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Potential of Castor Seed (*Ricinus communis*) for Remediation of Petroleum Products Contaminated Soil in Billiri, Gombe State, Nigeria

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ABSTRACT: Petroleum products consist of hazardous chemicals such as benzene, toluene, ethylbenzene, xylene, and naphthalene, which can be detrimental to all parts of the ecosystem, especially the land. Hence, the objective of this paper was to evaluate the potential of castor seed (*Ricinus communis*) for remediation of petroleum products contaminated soil in Billiri, Gombe State, Nigeria using appropriate standard techniques. Tests results showed that the petroleum products significantly altered the physicochemical properties, heavy metals and THC of the soil. The soil porosity decreased from 76.20% to 36.5%; the soil pH decreased from 7.10 to 6.0; the THC increased from 0.268 mg/kg to 878.4 mg/kg while heavy metals content such as copper level increased from 17.20 mg/kg to 53.9 mg/kg; the lead content increased from 10.39 mg/kg to 16.0 mg/kg; while the iron content increased from 31.72 mg/kg to 63.4 mg/kg after the contamination. After the 14 weeks phytoremediation period, *Ricinus communis* was able to degrade the THC in the soil from 878.4 mg/kg to 254 mg/kg while also showing potential for the degradation of other heavy metals in the soil.

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The environmental challenges posed by human activities, particularly industrialization, are significant, leading to ecosystem disruption and pollution (Tanee and Akonye, 2009). Industrial discharge, including petrochemical use, adversely affects humans, plants and soil microorganisms contributing to environmental degradation (Tanee and Akonye, 2009). Moreover, agricultural, industrial, and urban activities, along with population growth, generate large volumes of pollutants, further exacerbating environmental concerns (Saidu *et al*., 2021). In Nigeria, crude oil exploration has resulted in widespread land, air, and water pollution, posing health risks and threatening agricultural lands and water resources (Akpokodje and Uguru, 2019). The contamination of soil by crude oil, stemming from storage tank and pipeline leaks, waste disposal, and spills, has led to environmental degradation and health issues (Diab, 2008; Njoku *et al*., 2014). Total Petroleum Hydrocarbons (TPH) present a significant environmental concern, as they are released during the extraction, refinement, distribution, and storage of petroleum products (Barati *et al*., 2020). Petroleum hydrocarbons consists of various hazardous compounds, including saturated alkanes, alkynes, alkenes, naphthenes, polycyclic aromatic hydrocarbons, and heavy metals (Akpokodje and Uguru,2019).To address petroleum hydrocarbon

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pollution, phytoremediation offers a promising solution, utilizing plants to cleanse contaminated soil (Asiabadi *et al*., 2018). Plants possess the ability to degrade TPH in their rhizosphere through the secretion of oxidative enzymes, facilitating subsequent disposal (Diab, 2008; Barati *et al*., 2020). Compared to physical and chemical methods, biological approaches like phytoremediation are considered more economically viable and efficient for TPH pollution remediation (Okoh, 2006; Njoku *et al*., 2014).

Studies have demonstrated the efficacy of various plant species in reducing Total Hydrocarbon Content (THC) in petroleum-contaminated soil (Akpokodje *et al*., 2019; Barati *et al*., 2020; Njoku *et al*., 2014). Notably, plants like *Arachis hypogaea L*., *Amaranthus hybridus*, and *Celosia argentea* have shown significant THC reduction capabilities (Akpokodje *et al*., 2019). Additionally, Barley and oat plants have exhibited promising results in THC reduction (Barati *et al*., 2020). *Ricinus communis*, commonly known as the castor plant, shows promise for phytoremediation due to its ability to thrive in polluted environments (Saidu *et al*., 2022).

However, further research is needed to explore the potential of various plants, including *Ricinus communis*, in remediating oil-polluted soils. Hence, the objective of this paper was to evaluate the potential of castor seed (*Ricinus communis*) for remediation of petroleum products contaminated soil in Billiri, Gombe State, Nigeria

MATERIALS AND METHODS

Study area: A soil sample was collected within 6cm of a virgin plot at the botanical garden of the College of Education, Billiri, Gombe State.

Petroleum products: The spent motor engine oil was purchased from a mechanic workshop located along Gombe-Yola Road, Gombe State, Nigeria, while petrol, diesel, and kerosene were also purchased from a petrol filling station located close to the college.

Plant of Interest: The castor seed was purchased from a seed stock market located near the college.

Soil Sample Preparation: The topsoil from the college botanical garden was air-dried in the lab at a temperature of (23±4°C) for two weeks and sieved with a 2 mm stainless steel sieve to remove stones, large particles, and plant materials. Transparent plastic buckets were filled with 10 kg of the sieved soil before petroleum contamination. A mixture of petroleum products (2 L of spent engine oil, 2 L of kerosene, 2 L of petrol, and 2 L of diesel) was gradually poured into each bucket according to the study by Akpokodje and Uguru (2019) and allowed to drain through the soil. This procedure was repeated daily for five days before the contaminated soil in the buckets was left to stabilize for three weeks.

