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Biochar-Amended Polluted Soil for *Rhizophora racemosa* Growth

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ABSTRACT

Background and Objective: Soil physico-chemical properties play critical role in determining soil fertility, structure, and its ability to support plant growth. However, these properties are often negatively altered by anthropogenic activities, particularly hydrocarbon pollution from spent engine oil, which leads to soil degradation and reduced productivity. This study assessed the effect of biochar on the physicochemical composition of soil polluted with spent engine oil used in growing *Rhizophora racemosa*. **Materials and Methods:** A randomized complete block design was used with four treatments: garden soil (GS), garden soil plus biochar (GSB), garden soil plus 6% spent engine oil (GSSEO), and garden soil amended with both biochar and engine oil (GSBSEO), each treatment was replicated three times. Pre- and post-planting soil samples were analyzed for total organic matter (TOM), total organic carbon (TOC), total hydrocarbon content (THC), soil moisture content, and pH. Data were analyzed by ANOVA, and significant means separated using LSD at 5% probability. **Results:** The biochar application significantly enhanced TOM (20.70%) and TOC (12.00%), while spent engine oil reduced these values and increased THC. The combined treatment (GSBSEO) demonstrated that biochar could partly reduce the negative effects of oil contamination. Moisture content was highest in the biochar-treated soil (24.63%), confirming biochar's role in enhancing water retention. Soil pH remained relatively neutral across treatments, with no statistically significant changes observed. **Conclusion:** The potential of biochar as a sustainable amendment for improving soil quality and mitigating the adverse effects of hydrocarbon pollution. These findings provide valuable insights for the rehabilitation of degraded coastal soils and support the restoration of ecologically important mangrove species such as *R. racemosa*.

KEYWORDS

Biochar, spent engine oil, physicochemical properties, hydrocarbon, organic matter, organic carbon, mangroves, soil amendment

INTRODUCTION

Soil degradation, particularly in coastal areas, poses a significant threat to both agricultural productivity and the sustainability of vital ecosystems such as mangroves. Several studies have reported the application of different soil amendments like sawdust, detergent to remediate soil polluted with crude oil[1-3]. Biochar on the other hand, has gained attention as a potential strategy to enhance soil properties and support plant growth under challenging conditions pose by crude oil pollution.

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Biochar is a stable carbon-rich material produced through the pyrolysis of organic matter[4] and has been used by different researchers to grow plants in spent engine oil and crude polluted soil, due to its ability to improve soil fertility, plant productivity[5-7]. Its highly porous structure increases the soil's cation exchange capacity, enhances water retention, and reduces nutrient leaching, thereby supporting plant growth in degraded soils[8]. In addition to this, biochar contributes to long-term carbon sequestration, offering a dual benefit of soil improvement and climate change mitigation[9]. These attributes make biochar a promising amendment for soils in need of rejuvenation.

On the other hand, spent engine oil, which is a waste product from automotive engines, contains a complex mixture of hydrocarbons and other organic compounds that can significantly alter soil properties[10,11]. Its presence in the soil, poses serious environmental concerns, such as potential soil contamination and toxicity. However, some studies have suggested that, in controlled quantities, spent engine oil can enhance soil organic matter content and enrich microbial activity such as hydrocarbonoclastic organisms, potentially benefiting plant growth[12-14]. The interaction between biochar and spent engine oil in soil, particularly their combined effects on soil fertility and plant health, remains largely unexplored.

The growth of *R. racemosa* is intricately linked to the quality of the soil in which it is planted. Degraded soils, common in many coastal regions, especially in the Niger Delta Region of Nigeria[15], may limit the ability of these mangroves to thrive, impacting their ecological functions. Therefore, a proper understanding on how biochar and spent engine oil influence soil pH and soil structure, and other physicochemical properties is important for developing effective soil management strategies that can support the restoration and growth of *R. racemosa*.

Soil physicochemical properties play a critical role in determining soil fertility, structure, and its ability to support plant growth. However, these properties are often negatively altered by anthropogenic activities, particularly hydrocarbon pollution from spent engine oil, which leads to soil degradation and reduced productivity. This issue is seen to be prevalent in coastal ecosystems like the Niger Delta Region of Nigeria, where vital mangrove species such as *Rhizophora racemosa* are increasingly threatened by contaminated soils. Developing effective soil restoration strategies is important for promoting ecological resilience in such environments. This study therefore, investigated the impact of biochar as an amendment in spent engine oil polluted soil used in growing *R. racemosa* and its effect on the soil physicochemical properties.

MATERIALS AND METHODS

Study location: The study was conducted at the University of Port Harcourt Choba rainforest (Latitude N4°54 15″, Longitude E6°54 35″) from April to August 2020. Garden soil was collected from the same spot as the study area, while fully grown seedlings of *R. racemosa* G. Mayer were collected from Borokiri waterside in Port Harcourt Local Government Area of Rivers State. Grown and healthy seedlings were physically examined, then categorized based on their size, color, and maturity. Individuals with a reddish colour, measuring between 29 and 36 cm, and free from any physical harm, were deemed mature and suitable for utilization.

