carpet Grass, Petroleum Hydrocarbon, Soil*

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**Introduction**

The quality of life on Earth is linked inextricably to the overall quality of the environment. It is very difficult to define soil quality, as soil composition can vary from place to place. Soil quality is concerned with more than the soil's constituents and composition, but how it functions in a specific environment (Garba *et al.*, 2016). There has been an increasing concern with regard to the accumulation of toxic contaminants in the environment and their impact on both public health and the natural environment (Gardea-Torresdey *et al.*, 2004). Soil contamination has become a global phenomenon. Soil in many parts of the world has been contaminated by chemicals and contaminants due to

industrial and agricultural activities, and unregulated waste disposal. In the Europe alone, 2.5 million sites were identified as potentially contaminated with an estimated 342000 sites actually contaminated (Panagos *et al.*, 2013). A large proportion of chemical-contaminated soil is attributed to environmental release of petroleum products particularly crude oil (Liao *et al.*, 2016). Global intensification of oil and gas activities comprising exploration, drilling, production, onshore storage and transportation of petroleum have increased the risk of spillage and leakage of crude oil into the environment (Njoku *et al.*, 2008). Crude oil is a complex mixture of hydrocarbon and organic compounds,

some of which, such as benzene and polyaromatic hydrocarbons are known to pose environmental and health hazards (Ebadi *et al.*, 2018). Soil contaminated by crude oil could render it unsafe for habitation and agricultural activities due to potential human exposure to the harmful compounds of crude oil and bio-accumulation of the compounds in agricultural products (Hegazy *et al.*, 2015). Conventional method of remediating soil contaminated by crude oil involves excavation of the soil followed by subsequent chemical or physical treatments (Juck *et al.*, 2000). Chemical treatment utilizes strong oxidants which alter soil properties and are often pH-dependent. Physical treatment applies heat which converts crude oil-related contaminants to simpler compounds but the compounds could still be harmful (Rulkens *et al.*, 1998). Gaseous compounds from heat treatment may require further treatment prior to environmental release. In addition to the effect on soil properties, health and environment, in-situ excavation of soil is also cost and labour intensive (Juck *et al.*, 2000). Besides, in-situ treatment of soil using techniques such as in-situ extraction, soil vapour extraction, air sparging and stabilization can be employed. However, these methods require extensive site characterization to be effective, are complicated and could be costly (Rulkens *et al.*, 1998).

Phytoremediation provides a cost-effective alternative to soil remediation by expediting removal of contaminants from soil via physiological processes of plant and microbial activities at the roots of plant (Cunningham *et al.*, 1996). The use of local

plant species in phytoremediation is preferred as local plant species adapt well to local climate and soil conditions, thus, having higher probability of success in growing and propagating on contaminated soil (Anh *et al.*, 2017). Some plants can render harmless, extract or stabilize a contaminant in soil, thus making it unavailable for other organisms and reducing environmental hazards in a process termed phytoremediation (Cunningham *et al.*, 1996). Phytoremediation involves the use of plants to clean up accumulated Petroleum hydrocarbon in the soil (Njoku *et al.*, 2016) as reported in numerous studies (Zand *et al.*, 2016). These include grasses, vegetables, legumes, cultivated crops ornamentals and some woody plants (Atangana *et al.*, 2014). Current phytoremediation techniques require that plants live in the zone of contamination. Consequently, plants viability is a critical issue in the successful application of phytoremediation. If the contaminant in its present concentration is not phytotoxic, cultivation of plants can be a valuable tool in soil remediation (Merkl *et al.*, 2004). The mechanisms and efficiency of this technology called phytoremediation depend on the contaminant, bioavailability and soil properties (Cunningham and Ow, 1996). The mechanism believed to be responsible for most of the degradation of petroleum hydrocarbons in vegetated soil is the stimulation of growth and activity of degrading micro-organisms in the rhizosphere (Frick *et al.*, 1999). There are several approaches to selecting candidate plants for phytoremediation of soils contaminated with organic pollutants. These approaches have been based on the

occurrence of plants under specific climatic conditions (Banks *et al.*, 2003) their resistance to pollutant phytotoxicity (Kirk *et al.*, 2005), the presence of phenolic compounds in the plant root exudates (Schwab *et al.*, 2006), or their capability to reduce the pollutant concentration in soil. Most studies on the phytoremediation of petroleum hydrocarbon contaminated soils have employed grasses, vegetables, legumes, cultivated crops, ornamentals and some woody plants (Atangana *et al.*, 2014). Grasses are considered to be particularly suitable for phytoremediation since they offer an increased rhizosphere zone because of their multiple ramified root systems. This gives room for more microbial activity and growth around the root zone (Aprill and Sims, 1990). Researchers like, Adam and Duncan (1999), (Merkl *et al.* 2004, 2005) have concluded that grasses and legumes are the best candidates for the process of phytoremediation or rhizoremediation because of their root systems. Bioremediation is generally considered a promising technology for the tropics because climatic conditions favour microbial growth and activity (Merkl *et al.*, 2004). Grasses like *Panicum maximum* and *Brachiara brizantha* were able to degrade 55 and 63% of oil and grease present in the contaminated soils in the tropics. The screening of plant species for their ability to grow and establish in contaminated soil is one of the first steps in the selection of species for phytoremediation in the tropics, followed by the evaluation of their influence on the degradation of petroleum hydrocarbons in soil (Merkl *et al.*, 2004). However little is known about tropical species that could serve for the cleanup of

oil contamination. A successful phytoremediation requires the plants not only to survive the contamination, but to also grow and thrive. More importantly, the reclaimed site should have a sufficient diversity and composition similar to the plant species prior to the contamination in a given location to maintain the ecological functions, such as erosion control, water conservation, and wildlife habitat. Plant species that have good seed germination do not always tolerate drill cuttings or crude oil at seedling or mature stages. Furthermore, different species may have varying ability to reduce hydrocarbons in soil.

Phytodegradation is the uptake, metabolizing, and degradation of contaminants within the plant, or the degradation of contaminants in the soil, sediments, sludges, ground water, or surface water by enzymes produced and released by the plant. Phytodegradation is not dependent on microorganisms associated with the rhizosphere. Contaminants subject to phytodegradation include organic compounds such as munitions, chlorinated solvents, herbicides, and insecticides, and inorganic nutrients. Phytodegradation is also known as phytotransformation, and is a contaminant destruction process. For phytodegradation to occur within the plant, the plant must be able to take up the compound. Uptake of contaminants requires that they have a moderate log *K<sub>ow</sub>*, and laboratory experiments at the University of Washington indicated that short chain halogenated aliphatic compounds could be taken up by plants (Newman *et al.*, 1998). Plants can metabolize a variety of organic

compounds, including TCE (Newman *et al.*, 1997), trinitrotoluene (TNT) and the herbicide atrazine). Partial metabolism by wheat and soybean plant cell cultures was found for a variety of compounds, including 2,4-dichlorophenoxyacetic acid (2,4-D); 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), 4-chloroaniline; 3,4-dichloroaniline; PCP; diethylhexylphthalate (DEHP); perylene; benzo(a)pyrene; hexachlorobenzene; DDT; and PCBs. In phytodegradation applications, transformation of a contaminant within the plant to a more toxic form, with subsequent release to the atmosphere through transpiration, is undesirable. The formation and release of vinyl chloride resulting from the uptake and phytodegradation of TCE has been a concern. However, although low levels of TCE metabolites have been found in plant tissue (Newman *et al.*, 1997), vinyl chloride has not been reported.