Soil physicochemical analysis: Samples were air-dried ground and passed through a sieve of 2 mm standard mesh size. The soil pH was determined with a pH meter using a 1:2.5 soil to water ratio and 1: 2.5 soil to 0.1 KCl (potassium chloride) suspension. soil bulk density was determined by the core method while soil porosity values were derived from the bulk density data(Anikwe *et al*., 2017).

Sample Pre-Treatment/Digestion (soil samples) for Analysis of Heavy Metals: The samples were allowed to dry using the hot oven (Model 30GC lab oven) and then ground into fine powder by using a porcelain mortar and pestle. 100mg of each sample was weighed in to thoroughly clean plastic container (microwave tube) and 6ml of 65% HNO_3 and 2ml of H_2O_2 (and 2ml of HF for soil samples only) were added and allowed to stand for a while. The plastic container (microwave tube) was then covered and placed in to microwave digester (Master 40 serial No: 40G106M) and 150^0C for 40mins.

Determination of metal contents of each sample: The concentrations of the metals present in the samples were determined by reading their absorbance using AAS (Buck scientific model 210GP) and comparing it to the respective standard calibration curve. Three replicate determinations were carried out on each sample(Lawan and Garba, 2022).

THC Determination: Total Hydrocarbon Content The total hydrocarbon content was carried out following ASTM D 9071B – 7 (Soxhlet Extraction Method using Hexane Extractable Materials by American Society for Testing and Materials) as described by (Aigberua *et al*., 2016). During the analysis, the soil samples were air-dried and sieved through a 2 mm mesh size sieve before being thoroughly mixed, especially the composited samples. Foreign objects like sticks, leaves, and stones were discarded. About 10 grams of the sample was blended with 10 grams of anhydrous sodium sulphate, the homogenized sample was transferred to an extraction thimble and covered with glass wool. The extraction thimble was allowed to drain freely for the duration of the extraction period. The soxhlet apparatus containing the extraction thimble and sample was set up with the attachment of a 250ml boiling flask containing 90 ml of n-hexane. The heating control on the heating mantle was adjusted so that a cycling rate of 20 cycles/h was obtained. Extraction was carried out for a period of 4h, afterwards, a clean 250 ml boiling flask was oven-dried at 105ssC for 2 h, after which it was cooled in a desiccator at room temperature. The boiling flask was removed from the desiccator and weighed on a calibrated weighing balance. At the end of the 4 h extraction period, the organic extract was filtered through grease-free cotton, into the preweighed boiling flask with the aid of hand gloves. The flask and cotton wool were then rinsed with n-hexane and added to the 250 ml boiling flask. The boiling flask was connected to the distilling head apparatus and the solvent was distilled by immersing the lower half of the flask in a heating mantle. The temperature of the heating device was adjusted to complete the distillation in less than 30 min. The solvent was disposed of in a glass bottle designated for storing organic waste before appropriate waste disposal. On complete distillation, the distilling head was removed, followed by the immediate removal of the flask from the heating mantle, before the flask was then cooled in a desiccator for 30 minutes and weighed. The gain in weight of the boiling flask was determined by subtracting the initial weight from the final weight of the flask. Calculation: The concentration of HEM (Hexane Extractable Material) in the soil sample is as in equation 1.

$$HEM\ (mg/kg\ wet\ weight) = \frac{GW\ (mg)}{WWS\ (g)} \times 100 \quad (1)$$

Where WG = Gain weight; WWS = weight of wet solid

Phytoremediation Setup: The contaminated soil in the buckets was all arranged in an orderly manner under a shade in the botanical garden in other to reduce the rate of evapotranspiration and also the effect of rainfall on the experimental setup.

Ten seeds of castor plant were planted in the contaminated soil and Three weeks after germination, the seedlings were thinned down to five seedlings per bucket. Before planting, 200 g of manure made from cattle dung and poultry droppings mixed with 100 g of loamy soil was placed on top of all the buckets, to encourage the early establishment of the seedlings, as recommended by (Akpokodje *et al*., 2019).

Throughout the experimental period, all the buckets were moderately watered when necessary, and invasive weeds were all handpicked while pesticides were also applied at the 5th and 11th week of the planting. At the end of the experimental period, soil samples were taken at random at a depth (0-20 cm depth) from the containers and recorded. The depth (0-20 cm) is considered to be the rhizosphere region of the plants and it is believed to be the region of the soil closest to the plant's root which is under the direct influence of the root system.
All the soil samples collected were air-dried and sieved with a 2 mm sieve before the soil analysis.

