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IMPACT OF CASSAVA PEEL ON SOIL NUTRIENT AND MICROBIAL RESTORATION OF CRUDE OIL CONTAMINATED SOIL IN RIVERS STATE, NIGERIA

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ABSTRACT

The decrease in essential soil nutrients and microbial load in crude oil-contaminated soils poses a significant challenge to soil restoration efforts. This research was conducted to investigate the impact of cassava peel waste on enhancing soil nutrients and restoring microbial communities in crude oil-polluted soils. The study employed a Complete Randomized Design with the following treatments: ***T1:*** *Crude oil-contaminated soil + 100g cassava peel waste;* ***T2:*** *Crude oil-contaminated soil + 200g cassava peel waste;* ***T3:*** *Crude oil-contaminated soil + 300g cassava peel waste;* ***T4:*** *Crude oil-contaminated soil only (control) + 0g cassava peel waste* ***T5:*** *Uncontaminated soil only (control) + 0g cassava peel waste. Two seedlings of Abelmoschus esculentus were planted in each treatment to assess the effects on plant growth. The application of cassava peel waste in crude oil-polluted soils (T1-810.05mg/kg; T2-809mg/kg; T3-640.5mg/kg) resulted in a significant decrease in Total hydrocarbon (THC) compared to (T4-1350mg/kg). Among the treatments, T3 exhibited the greatest reduction in THC. The highest mean values of potassium (K-32.3 mg/kg), and phosphorus (P-14.8 mg/kg) were recorded in T3 and T1 for nitrogen (N- 4.92 mg/kg) content. The height of the plants varied across the treatments, with the highest measurements recorded in T1 during week 2 (15.3 cm), T3 during weeks 4 and 8 (19.6 cm and 36.9 cm, respectively), and T2 during week 6 (26.3 cm). Additionally, T4 and T5, showed the least reduction in leaf number, stem girth, fresh and dry weight, and microbial population. Higher microbial loads were observed in the treatments with cassava waste T1 at 6wks and 8kws (24.0 x10^4; 26.0 x10^4); T3 at 2wks and 4kws (7.31 x10^4; 17.2x10^4) compared to the untreated contaminated soil (T4). This increase in microbial population is essential for the biodegradation of hydrocarbons and the overall recovery of soil health. The study highlights the potential of cassava peel as a cost-effective and environmentally friendly amendment that can be utilized in large-scale soil restoration efforts, particularly in regions affected by crude oil pollution.*

Keywords: *Abelmoschus esculentus*, Soil, Crude oil, cassava peel, bioremediation

INTRODUCTION

Rivers State, Nigeria, is one of the regions significantly affected by crude oil pollution due to extensive oil extraction and production activities. The environmental consequences of crude oil spills in this area are severe, leading to soil degradation, loss of fertility, and a decline in microbial populations essential for soil health. These adverse effects pose a substantial challenge to agricultural productivity and ecological stability in the region (Amadi *et al*. 2023). Soil is a dynamic and complex natural resource that forms the uppermost layer of the Earth's crust. It is a fundamental component of terrestrial ecosystems, playing a crucial role in supporting plant life, regulating water cycles, and sustaining biodiversity. Soil is composed of a mixture of mineral particles, organic matter, water, air, and living organisms, each contributing to its overall structure and function. The study of soil, known as soil science or pedology, encompasses its formation, classification, and mapping, as well as its physical, chemical, and biological properties (Coleman *et al*., 2017). Soil particles are primarily composed of minerals, which can vary in type and size. Common minerals found in soil include quartz, feldspar, and clay minerals range from large gravel and sand particles to much smaller silt and clay particles. The classification of these particles is based on their size: particles larger than 2 mm in diameter, between 0.06 mm and 2 mm, between 0.002 mm and 0.06 mm and smaller than 0.002 mm for gravel, sand, silt and clay respectively which are used in construction and various industries (Weil and Brady, 2016; Uyigue &Agbo, 2017). Soil is home to an immense variety of organisms, ranging from bacteria and fungi to insects and earthworms. These organisms are integral to nutrient cycling, organic matter decomposition, and soil structure maintenance, contributing to overall ecosystem health and resilience (Coleman *et al*., 2017).Soil plays a key role in the global water cycle by regulating the infiltration, storage, and purification of water. It acts as a natural filter, removing pollutants and providing clean water to ecosystems and human populations (Brady and Weil, 2016). Soil is a significant carbon sink, storing more carbon than the atmosphere and all plant biomass combined. This capacity for carbon sequestration helps mitigate climate change by reducing atmospheric carbon dioxide levels (Lal, 2004; Nwilo & Badejo, 2005).The Niger Delta region of Nigeria, known for its rich biodiversity and vast oil reserves, faces significant environmental challenges due to extensive industrial activities, particularly oil exploration and extraction. The soil in this region has experienced various forms of degradation, impacting agriculture, ecosystems, and the livelihoods of local communities such as oil spills, toxicity, gas flaring resulting in soil acidification, and thermal effects, deforestation and land use changes leading to loss of vegetation and soil compaction (Amadi *et al*., 1993; Ana *et al*., 2009; Chindah and Braide, 2000; Obioh*et al*., 2012).