Plant-produced enzymes that metabolize contaminants may be released into the rhizosphere, where they can remain active in contaminant transformation. Plant-formed enzymes have been discovered in plant sediments and soils. These enzymes include dehalogenase, nitroreductase, peroxidase, laccase, and nitrilase (Schnoor *et al.*, 2000). These enzymes are associated with transformations of chlorinated compounds, munitions, phenols, the oxidative step in munitions, and herbicides, respectively. In one week, the dissolved TNT concentrations in flooded soil decreased from 128 ppm to 10 ppm in the presence of the aquatic plant parrot feather (*Myriophyllum aquaticum*), which produces nitroreductase enzyme that can partially degrade TNT (Schnoor *et al.*,

2000). The nitroreductase enzyme has also been identified in a variety of algae, aquatic plants, and trees (Schnoor *et al.*, 2000). Hybrid poplar trees metabolized TNT to 4-amino-2,6-dinitrotoluene (4-ADNT), 2-amino-4,6-dinitrotoluene (2-ADNT), and other unidentified compounds in laboratory hydroponic and soil experiments.

Carpet grass (*Axonopus fissifolius* (Raddi) Kuhl.) is a rhizomatous, stoloniferous perennial pasture grass. It forms dense mats that are 15-30 cm high but the flowering culms may reach 60-75 cm. This shallow-rooted species (almost 90% of the roots are at a depth of 0-5 cm) develops short rhizomes and stout stolons with short internodes. The general habit is erect and branching. The stems root at the nodes (FAO, 2012). Carpet grass is a summer-growing perennial plant believed to have originated from the Southern USA, the West Indies or Central America (FAO, 2012). It is now found in many tropical and subtropical regions of America, Africa, Asia and the Pacific Islands (FAO, 2012). It generally grows in low, flat or hilly humid and sub-humid areas of warm temperate or tropical woodland and savannahs (FAO, 2012; Cook *et al.*, 2005). It can be vegetatively propagated through runners or sown, as it seeds easily (FAO, 2012; Cook *et al.*, 2005; Smith *et al.*, 2002).

The objectives of this study is to determine the potential of the grass (*Axonopus Fissifolius*) in remediating petroleum hydrocarbon contaminated soil.

## **Material and Methods**

### *Sample Collection*

Soil samples were collected as composite topsoil samples at a depth of 0–20 cm from University of Maiduguri football pitch. The samples were air-dried and sieved to remove debris. Petroleum hydrocarbon (crude oil) was obtained (purchased) from Kaduna refinery, Kaduna state. Seeds of the grass plants, Carpet grass (*Axonopus fissifolius*) species were purchased from Monday market, in Maiduguri, Borno state. Samples collected were labelled with unique identification numbers.

### *Laboratory Experimental Design*

Four groups of experimental pots were prepared. Each group had four sets of replicates experimental pots for statistical analysis. A control experimental pot was also being prepared. An experimental pot in each group contained 2.5 kg of soil, contaminated (mixed) with; 5, 15, 25 and 35 g/Kg of the crude oil obtained. Another set of the experiment amended with constant 75.0g of cow dung were prepared. This is to catalyze the growth and efficiency of the grass plants. All the mixing was done with small quantity of water and were allowed to stand for seventy-two hours before sowing/planting the grasses. Equal number of viable seeds of the grasses were seeded into the pots including the control (Uwazie *et al.*, 2020). Experiments were exposed to natural day light and temperature. The pots were watered sufficiently to maintain a constant moisture and to minimize the generation of leachate. Polyvinyl chloride (PVC) pans were placed under each pot to collect leachate in case of spillage. Collected leached water were included in the next watering to avoid petroleum hydrocarbons loss. Monitoring of plant growth were

carried out in every 10 days from the date of planting. This research work was conducted for approximately twelve weeks, during which soil and plant samples were taken to the laboratory for further analytical procedures.

### *Sample Preparation and Analysis*

At the end of the experiment, fresh weights of the shoots and roots of the plants were taken by cutting at the base and the length of the plants were determined. The roots were carefully separated from the soil and rinsed. The partitioned plant parts (shoots and roots) were then oven-dried at 65°C to a constant weight and dry matter yield was determined (Basumatary *et al.*, 2012). After removal of the plants, Physicochemical properties of the soil were determined before, during and after the experiments. 5 g of soil sample from each experimental pot including the control were acidified with Hydrochloric acid (HCl) to pH 2 and dehydrated with Magnesium sulphate (MgSO<sub>4</sub>). Soxhlet extraction with dichloromethane (DCM) was done for about eight hours. The extract obtained was passed through a filter paper (Whatman No.4) with approximately 1 g Sodium sulphate (Na<sub>2</sub>SO<sub>4</sub>), the solvent was then being evaporated and constant weight of the dry extract were determined (USEPA, 1994). The percentage of total petroleum hydrocarbon (TPH) was then calculated based on the soil dry weight (Merkl *et al.*, 2005a). The degradation of TPH was obtained by subtracting the TPH values of different treatment (after) from initial (before) TPH values.

### *Data Handling*

Analysis of variance (ANOVA) using SPSS version 20.0 was used to access whether the concentration of the TPH

varied significantly between treatments. A significant level less than 0.05 ( $p < 0.05$ ) was used throughout the experiment.

## Results and discussion

### Physio-chemical parameters for non-contaminated soil Samples

Table 1 shows summary result of Physio-chemical parameters for non-contaminated soil Samples. The levels of the Physio-chemical parameters decrease with the increase in the soil depth from 0-15 cm to 15-30 cm with the exception of  $K^+$ , N, O.M, C: N, clay and silt.

The result revealed that at depth of 0-15 cm and 15-30 cm, the level of pH are  $6.96a \pm 0.02$  and  $4.10 \pm 0.05$  respectively, the less acidic nature of the soil is generally within the range for soil in the region the values of pH are in line with that of Ruley *et al.*, (2019). A very low Electric Conductivity was observed in the experimental soil ( $0.24 \pm 0.02$  and  $0.05 \pm 0.02$ ), EC does not directly affect plant growth but can be used to indicate the amount of nutrients available for uptake by plants and the salinity levels of soils which can impede growth and microbial activity (USDA, 2011). Also, low calcium concentration  $Ca^{2+}$  ( $9.35 \pm 0.34$  and  $6.5 \pm 0.12$ ) was observed in the soil sample which are lower than the value (9.92) observed by Ruley *et al.*, (2019).