Soil samples and treatments: The four treatments were as follows: Garden soil only [Control (G)], Garden soil+Biochar (GSB), Garden soil+6% Spent engine oil (GSSEO), and Garden soil+biochar+6% Spent engine oil (GSBSEO). The experimental setup was a randomized complete block design (RCBD) with three replications for each treatment. Seedlings of *R. racemosa* were planted in these four garden soils with various amendments (G, GSB, GSSEO, and GSBSEO). The control was garden soil with no mixture of either biochar or spent engine oil, GSB consisted of the mixture of biochar and garden soil in a ratio of 1:1. The GSSEO had the garden soil polluted with 6% spent engine oil, while GSBSEO had garden soil mixed with biochar in a 1:1 ratio with the addition of 6% spent engine oil. *Rhizophora racemosa* propagules were planted on the different soil treatments on the same day. Before planting, soil pollution was done one week before mixing with or without biochar in the different treatments. The soil total organic matter (TOM), total organic carbon (TOC), total hydrocarbon (THC), soil moisture content (SMC) and pH were investigated using standard procedures for the initial and after the experiment.

Determination of pH: The pH was determined by using a hand pH meter[16]. This involved firstly, homogenizing the soil samples to remove the lump and coarse soil particles, which was mixed with distilled water to form a solution, and it was allowed to settle for about 20 min. The pH electrode was placed directly in the mixture, and readings for each soil sample were taken and duly recorded, after few seconds as the pH of the soil stabilized.

Determining total organic carbon: Soil total organic carbon content was determined by the titrimetric method using the Walkley-Black technique[17]. Labeled samples were taken and ground to pass through 0.5 mm sieve. Samples were weighed in duplicate and transferred to 250 mL Erlenmeyer flask. Ten milliliters (10 mL) of 1N $K_2Cr_2O_7$ solution was pipetted into each flask and the solution was gently swirled and dispensed. Then, 20 mL of a 20% H_2SO_4 was added using an automatic pipette, directing the stream into the suspension. The mixture was allowed to stand for 30 min before adding 100 mL of distilled water. Four drops of indicator were added to the mixture and titrated with 0.5N ferrous sulfate solution. The solution turned a greenish color and then changed to dark green, which indicated the presence of carbon:

$$\text{Total organic carbon (\%)} = \frac{\text{Blank titer - Sample titer} \times 0.2 \times 0.3}{0.1\,\text{g}}$$

Determining total organic matter: Total organic matter (TOM) was determined by calculation using total organic carbon result. This was calculated using the formula[18]:

$$\text{Total organic matter (\%)} = \text{TOC (\%)} \times 1.72$$

Determining total hydrocarbon content: A modified approach published by Akpan and Usuah[19] was used to determine the total hydrocarbon content in the polluted soil samples before planting and after the study. The hydrocarbon content in the oil-polluted soil was extracted using 10 mL of n-hexane after 10 g of soil samples were measured into a 50 mL flask. In order to completely separate the oil from the soil sample, the mixture was agitated violently on a magnetic stirrer for 30 min and then let to stand for 10 min. A Whatman filter paper was used to filter the solution, and the filtrate was then diluted by adding 1 mL of the extract to 50 mL of n-hexane. Utilizing n-hexane as a blank, the absorbance of this solution was measured in a spectrophotometer at 480 nm. It was then represented as mg/kg of total hydrocarbon content.

Determination of soil moisture content: The moisture content of soil is described as the ratio of the mass of water held in the soil to the dry soil:

$$\text{Soil moisture content (\%)} = \frac{\text{Fresh weight - Dry weight}}{\text{Dry weight}} \times 100$$

Nature of soil physicochemical composition used: Table 1 shows the initial composition of some of the physicochemical parameters assessed before the planting of *R. racemosa*.

Statistical analysis: The data collected were subjected to Analysis of Variance (ANOVA) using Microsoft Excel. Significant means were separated using the least significant difference at 5% probability level (LSD 0.05).