Statistical Analysis: The statistical analysis of data for the study was done by using the Statistical Product and Service Solutions (SPSS) version 20.0. The data were presented with Mean values as (Mean±SD).

RESULT AND DISCUSSION

Soil Analysis: From the result obtained in Table 1 for the analysis of the soil before contamination and the analysis after contamination of the soil with petroleum products, the result showed that the contamination had a significant effect on the physicochemical parameters of the soil such as pH, Soil gravity, Soil porosity, etc. before contamination of the soil the uncontaminated soil had a pH of 7.1 while the pH reduced to 6.0 after contamination, which is in concordance with the study of (Akpokodje and Uguru,2019) whose uncontaminated soil had a pH of 7.05 while after contamination had a pH of 5.34 showing a decrease in the pH level of the soil due to the addition of petroleum products. In another study by (Tang *et al*., 2010), the various activities of microorganisms in petroleum-contaminated soil produce organic acids which also act in the reduction of the pH level of contaminated soil. The reduction of the soil pH can be linked to the nature of the various components of the petroleum product.

The porosity of the soil before contamination was found to be 76.2% while after contamination the soil porosity reduced to 36.5 % showing about a 56% reduction in the porosity level of the soil.

In a similar study by (Anikwe *et al*., 2017), the contaminated soil had a reduction in the porosity level to 43.75% compared to the control soil which had a higher porosity value. The nature of petroleum products tends to block the pores in between soils thereby reducing the effective movement of particles and molecules in the soil which is in agreement with the study of Achuba, (2006).

While the contaminated soil had a reduction in the level of soil porosity and soil pH, the soil bulk density increased from 1.42 g/cm^{-3} to 1.57 g/cm^{-3}, According to (Anikwe *et al*., 2017) Oil tends to increase the bulk density of soil by reducing the frictional forces between soil particles and when impacted by rain or other agents, the particles assume a complex and packed structure.

Table 1. Result of the impact of petroleum products on the physicochemical properties of soil before and after contamination

Parameters	Level	
	Before contamination	**After contamination**
Soil pH (H_20)	7.10	6.0
Soil porosity (%)	76.20	36.5
Soil bulk density (g/cm^3)	1.42	1.57
Specific gravity	1.7147	1.3188
THC		
Soil sample (mg/kg)	0.268	878.4

Phytoremediation potential of Ricinus communis: The result of the study in Figure 1 shows the ability of the castor plant to significantly degrade THC from the soil, from the result obtained it was discovered that the castor plant was able to reduce the THC content in the soil from about 878.4 mg/kg to a much lower figure of 254 mg/kg after 14 weeks experimental period which signifies a 71% success in degradation of THC. According to (Saadawi *et al*., 2015) The ability of the plant to degrade such an amount of THC could be attributed to enhanced microbial degradation where the plant roots encourage microbial activities by providing nutrients for the soil microbes.

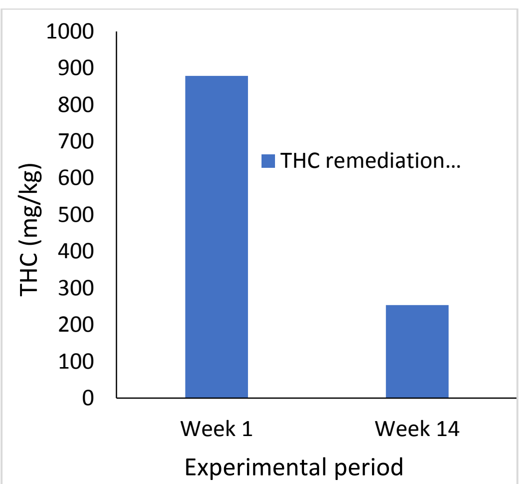

Fig. 1. Effect of *Ricinus communis* on the THC of contaminated soil

In a related study (Akpokodje and Uguru, 2019) where *Telfairia occidentalis* and *Abelmoschus esculentus* were used for degrading THC in an oil-contaminated soil, the result obtained from the study showed that *Telfairia occidentalis* was able to degrade THC from 964.35 mg/kg to 82.67 mg/kg showing 91.4% degradation while *Abelmoschus esculentus* was able to degrade THC in the soil from 964.35 mg/kg to 104 mg/kg showing 89.21% degradation which proof that the two plants are better at degrading THC than the castor plant which is the seed of interest in this study. In a similar study by (Saadawi *et al*., 2015) the percentage of removal of 0.5 % crude oil concentration, *Triticum repens* and *Malva punilora* displayed the most effective ability at degrading crude oil reaching 94% removal followed by *Ricinus communis* which was able to degrade about 77% of crude oil similar to the result obtained in this study.