In a similar study by Ruley *et al.*, (2019), the level of CEC (13.84) obtained is within the range of the present study which are  $18.29 \pm 0.06$  and  $9.67 \pm 0.02$  for 0-15 cm and 15-30 cm respectively, CEC measures the ability of soil to allow for mobility of

electron within the soils. The concentration of Magnesium ( $13.24 \pm 0.24$  and  $3.40 \pm 0.02$ ) and potassium ( $6.52 \pm 0.00$  and  $0.20 \pm 0.0$ ) obtained in the present study are higher than that obtained by Ruley *et al.*, (2019) which is 1.25 and 1.96 respectively. Also, the concentration (0.94) of sodium obtained by Ruley *et al.*, (2019) is higher than that obtained in the present study which are  $0.15 \pm 0.04$  and  $0.07 \pm 0.03$ . ECEC are  $23.29 \pm 0.82$  and  $9.97 \pm 0.04$ , Base sat. are  $98.10 \pm 0.56$  and  $96.99 \pm 0.45$ , E.A ( $cmol^{(+)} / kg$ ) are  $0.61 \pm 0.08$  and  $0.3 \pm 0.01$ . The level of nitrogen observed in the present ( $0.77 \pm 0.01$  and  $0.25 \pm 0.01$ ) are higher than that obtained by Ruley *et al.*, (2019) which is (0.27). The level of Organic Carbon observed in the present study are  $0.25 \pm 0.04$  and  $1.0 \pm 0.00$  (%) which are in line with that of Donatus and Akogwu, 2021.

The concentration (mg/kg) of Phosphorous obtained in this study which are  $16.10 \pm 0.29$  and  $15.40 \pm 0.03$ , are in line with the value (15.64) obtained by Ruley *et al.*, (2019).

The percentage of clay obtained in the present study are  $17.3 \pm 0.06$  and  $19.8 \pm 0.02$ , which are very low when compare with that of Ruley *et al.*, (2019) which is (61.9%). Appreciable amount of silt was observed in both samples ( $17.4 \pm 0.02$  and  $25.04 \pm 0.00$ ) which are higher than that obtained by Ruley *et al.*, (2019) which is 14.47% silt improves the soil, resulting in better plant growth. The taxonomic classification of the soil is Sandy-loam.

**Table 1: Physio-chemical parameters for non-contaminated soil Samples**

Depth (cm)	pH	EC	cmol <sup>(+)</sup> /kg soil								Base sat.	%				mg/kg soil	%	Textural class		
			E.A	Ca <sup>2+</sup>	Mg <sup>2+</sup>	K <sup>+</sup>	Na <sup>+</sup>	CEC	ECEC	N		O.C	O.M	C:N	P				Clay	sand
0-15	6.96 ±0.02	0.24 ±0.0	0.61 ±0.0 8	9.35 ±0.3 4	13.2 ±0.2 4	6.52 ±0.0 0	0.15 ±0.0 4	18.2 ±0.0 6	23.2 ±0.8 2	98.1 ±0.5 6	0	0.77 ±0.0 1	0.25 ±0.0 4	0.31 ±0.0 2	2.57 ±0.3 3	16.1 ±0.2 9	17.3 ±0.0 6	65.3 ±0.2 3	17.4 ±0.0 2	Sandy loam
15-30	4.10 ±0.05	0.05 ±0.0	0.30 ±0.0 1	6.50 ±0.1 2	3.40 ±0.0 2	0.20 ±0.0 1	0.07 ±0.0 3	9.67 ±0.0 2	9.97 ±0.4 0	96.9 ±0.4 5	9	0.25 ±0.0 1	1.00 ±0.0 0	1.78 ±0.0 2	4.15 ±0.0 4	15.4 ±0.0 3	19.8 ±0.0 2	55.3 ±0.1 8	25.0 ±0.0 0	Sandy loam

EC=Electrical Connectivity

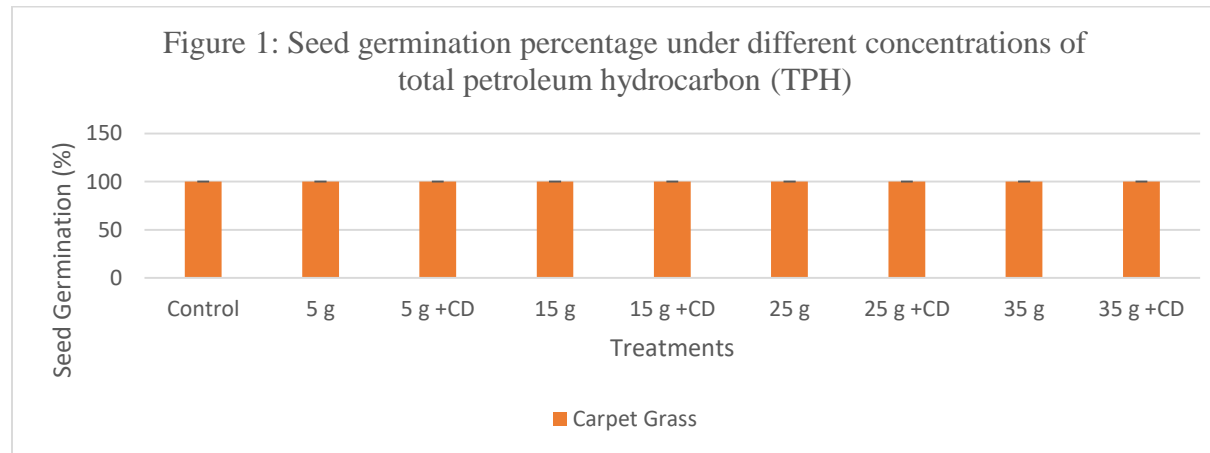
CEC=Cation Exchange Capacity

E. A= Exchangeable Acidity

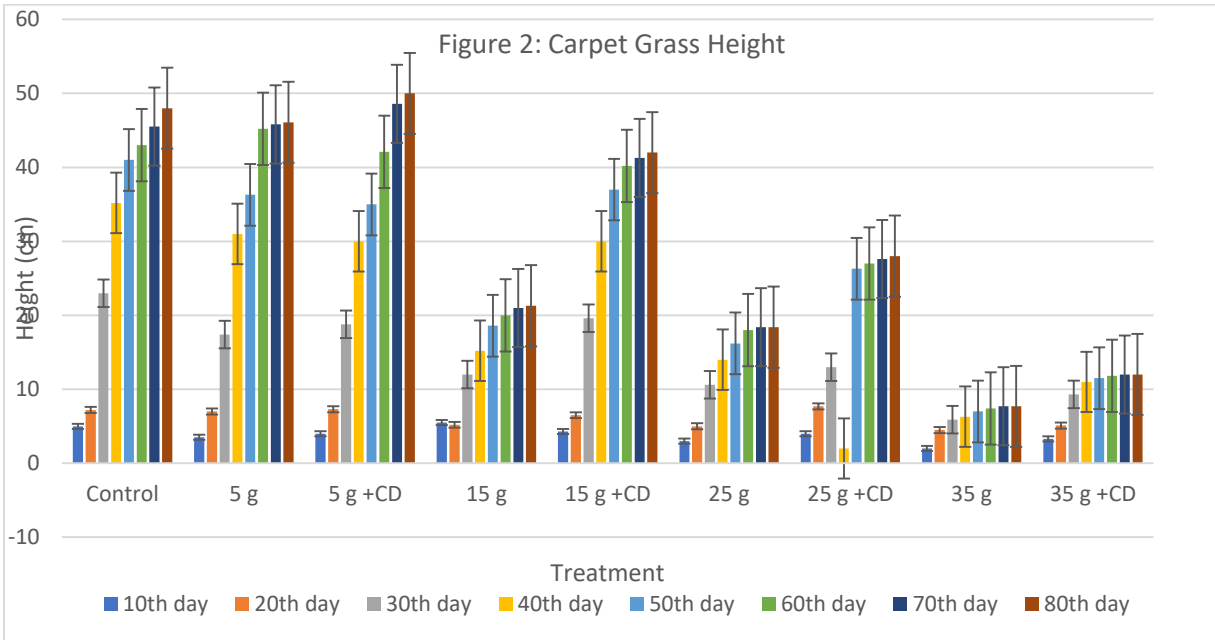
ECEC= Effective Cation Exchange Capacity