Table 1: Some physicochemical compositions of the soil before planting *R. racemosa*

Parameter	Garden soil (GS)	Spent engine oil polluted soil (GSSEO)
TOM (%)	11.70	20.60
TOC (%)	12.10	6.80
THC (mg/kg)	29.95	62.15
SMC (%)	12.70	14.10
pH	6.76	6.09

TOM: Total organic matter, TOC: Total organic carbon, THC: Total hydrocarbon content and SMC: Soil moisture content

Table 2: Physico-chemical profile of soil after the study

Parameter	GS	GSB	GSSEO	GSBSEO	LSD
TOM (%)	17.60±0.63^{ab}	20.70±1.59^{a}	15.10±0.11^{b}	13.20±0.60^{b}	4.60
TOC (%)	9.70±0.50^{b}	12.00±0.06^{a}	8.80±0.60^{b}	7.62±0.30^{b}	2.12
THC (mg/kg)	34.88±4.81^{c}	42.68±3.98^{b}	59.66±9.45^{a}	57.65±3.50^{a}	3.11
SMC (%)	21.40±0.32	24.63±0.20	17.20±0.15	19.77±0.19	NS
pH	6.37±0.03	6.78±0.02	6.42±0.06	6.57±0.02	NS

Mean±Standard Error, LSD: Least significant difference, NS: Not significant at $p>0.05$ and Means with different alphabet across treatments are significantly different

RESULTS AND DISCUSSION

The results from this study showed significant alterations in soil physico-chemical composition following the application of biochar and spent engine oil amendments, as shown in Table 2. The introduction of biochar into the soil increases soil organic carbon, soil organic matter, and moisture content of the soil when compared with the spent engine oil amendments, while the reverse was the case for total hydrocarbon content. Also, biochar increases the pH of the garden soil with respect to the control treatment.

The result revealed that total organic matter (TOM) was highest in the biochar-amended soil (GSB) at 20.7%, followed by the garden soil control (GS), indicating the organic-enriching potential of biochar. This aligns with Dong *et al.*[20], who reported that biochar application increases soil organic matter content due to its stable carbonaceous composition. The observed reduction in TOM in the soils treated with spent engine oil (GSSEO and GSBSEO) suggests that oil contamination may interfere with organic matter stabilization, possibly by inhibiting microbial decomposition processes essential for humus formation[21,22].

Similarly, total organic carbon (TOC) followed a comparable trend, where GSB recorded the highest value (12.0%) and GSBSEO the lowest (7.62%). The increase in TOC under GSB corroborates reports by Zubairu *et al.*[23] that biochar, being carbon-rich, contributes to elevated TOC levels, improving nutrient retention and soil fertility. However, the presence of spent engine oil significantly reduced TOC, likely due to the complex hydrocarbon composition of the oil that can inhibit microbial activity and carbon mineralization[24-26]. The total hydrocarbon content (THC) was predictably highest in soils treated with spent engine oil (GSSEO and GSBSEO), measuring 59.66 and 57.65 mg/kg, respectively, compared to much lower values in GSB and GS. These elevated levels indicate residual contamination, which may pose ecological risks if not managed properly. Although some studies suggest that certain hydrocarbons may be metabolized by hydrocarbonoclastic organisms, enabling limited bioremediation[27,28], the persistently high THC levels in this study suggest that either the microbial population was insufficient or that oil degradation was limited within the study period.

Soil moisture content (SMC) was generally higher across all treatments than in the pre-treatment soils, with the biochar-amended soil (GSB) having the highest SMC (24.63%). This supports previous findings that biochar improves soil water retention due to its porous nature and large surface area[29]. Interestingly, even the spent engine oil-contaminated soils (GSSEO and GSBSEO) maintained appreciable moisture levels, which could be attributed to the hydrophobic nature of hydrocarbons that reduce evaporation losses. However, this moisture may not be entirely available for plant uptake due to possible toxicity effects on root physiology[30]. Also, Soil pH remained near neutral across all treatments, with values ranging between 6.37 and 6.78, and no significant differences were observed statistically. Notably, GSB had the highest pH (6.78), reflecting the liming effect of biochar, which has been documented to moderate soil acidity and improve nutrient availability[31]. On the other hand, soils treated with spent engine oil did not show marked acidification, indicating that the short-term application of 6% oil concentration may not be sufficient to alter pH significantly, contrary to some long-term studies where petroleum hydrocarbons lead to soil acidification and nutrient immobilization[32,33].

CONCLUSION

This study demonstrated that soil amendment with biochar significantly improved key soil physico-chemical properties such as total organic matter, organic carbon, and moisture content, enhancing conditions suitable for the growth of *R. racemosa*. In contrast, the addition of spent engine oil, while increasing hydrocarbon content, reduced organic matter and carbon levels, potentially posing environmental and ecological risks. However, when combined, biochar appeared to buffer some of the negative impacts of the oil, suggesting its potential role in remediating polluted soils. These findings underscore the value of biochar as a sustainable soil amendment, particularly in degraded or oil-impacted coastal environments. Further long-term studies are recommended to assess the cumulative effects on soil health, microbial dynamics, and plant productivity.

SIGNIFICANCE STATEMENT

This study demonstrates that biochar can effectively improve the quality of hydrocarbon-polluted soils, enhancing soil organic matter, carbon content, and water retention, while mitigating the negative effects of spent engine oil. These findings provide practical insights for the rehabilitation of degraded coastal soils and support the sustainable growth of ecologically important mangrove species like *Rhizophora racemosa*.

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