EU, 2021 also reported that the addition of poultry manure helped in enhancing plant growth thereby increasing the efficiency in the uptake of hydrocarbon plants. It is also of interest to note that the observed reduction in spent oil or THC may not only be due to the biodegradation process induced by plant or nutrient addition but other processes such as volatilization, adsorption to organic compounds, other abiotic factors are equally implicated in the reduction process.

Heavy Metal Removal: The result in Table 2 obtained for the removal of heavy metals in such as iron, copper and lead in this study after contamination and remediation by *Ricinus communis* showed that the plant was able to degrade lead from 16mg/kg to 12.6 mg/kg which is about (56.6%) similarly the castor oil plant was able to degrade copper from 53.9 mg/kg to 33.4 mg/kg which is about (67.4%) while the plant was also able to degrade iron from 63.4 mg/kg to 46.7 mg/kg and signifies about (49.9%).

Table 2. Impact of petroleum products on the soil heavy metals

Parameters	Level	
	Before contamination	**After contamination**
Iron (mg/kg)	31.72	63.4
Copper (mg/kg)	17.20	53.9
Lead (mg/kg)	10.39	16.0

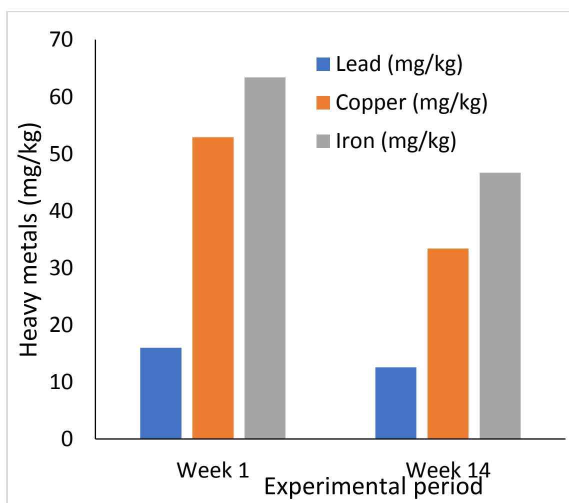

Fig. 2. Effect of phytoremediation seed on the heavy metals content of contaminated soil

As reported by various other authors who have carried out studies on the efficiency of *Ricinus communis* for the removal of heavy metals the plant shows a good prospect of heavy metals removal as stated by (Akintola *et al*., 2022), who studied the removal of heavy metal by castor plant, he obtained a result showing that the plant was able to reduce iron from 112.86 mg/kg before remediation to 89.87 mg/kg after remediation similarly the plant was able to reduce copper from 37.81 mg/kg to 22.51 mg/kg after remediation while lead was reduced from 22.21 mg/kg to 16.21 mg/kg. In another study by (*Saidu et al*., 2022), the castor plant was found to be able to remove copper at 97,98 and 99 % at different concentrations of contamination while the same study also showed castor oil plant was able to remove Lead at 100,99 and 97% at 1.5, 2 and 2.5g concentration of heavy metal contaminants. Bioconcentration (BCF) and translocation (TF) factors are important evaluation indices used to assess the remediation potentials of plants. Translocation factor (TF) in a plant indicates the ability of the plant to move materials from its root to the shoot and as observed in the study of (Akintola *et al*., 2022) the castor plant has a good TF which makes it suitable for removal of heavy metal and still maintaining the good nature of the soil.

This study investigated the effect of petroleum product contamination on the physiochemical, THC, and heavy metals content of agricultural soil and how the soil can be remediated using the seeds of *Ricinus communis* also known as castor seed. The result of the soil analysis indicated significant changes in the physicochemical properties, THC, and heavy metals content of the soil. The study was carried out within a 14-week experimental period using viable seeds of *Ricinus communis*. From the result obtained from the study, it can be deduced that *Ricinus communis* seed is a good plant for the remediation of petroleum product-contaminated soil and also the reduction of heavy metal contents in soil. At the end of the experimental period, *Ricinus communis* was able to degrade the THC content in the soil from 878.4 mg/kg to 254 mg/kg showing a good prospect for future studies in bioremediation of other complex compounds in the soil.

Conclusion: This study investigated the effect of petroleum products contamination on the physiochemical, THC and heavy metals content of agricultural soil and how the soil can be remediated using the seeds of *Ricinus communis* also known as castor oil seed. The result of the soil analysis indicated significant changes in the physicochemical properties, THC and heavy metals content of the soil. The study was carried out within 14 weeks experimental period using viable seeds of *Ricinus communis*. From the result obtained from the study it can be deduced that *Ricinus communis* seed is a good plant for remediation of petroleum product contaminated soil and also the reduction of heavy metal contents in soil. At the end of the experimental period *Ricinus communis* was able to degrade the THC content in the soil from 878.4 mg/kg to 254 mg/kg showing a good prospect for future studies in bioremediation of other complex compounds in the soil.

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