O.M= Organic Matter

O.C= Organic Content



CD= Cow Dung



CD= Cow Dung

**Plants growth parameters**

Figure 1 shows the result of the Seed Germination of the *axonopus fissifolius*. The result revealed that all the planted seeds in the different concentrations or treatment of the TPH (including control) germinated. In such a situation, it is eminent that plant germination, and consequently growth, is interfered with. Moreover, aerated and nutrient-rich soils present the potential factors for seed germination and plant growth to occur (Ruley *et al.*, 2019).

Figure 2 shows the result of the Height of the Carpet grass (*axonopus fissifolius*) every ten days for eighty days. The result revealed that there is increase in the height of the plants every ten days for all the plants in each treatment. Generally, there is decrease in the height of the plants has the mass or concentration of the TPH increase

relatively. The highest plant height was observed in the plant treated with 5g of TPH and Cow dung on the 80<sup>th</sup> day followed by the control while the lowest heights was observed in the pots treated with 25g of the TPH on the 10<sup>th</sup> day. It was observed that there was reduction in the height and root length of plants in contaminated samples after as compared to the control sample which corresponds to the findings made by Basumatary *et al.* (2013).

The results of the present study are also in line with that of Ruley *et al.* (2019). According to Ruley *et al.*, (2019), four months after planting, all the plant species displayed a significant decrease in plant height when compared to the control. The plant height response varied with the presence of different concentrations of TPH. The plants in the control treatment

grew taller than in the hydrocarbon-contaminated soil at 25, 50, and 75 g/kg, implying that TPH had an adverse effect. As earlier indicated, plant nutrients, air and water tremendously reduce with increase in the concentration of TPH in the soil. Deficiency in these conditions results in stunted plant growth. Similar results were reported in separate studies by Milala *et al.* (2015) and Umeh *et al.* (2017), who observed that presence of excessive hydrocarbons in a plant environment affects oxygen and nutrient transfer as it covers the roots and pores. It leads to

asphyxiation of sub-surface roots especially in fine-textured (clay) or shallow soils with impervious subsoils. The small fibrous roots are deprived of oxygen leading to their death. In totality, this impairs the root system making it unable to supply the necessary water to replace that transpired by the leaves. This causes a water shortage leading to withering and/or death of plants. Besides height, all plant species in the control treatment exhibited the greatest mean values for destructive pot plant biomass (Ruley et al., 2019).

**Physio-chemical parameters for contaminated soil Samples**

**Table 2: Levels of pH values for contaminated soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	6.94a ±0.01	6.18a ±0.03	6.00a ±0.04	6.99a ±0.02	6.05a ±0.04	6.21a ±0.02	7.00a ±0.04	6.10a ±0.03	5.71a ±0.03	6.93a ±0.06	6.10a ±0.09	5.10a ±0.08
Amended	6.95a ±0.04	6.08a ±0.15	6.59 b ±0.02	6.97a ±0.01	6.51 b ±0.03	6.98b ±0.05	6.95a ±0.05	6.30a ±0.04	6.93b ±0.03	6.92a ±0.02	5.66b ±0.02	6.95b ±0.01
Control	6.68a ±0.45	6.26a ±0.10	5.06c ±0.04	6.68a ±0.45	6.26a ±0.10	5.06c ±0.04	6.68a ±0.45	6.26a ±0.10	5.06c ±0.04	6.68a ±0.45	6.26a ±0.10	5.06a ±0.04

N= 4 replicates. Within the columns, means with different alphabet are statistically different (p<0.05)

**Table 3: Concentration of EC(Dsm<sup>-1</sup>) values for contaminated soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	0.03a ±0.01	0.05a ±0.01	0.14a ±0.02	0.04a ±0.02	0.07a ±0.02	0.30a ±0.33	0.03a ±0.00	0.07ab ±0.01	0.15b ±0.00	0.04a ±0.01	0.05a ±0.02	0.13a ±0.02
Amended	0.05a ±0.00	0.04a ±0.01	0.14a ±0.02	0.12ab ±0.18	0.07a ±0.01	0.40a ±0.16	0.01a ±0.00	0.06a ±0.00	0.24c ±0.01	0.02a ±0.01	0.08a ±0.00	0.14a ±0.01
Control	0.21a ±0.07	0.11b ±0.02	0.14a ±0.00	0.21ab ±0.07	0.11a ±0.02	0.14a ±0.00	0.21b ±0.07	0.11b ±0.02	0.14ab ±0.00	0.21b ±0.07	0.11b ±0.02	0.14a ±0.00

N= 4 replicates. Within the columns, means with different alphabet are statistically different (p<0.05)

**Table 4: Concentration of EA values for polluted soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	0.50a ±0.11	2.67a ±0.40	0.52ab ±0.90	0.32a ±0.17	2.37a ±0.09	0.67a ±0.95	0.17a ±0.05	2.55a ±1.91	0.60a b ±0.08	0.27a ±0.09	2.42a ±0.12	0.60ab ±0.81
Amended	0.42a ±0.09	2.42ab ±0.43	0.42a ±0.09	0.42a ±0.17	2.50a b ±0.21	0.27b ±0.05	0.60b ±0.81	2.07b ±0.09	0.47a ±0.09	0.50b ±0.08	2.22a ±0.10	0.47b ±0.09
Control	0.52a ±0.02	2.91b ±0.16	0.67b ±0.02	0.52a ±0.02	2.91b ±0.16	0.67a ±0.02	0.52b ±0.02	2.91a ±0.16	0.67b ±0.02	0.52b ±0.02	2.91b ±0.16	0.67a ±0.02

N= 4 replicates. Within the columns, means with different alphabet are statistically different ( $p < 0.05$ )

**Table 5: Concentration of Calcium in the soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	2.50a ±0.14	5.12a ±0.09	9.37a ±0.12	3.55a ±0.05	4.35a ±0.23	7.72a ±0.09	2.80a ±0.14	6.32a ±0.12	9.05a ±0.28	1.47a ±0.12	5.40a ±0.36	9.85a ±0.19
Amended	2.27a ±0.09	6.17b ±0.12	10.17b ±0.41	1.52b ±0.09	7.65b ±0.19	12.20a ±0.21	2.75a ±0.19	6.12b ±0.15	8.30b ±0.25	2.20b ±0.16	6.25b ±0.17	10.37b ±0.28
Control	9.26b ±0.17	6.56b ±0.17	11.16c ±0.26	9.26a ±0.17	6.56c ±0.17	11.16a ±0.26	9.26b ±0.17	6.56a ±0.17	11.16c ±0.26	9.26c ±0.17	6.56b ±0.17	11.16c ±0.26

N= 4 replicates. Within the columns, means with different alphabet are statistically different ( $p < 0.05$ )

**Table 6: Concentration of Magnesium in the soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	8.92a ±0.09	6.62a ±0.12	9.10a ±0.08	7.25a ±0.19	6.12a ±0.15	6.98a ±0.01	5.47a ±0.15	3.52a ±0.01	5.99a ±0.01	7.15a ±0.12	6.10a ±0.08	2.98a ±0.01
Amended	7.20b ±0.14	2.80b ±0.14	4.17b ±0.17	13.70b ±0.08	0.27b ±0.12	3.22b ±0.12	6.22b ±0.17	10.22b ±0.17	6.87b ±0.09	3.32b ±0.09	3.57b ±0.20	3.50b ±0.14
Control	13.47c ±0.36	7.89c ±0.26	5.44b ±0.18	13.47b ±0.36	7.89a ±0.26	5.44c ±0.18	13.47c ±0.36	7.89c ±0.26	5.44c ±0.18	13.47c ±0.36	7.89c ±0.26	5.44c ±0.18

N= 4 replicates. Within the columns, means with different alphabet are statistically different ( $p < 0.05$ )

**Table 7: Concentration of Potassium in the soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	0.02a ±0.00	0.76a ±0.01	0.16a ±0.01	7.47e ±0.15	0.72a ±0.00	0.21b ±0.00	0.89b ±0.01	0.82c ±0.00	0.16b ±0.01	2.83b ±0.02	0.74c ±0.00	0.22b ±0.14
Amended	3.58d ±0.00	0.78b ±0.00	0.23b ±0.00	6.42d ±0.09	1.39a ±0.02	0.19a ±0.00	3.46d ±0.00	0.73bc ±0.00	0.12a ±0.01	3.83d ±0.00	0.67abc ±0.00	0.16a ±0.01
Control	0.13b ±0.00	0.65b ±0.05	0.14a ±0.02	0.13a ±0.00	0.65a ±0.05	0.14a ±0.02	0.13a ±0.00	0.65ab ±0.05	0.14ab ±0.02	0.13a ±0.00	0.65ab ±0.05	0.14a ±0.02

N= 4 replicates. Within the columns, means with different alphabet are statistically different ( $p < 0.05$ )

**Table 8: Concentration of Sodium in the soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	0.23a ±0.00	1.38a ±0.00	0.76a ±0.01	0.85a ±0.03	1.30a ±0.03	0.78a ±0.03	0.86a ±0.02	1.99a ±0.02	0.84a ±0.01	0.17a ±0.05	2.39a ±0.11	0.70a ±0.07
Amended	0.31b ±0.04	3.95b ±0.20	0.79a ±0.02	0.78a ±0.05	0.70b ±0.00	0.78a ±0.03	0.29b ±0.03	1.98a ±0.00	0.87a ±0.02	0.32b ±0.09	0.86b ±0.00	0.65a ±0.08
Control	0.11c ± 0.01	0.56c ±0.06	0.76a ±0.02	0.11b ± 0.01	0.56c ±0.06	0.76a ±0.02	0.11c ± 0.01	0.56b ±0.06	0.76b ±0.02	0.11a ± 0.01	0.56c ±0.06	0.76a ±0.02

N= 4 replicates. Within the columns, means with different alphabet are statistically different (p<0.05)

**Table 9: Concentration of CEC in the soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	17.58a ±0.29	14.15a ±0.03	19.54a ±0.08	19.09a ±0.12	12.46a ±0.05	15.75a ±0.07	16.03a ±0.19	12.63a ±0.29	16.23a ±0.26	11.78a ±0.33	15.26a ±0.04	13.92a ±0.17
Amended	13.08b ±0.09	13.68a ±0.26	16.28b ±0.02	22.50 b ±0.07	10.01b ±0.21	16.35ab ±0.05	12.90b ±0.31	18.79b ±0.23	16.86ab ±0.51	9.35b ±0.25	10.80b ±0.27	14.81b ±0.52
Control	23.45c ±0.43	15.74c ±0.34	17.05c ±0.25	23.45c ±0.43	15.74c ±0.34	17.05b ±0.25	23.45c ±0.43	15.74c ±0.34	17.05b ±0.25	23.45c ±0.43	15.74c ±0.34	17.05c ±0.25

N= 4 replicates. Within the columns, means with different alphabet are statistically different (p<0.05)

**Table 10: Concentration of ECEC in the soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	18.10a ±0.21	16.73ab ±0.43	19.97a ±0.07	19.43a ±0.10	14.68a ±0.15	16.33a ±0.17	16.14a ±0.11	15.27a ±0.16	16.76a ±0.16	11.92a ±0.08	17.71a ±0.43	14.69a ±0.21
Amended	13.39b ±0.25	15.72b ±0.40	16.68b ±0.32	23.00b ±0.34	13.02b ±0.27	16.58a ±0.29	13.18b ±0.13	21.07b ±0.21	17.28a ±1.23	9.88b ±0.15	13.36b ±0.09	14.98a ±0.66
Control	22.31c ±1.29	17.76a ±1.16	17.03b ±0.92	22.31b ±1.29	17.76c ±1.16	17.03a ±0.92	22.31c ±1.29	17.76c ±1.16	17.03a ±0.92	22.31c ±1.29	17.76a ±1.16	17.03b ±0.92

N= 4 replicates. Within the columns, means with different alphabet are statistically different (p<0.05)

**Table 11: Levels of Base Saturation in the soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	96.23a ±0.24	82.86a ±0.18	97.26a ±0.21	98.53a ±0.34	83.46a ±0.41	95.49a ±0.64	98.75a ±0.19	82.26a ±0.27	95.96a ±0.22	97.76a ±0.38	85.52a ±0.41	94.87a ±0.46
Amended	96.51b ±1.20	87.26b ±0.18	96.75ab ±0.19	97.52a ±0.100	78.43b ±0.25	97.56b ±0.75	94.80b ±0.45	89.61b ±0.37	78.82a ±43.8	95.15b ±0.21	83.40ab ±0.48	97.19b ±0.34
Control	97.89c ±0.94	82.08a ±1.80	95.69b ±0.39	97.89a ±0.94	82.08a ±1.80	95.69a ±0.39	97.89a ±0.94	82.08a ±1.80	95.69a ±0.39	97.89a ±0.94	82.08b ±1.80	95.69ab ±0.39

N= 4 replicates. Within the columns, means with different alphabet are statistically different (p<0.05)

**Table 12: Concentration of Nitrogen in the soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	0.21a ±0.00	0.22a ±0.00	0.35a ±0.02	0.12a ±0.01	0.29a ±0.01	0.26a ±0.00	0.16a ±0.00	0.33a ±0.01	0.33a ±0.01	0.13a ±0.03	0.26a ±0.00	0.48a ±0.00
Amended	0.15b ±0.01	0.21b ±0.01	0.66a ±0.89	0.18b ±0.01	0.30a ±0.01	0.24a ±0.02	0.20a ±0.01	0.31a ±0.01	0.30b ±0.02	0.22b ±0.01	0.26b ±0.00	0.46a ±0.01
Control	0.60c ±0.02	0.12b ±0.01	0.18a ±0.02	0.60c ±0.02	0.12a ±0.01	0.18a ±0.02	0.60b ±0.02	0.12b ±0.01	0.18b ±0.02	0.60c ±0.02	0.12b ±0.01	0.18b ±0.02

N= 4 replicates. Within the columns, means with different alphabet are statistically different ( $p < 0.05$ )

**Table 13: Concentration of Organic Carbon in the soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	0.77a ±0.00	0.86ab ±0.10	0.70a ±0.00	0.34a ±0.01	1.07a ±0.04	0.93a ±0.02	0.53a ±0.03	1.23a ±0.03	1.31a ±0.02	0.33a ±0.01	1.03a ±0.07	1.83a ±0.03
Amended	0.50b ±0.00	0.99b ±0.01	0.71a ±0.01	0.62b ±0.03	1.19a ±0.03	0.88ab ±0.13	0.79b ±0.02	1.25a ±0.01	1.19a ±0.01	0.71b ±0.01	1.25ab ±0.02	1.76a ±0.02
Control	0.25c ±0.03	0.57a ±0.03	0.77b ±0.03	0.25a ±0.03	0.57b ±0.03	0.77b ±0.03	0.25c ±0.03	0.57b ±0.03	0.77b ±0.03	0.25c ±0.03	0.57b ±0.03	0.77b ±0.03

N= 4 replicates. Within the columns, means with different alphabet are statistically different ( $p < 0.05$ )

**Table 14: Concentration of Organic Matter in the polluted soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	1.36a ±0.01	1.38a ±0.02	1.24a ±0.04	0.59a ±0.03	1.90a ±0.09	1.58a ±0.05	0.87a ±0.03	2.12a ±0.03	2.21a ±0.03	0.56a ±0.04	1.95a ±0.13	3.20a ±0.06
Amended	0.83b ±0.01	1.71a ±0.02	1.22a ±0.05	1.08b ±0.03	2.16b ±0.04	1.48ab ±0.05	1.32b ±0.06	2.20a ±0.04	2.01a ±0.14	1.26b ±0.04	0.36b ±0.06	3.05a ±0.10
Control	0.36c ±0.03	1.00a ±0.01	1.34a ±0.11	0.36c ±0.03	1.00c ±0.01	1.34b ±0.11	0.36c ±0.03	1.00b ±0.01	1.34b ±0.11	0.36 c ±0.03	1.00b ±0.01	1.34b ±0.11

N= 4 replicates. Within the columns, means with different alphabet are statistically different (p<0.05)

**Table 15: Concentration of C:N in the soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	3.74a ±0.04	3.65a ±0.03	2.28a ±0.19	3.01a ±0.11	3.77a ±0.03	3.72a ±0.07	3.04a ±0.04	3.88a ±0.03	3.86a ±0.04	2.98a ±0.16	3.97a ±0.02	3.90a ±0.10
Amended	3.20b ±0.03	4.09a ±0.07	3.44b ±0.10	3.38a ±0.05	4.06a ±0.08	3.60a ±0.14	3.61b ±0.03	3.99a ±0.08	3.69a ±0.07	3.58a ±0.02	4.00a ±0.30	3.61ab ±0.03
Control	2.27c ±0.26	3.91a ±0.70	3.45b ±0.25	2.27b ±0.26	3.91a ±0.70	3.45a ±0.25	2.27c ±0.26	3.91a ±0.70	3.45b ±0.25	2.27b ±0.26	3.91a ±0.70	3.45b ±0.25

N= 4 replicates. Within the columns, means with different alphabet are statistically different (p<0.05)

**Table 16: Concentration of Phosphorus in the oil sample**

Carpet grass	5g			15g			25g			35g		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
Unamended	16.21a ±0.32	7.08a ±0.14	7.38a ±0.45	18.1a ±0.15	10.75a ±0.53	7.87a ±0.77	16.14a ±0.04	1.78a ±0.05	8.82a ±0.51	17.68a ±0.27	2.20a ±0.08	6.47a ±0.39
Amended	17.86b ±0.02	5.63b ±0.12	12.84b ±0.28	18.19a ±0.13	7.62b ±0.62	14.66b ±0.64	23.32b ±0.14	1.45a ±0.11	15.11b ±0.24	17.99a ±0.63	1.34a ±0.07	13.11a ±0.74
Control	16.22a ±0.47	7.07a ±0.98	13.80b ±0.29	16.22b ±0.47	7.07b ±0.98	13.80a ±0.29	16.22a ±0.47	7.07b ±0.98	13.80c ±0.29	16.22b ±0.47	7.07b ±0.98	13.80b ±0.29

N= 4 replicates. Within the columns, means with different alphabet are statistically different ( $p < 0.05$ )

Table 2 shows the results of the contaminated soil sample for *axonopus fissifolius* before, during and after the experiment with the different concentrations of the petroleum hydrocarbon. The result revealed that there is irregular variation in the levels of pH before, during and after the experiment. Generally, highest pH value was observed in amended *axonopus fissifolius*. In a similar work carried out by Uwazie et al. (2020), for all results, there is reduction in the pH value as time progresses. The result showed that the soil becomes more acidic as time progresses for all sample mixture (Uwazie et al., 2020) which is in line with the present study.

Table 3 shows the results of the concentration of EC ( $\text{Dsm}^{-1}$ ) value in contaminated soil sample for *axonopus fissifolius* before, during and after the experiment with the different concentrations of the Petroleum Hydrocarbon respectively. The result revealed that there is irregular variation in the levels of EC before, during and after the experiment. Generally, highest EC value was observed in the control.

Table 4 shows the result of the concentration of Exchangeable acidity (EA) values for contaminated soil samples of *axonopus fissifolius*. The result revealed that there is irregular variation in the levels of EA before, during and after the experiment. Generally, highest EA value was observed in the control. Which means the concentration of TPH has affects the level of EA in the soil.

Table 5 shows the result of the concentration of Calcium values for contaminated soil samples of *axonopus fissifolius*. The result revealed that there is

irregular variation in the levels of Calcium before, during and after the experiment. Generally, highest Calcium value was observed in the control. Generally, amended soils have the higher value of calcium when compare with the corresponding unamended soil. The same pattern is observed irrespective of the different masses of the petroleum hydrocarbon for the carper grass. Generally, there was no significant change in the value of calcium with the addition of cow dung (Uwazie et al., 2020) which is in line with the present study.

Table 6 shows the result of Concentration of Magnesium in the different samples of the soils of *axonopus fissifolius*. The results revealed that there are irregular variations in the concentration of magnesium in all the experiment. Generally, control soil has the highest value of magnesium follow by amended soils and the unamended soil.

Table 7 shows the result of Concentration of Potassium in the different samples of the soil of *axonopus fissifolius*. The results revealed that there is decrease in the concentrations of Potassium in the soil as the time increase before the experiment to after the experiment for both the amended and unamended soil samples. Generally, amended soils have the higher value of potassium when compare with the corresponding unamended soil. The same pattern is observed irrespective of the different masses of the petroleum hydrocarbon for the carpet grass. There was a very high decrease in the potassium content of the soil with time, most especially with the addition of cow dung. There was no significant change in the initial values of the potassium with the addition of cow dung. Potassium is

essential for the regulation of CO<sub>2</sub> intake by plants. Macro nutrients such as Nitrogen, Potassium and Phosphorus are necessary for plant growth and were found to be below the soil agricultural standards (HSE-ENV, 2004).

Table 8 shows the result of Concentration of sodium in the different samples of the soils of *axonopus fissifolius*. The results revealed that there are irregular variations in the concentration of sodium in all the experiment. Generally, amended soils have the higher value of sodium when compare with the corresponding unamended soil.

Table 9 shows the result of Concentration of cation exchange capacity (CEC) in the different samples of the soil. The results revealed that there are irregular variations in the concentration of CEC in all the experiment. Generally, amended soils have the higher value of CEC when compare with the corresponding unamended soil.

Table 10 shows the result of Concentration of effective cation exchange capacity (ECEC) in the different samples of the soil. The results revealed that there are irregular variations in the concentration of ECEC in all the experiment. Generally, control has the highest value of ECEC while the corresponding amended soil has least value.

Table 11 shows the result of Concentration of base in the different samples of the soil. The results revealed that there are irregular variations in the concentration of base in all the experiment.

Table 12 shows the result of Concentration of nitrogen in the different samples of the soil. The result revealed that there was a massive decrease at both the control of carpet grass. The results revealed that there are irregular variations in the concentration of nitrogen in the soil samples before, during and after the experiment.

Table 13 shows the result of Concentration of organic content in the different samples of the soil. The results revealed that there are irregular variations in the concentration of organic carbon in the soil samples before, during and after the experiment. The results show as the concentration of petroleum hydrocarbon increases the value of organic carbon also increases both for amended and unamended soil sample.

Table 14 shows the result of Concentration of organic matter in the different samples of the soil. The highest value of organic matter was observed in the unamended carpet grass treated with 35 g after the experiments while the lowest value of organic matter was observed in the unamended carpet grass soil treated with 5g when compared with the control. The results revealed that there are irregular variations in the concentration of organic content in the soil samples before, during and after the experiment. Generally, it can be seen that the addition of cow dung shows a significant increase in the value of the organic matter (Uwazie et al., 2020). This is also in line with the present study.

## Concentration of TPH in the contaminated soil sample

**Table 17: Concentration of TPH values for polluted soil sample**

Carpet grass	5g			15g			25g			35g		
	Before	After	%	Before	After	%	Before	After	%	Before	After	%
Unamended	1.31a ±0.11	0.05a ±0.00	96	0.72a ±0.05	0.05a ±0.00	93	0.62a ±0.01	0.24a ±0.01	61	0.67a ±0.02	0.27a ±0.01	60
Amended	0.75b ±0.00	0.24b ±0.01	91	0.87b ±0.00	0.26b ±0.00	70	0.75b ±0.01	0.06b ±0.00	69	0.63b ±0.01	0.24b ±0.00	62

N= 4 replicates. Within the columns, means with different alphabet are statistically different ( $p < 0.05$ )

Table 17 shows the results of the concentration of TPH value in the contaminated soil sample for Carpet grass before and after the experiment with the different concentrations of the Petroleum Hydrocarbon respectively. There is decrease in the values of TPH for all samples considered after the phytoremediation. The result revealed that the highest value of TPH ( $0.27 \pm 0.01$ ) was observed in unamended carpet grass pot treated with 35g TPH with the least parentage reduction of 60% while the lowest value of TPH ( $0.05 \pm 0.01$ ) was observed in the unamended carpet grass pot treated with 5g TPH with the highest parentage reduction of 96%. There is statistically difference between the means of TPH in the experiment.

The relative potential or efficiency (parentage reduction) of the grasses remediating the TPH contaminated soils are in the order  $5g > 15g > 25g > 35g$ . Generally, the phytodegradation of the TPH contaminated soil is lower when amended with the cow dung than unamended for carpet grass. In summary, carpet grass is having higher percentage reduction. This is due to the fact that almost 100% of the carpet grass seeds germinated in the different concentrations of TPH.

Donatus and Akogwu (2021) carried out Phytoremediation of Petroleum Hydrocarbons Using *Jatropha curcas* in Soils Contaminated with Spent Engine Oil (SEO). 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. This agrees with the findings of Marinescuet al. (2010), Agbogidi and Enujeke (2012), Nwite and Alu (2015) and Onwusiriet al. (2017). On the contrary, Okonokhuaet 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. 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 (Donatus and Akogwu, 2021).

In a similar work carried out by Uwazie et al. (2020), The result for TPH concentration gave a decrease in the values of TPH for all samples considered. The decrease for sample B was very minute as compared to sample D when cow dung was not added, and similar result was also noticed for C and E. The addition of cow dung reduced the concentration of the TPH in the soil for both 75 g and 150 g crude oil contaminations. (Uwazie et al., 2020). In his assertion rhymes Oyedele and Amoo (2014) that addition of cow dung manure improves on the calcium, magnesium, phosphorus, potassium, and nitrogenous contents which are vital elements for better growth of plant species. The percentage degradation of TPH in soils amended with poultry droppings was higher (52%) compared to non-amended soils (45%) (Donatus and Akogwu, 2021). 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 recorded in 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*. The results showed that all vegetated pots had higher crude oil removal compared to the control. *Epipremnum aureum* demonstrated the highest ability of crude oil removal with 50.4% of crude oil removed, followed by *Imperata cylindrica* (39.5%), *Pteris vittata* (36%) and *Mucuna bracteata* (30.9%). This finding rhymes the observations made in numerous studies in which it is reported that the grasses (Poaceae) and legumes (Leguminosae) are effective in the clean-up of contaminants from the environment (Merkl et al. 2005, Zand et al. 2016). More light about the suitability of legumes and plant species is shed by Merkl et al. (2004) and Zand et al. (2016) who conclude that grasses and legumes are the best candidates for phytoremediation process owing to their multiple and larger root surface area. Further, they espouse that legume can fix atmospheric nitrogen by potentially replenishing what is lost from the soil during oil spills.

Similar observations have been reported for the use of plant and animal-derived organic waste in the bioremediation of soil contaminated with petroleum hydrocarbons. Liu et al. (2009)

used organic manure made up of rice straw and pig dung to bio-stimulate the degradation of an oily sludge and obtained a TPH reduction of 58.2% in a remediation period of 360 days, while Agarry et al. (2013) in their investigation on kinetic model and half-life study of Bonny light crude oil amended with crop residue and animal derived organic manure confirms that the use of crop residue and animal derived organic manure improved the rate of biodegradation of hydrocarbon in a crude oil contaminated soil.

Phytoremediation is an innovative technology that uses plants to remove and/or degrade environmental contaminants such as heavy metals and organic compounds. This technology is environmentally friendly and potentially cost effective (Rahman *et al.*, 2008). In this study an assessment of remediation was done to observe the remediation potential of crude oil contaminated soil by using *Cyperus esculentus* and *axonopus fissifolius* where both grasses demonstrated their ability to absorb crude oil contamination from the soil.

In this present study the technology for phytodegradation that was employed is a simple, effective, inexpensive and environmentally friendly approach. This

study shows that the Carpet Grass (*Axonopus fissifolius*) seeds were able to germinate and grow in the different concentrations of the TPH in the soil. The relative potential or efficiency (percentage reduction) of the grasses remediating the TPH contaminated soils are in the order 5g > 15g > 25g > 35g. Generally, the phytoremediation of the TPH contaminated soil is lower when amended with the cow dung than unamended for the carpet grass. Therefore, the study suggest that carpet grass is having a high percentage reduction in the phytoremediation of TPH polluted soil. Hence, the carpet grass (with average of 76% percentage reduction) is having a high efficient in the degradation of TPH polluted soil.

The following are recommendations from the study; Replanting of carpet grass with organic manure (cow dung) can be done after 80 days to improve the cleanup activity of the plant samples, since the plant samples died at the 80<sup>th</sup> day. Other local plants should be investigated for tolerance with different crude oil concentration to increase the amount of phytoremediation.

## References

Anh, B.T.K., Ha, N.T.H, Danh, L.T., Van Minh, V and Kim D.D (2017) Phytoremediation applications for metal-contaminated soils using terrestrial plants in Vietnam. *Phytoremediation* **495**: 012054 157-181

Aprill, W. and Sims, R.C. (1990). Evaluation of the use of prairie grasses for stimulating polycyclic aromatic hydrocarbon treatment in soil. *Chemosphere*. **20**:253-265.

Atangana, A., Khasa, D., Chang, S. and Degrande, A. (2014). Phytoremediation in Tropical

- Agroforestry. *Dordrecht, Springer*, **136**:343–351.
- Banks, M.K., Schwab, P., Liu, B., Kulakow, P.A., Smith, J.S. and Kim, R. (2003). The effects of plants on the degradation and toxicity of petroleum contaminants in soil: A field assessment. *Advances in Biochemical Engineering/Biotechnology*. **78**: 75-96.
- Basumatary, B. Saikia, R. and Bordoloi, S. (2012). Phytoremediation of crude oil contaminated soil using nut grass, *Cyperus rotundus*, *Journal of Environmental Biology*, **33**: 891-896.
- Cook, B. G., Pengelly, B. C., Brown, S. D., Donnelly, J. L., Eagles, D. A., Franco, M. A., Hanson, J., Mullen, B. F., Partridge, I. J., Peters, M. and Schiltze-Kraft, R. (2005). Tropical forages. CSIRO, DPI&F (Old), CIAT and ILRI, Brisbane, Australia.
- Cunningham, S. D., Anderson, T. A., Schwab, A. P. and Hsu, F. C. (1996) Phytoremediation of soils contaminated with organic pollutants. *Advances in Agronomy* **56** 55-114.
- Ebadi, A., Sima, N. A. K., Olamaee, M., Hashemi, M. and Nasrabadi, R. G. (2018). Remediation of saline soils contaminated with crude oil using the halophyte *Salicornia persica* in conjunction with hydrocarbon-degrading bacteria. *Journal of Environmental Management*. **219**: 260-268.
- FAO, (2012). Grassland Index. A searchable catalogue of grass and forage legumes. FAO, Rome, Italy.
- Frick, C.M., Farrell, R.E. and Germida, J.J. (1999). Assessment of Phytoremediation as an In-Situ Technique for Cleaning Oil-Contaminated Sites. Petroleum Technology Alliance of Canada. Available at <http://www.rtdf.org/public/phyto/phylinks.htm>
- Garba, S.T., Idi, A.M. and Baba, A. (2016). Assessing the phytoremediation potential of the grass; *Chrysopogon Aciculatus* for the heavy metals: Cr, Co, Cd, Cu, Pb, Zn, Ni and Mn. *Global Journal of Science Frontier Research: H Environment & Earth Science*. **16** (1.0):15-21.
- Gardea-Torresdey, J.L., de la Rosa, G. and Peralta-Videa, J.R. (2004). Use of phytofiltration technologies in the removal of heavy metals: *A review. Pure and Applied Chemistry* **76**:801–813.
- Hegazy, A. K., Mohamed, N. H., Moustafa, Y. M. and Hamad, A. A. (2015) Phytoremediation of soils polluted with crude petroleum oil using *Bassia scoparia* and its associated rhizosphere microorganisms. *International Bio deterioration and Biodegradation* **98**:113-120.
- Juck, D., Charles, T., Whyte, L. G. and Greer, C. W. (2000). Polyphasic microbial community analysis of petroleum-contaminated soils from two northern Canadian communities. *FEMS Microbial Ecology*. **33**:241.

- Merkl, N., Schultze-Kraft, R. and Infante, C. (2005). Assessment of tropical grasses and legumes for phytoremediation of petroleum contaminated soils. *Water Air Soil Pollut.* **165**:195-209.
- Newman, M.C. (2009): Fundamentals of Ecotoxicology. Boca Raton, London, New York, *CRC Press*.
- Njoku, K. L., Akinola, M. O. and Oboh, B. O. (2008). Does crude oil affect the pH, moisture and organic content of soils? *Ecology, Environment and Conservation Paper* **14**(04): 731-736.
- Panagos, P., Liedekerke, M. V., Yigini, Y. and Montanarella L. (2013) Contaminated sites in Europe: Review of the current situation based on data collected through a European network. *Journal of Environmental Public Health* **1**-11.
- Rascio, N. and Navari-Izzo, F. (2011). Heavy metal hyperaccumulating plants: How and why do they do it? And what makes them so interesting? *Plant Science.* **180**(2):169-181.
- Rahman, M. M., Ishii, Y., Niimi, M. & Kawamura, O. (2008). Effect of salinity stress on dry matter yield and oxalate content in napier grass (*Pennisetum purpureum* Schumach). *Asian Australasian Journal of Animal Sciences*, **21**(11): 1599-1603.
- Rulkens, W. H., Tichy, R. and Grotenhuis, J. T. C. (1998) Remediation of polluted soil and sediment: Perspectives and failures. *Water Science Technology* **37**:27-35.
- Schnoor, J. L. (2000), "Phytostabilization of Metals using Hybrid Poplar Trees, Phytoremediation of Toxic Metals: Using Plants to Clean-up the Environment", *New York, John Wiley & Sons, Inc, pp.* 133-150.
- Schwab, P., Banks, M.K. and Kyle, W.A. (2006). Heritability of phytoremediation potential for the alfalfa cultivar Riley in petroleum contaminated soil. *Water, Air, Soil Pollution.* **177**:239-249.
- Smith, J. and Valenzuela, H. (2002). Carpetgrass. Univ. Hawaii at Manoa, Coop. Ext. Service, Sustainable Agriculture, Cover Crops, Aug. 2002, SA-CC-1.
- Uwazei, M. C., Obijaku J. C., Onukwuli O. D., Babayemi A. K and Umeuzuegbu J. C. (2020). Remediation Ability of Melon grasss in a crude oil polluted soil in a tropical region. *International journal of engineering technologies and management research*, **7**(6), 89-101.
- Zand A.D., Bidhendi G.N. and Hoveidi H. (2016): Ability of white clover and alfalfa to grow in petroleum hydrocarbon-contaminated soil in Iran and their phytoremediation potential. *Advances in Bioresearch*, **7**: 407–410.