Incorporating organic matter such as compost, manure, and biochar can improve soil structure, enhance microbial activity, and increase nutrient availability. This practice helps in restoring soil fertility and productivity (Egharevba and Ataga, 2003). Cassava peels and other organic wastes can be composted to produce organic fertilizer. This compost enriches soil fertility and improves soil structure, promoting sustainable agriculture (Ogunwande*et al*., 2008). Cassava peels are rich in carbohydrates, primarily in the form of starch, but they also contain fiber, protein, and minerals. However, the nutritional value is lower than the flesh of the tuber (Oladunjoye *et al*., 2010).Cassava, scientifically known as *Manihotesculenta*, is the third major source of carbohydrates globally, with its diverse uses varying by community. It plays a crucial role in food security for millions in developing countries, particularly in tropical regions. According to Akoroda and Ekanayake (2005), cassava is an essential staple crop, ranking fourth in importance worldwide after rice, wheat, and maize (Agbogidi, 2023a). The most extensive cultivated cassava are *Manihot esculenta* (sweet cassava) and *Manihot utilissima* (bitter casssava). Both varieties form hydrocyanic acid during processing, a compound that can be toxic if not properly removed either by prolong dryness or otherwise. Okoye and Onuorah (2023) noted that hydrogen cyanide can be effectively removed through cooking or fermenting the cassava in water for a specific period. Cassava tubers are primarily known for their high carbohydrate content, which constitutes about 85.9% of their composition. However, they contain very little protein, with only about 1.3% present (Nawbueze and Odunsi, 2007; Okerentugba, & Ezeronye, 2003). This high carbohydrate content makes cassava an energy-rich food source, which is vital for many people in developing countries who rely on it as a staple food. Cassava tubers are typically harvested between 7 to 12 months after planting, depending on the cultivar. The harvesting period is crucial as it affects the yield and quality of the tubers. Proper timing ensures that the tubers have developed sufficient carbohydrates while minimizing the formation of cyanogenic-glucosides. Cassava's importance extends beyond its nutritional value. It serves various purposes, including being used as a raw material for producing different products such as tapioca, cassava flour, and animal feed. In many communities, cassava leaves are also consumed as vegetables, providing additional nutrients.

The use of agricultural waste, particularly cassava waste, has emerged as a promising approach to address these challenges. Cassava is widely cultivated in Nigeria, and its processing generates large amounts of waste, primarily peels and pulp, which can be repurposed for environmental restoration. This approach not only provides a solution for waste management but also contributes to soil and microbial restoration in crude oil-contaminated areas (Okoye and Onuorah 2023).

Aim

The primary aim of this research is to evaluate the effectiveness of cassava peel waste in remediating crude oil-polluted soil and enhancing the restoration of essential soil nutrients.

Objective

This study addressed the following key objectives:

1. Investigate the ability of cassava waste to degrade and reduce the concentration of crude oil contaminants in polluted soil.
2. Analyze the changes in soil nutrient levels (such as nitrogen, phosphorus, potassium, and organic matter) following the application of cassava waste to crude oil-contaminated soil.
3. Compare the nutrient profiles of treated soil with those of untreated polluted soil and unpolluted control soil.
4. Monitor the changes in soil microbial populations and activity levels, which are critical for the degradation of hydrocarbons and the cycling of nutrients.

MATERIALS AND METHODS

Study Area

This experimental was conducted at the Department of Forestry and Environment Ecological Centre, Rivers State University, situated in the tropical rainforest region of southern Nigeria, known as the Niger Delta. The region experiences daily temperatures of 36°C and an annual average temperature of 28°C. It has two distinct seasons: the rainy season, which spans from April to October, and the dry season, from November to March. The climatic conditions, characterized by an annual rainfall of 2400mm, high humidity, and significant sunshine, adversely affect the nutrient patterns in the area (Dike and Nwachukwu, 2003).

Sample collection, processing and analysis

Crude oil-polluted soil was excavated from a Hydrocarbon Pollution Remediation Project

(HYPREP) site in Ogale, Eleme, Rivers State, and transported to the experimental research center at Rivers State University. Uncontaminated soil was collected from a fallow farmland in the research area. Both soil samples were air-dried and sieved through a 2mm wire mesh to obtain a homogeneous fine fraction of soil composites. Cassava peels were sourced from local farmers in the Ibaa Community, Rivers State. The collected cassava peel waste, obtained through a mechanical process, were dried and processed into a powdered form. Both the cassava waste and soil samples were analyzed for nutrient components. Additionally, the soil was examined for nutrient content and microbial load to establish a baseline data.

Physicochemical properties of the crude oil polluted and unpolluted soil

Parameter	Crude oil soil	Control soil
Bulk density	1.89	1.1
Particle density	5.2	4.3
Porosity	0.34	0.45
THC mg/kg	1465	1.92
TOC%	8.9	1.8
CEC meq/100g	5.3	20.5
N mg/kg	5.03	13
P mg/kg	10	45
K mg/kg	12	26
pH	8.5	6.4
Ca mg/kg	1.03	8.45
THBC	1.2×10^5.	3.4×10^5.

Proximate analysis of cassava peel waste

Parameter	**Cassava peel waste**
TPH mg/kg	Nil
TOC%	1.02
CEC meq/100g	73.4
N mg/kg	1.87
P mg/kg	2.89
K mg/kg	248
pH	8.5
Ca mg/kg	1.03

Experimental Design and Treatment Application

Adopting a Complete Randomized Design, two kilograms (2 kg) of soil were introduced into each of 4 planting bags with 5 replications for each treatment option. The treatments were as follows:

T1: Crude oil-contaminated soil + 100g cassava peel

T2: Crude oil-contaminated soil + 200g cassava peel

T3: Crude oil-contaminated soil + 300g cassava peel

T4: Crude oil-contaminated soil only (control) + 0g cassava peel

T5: Uncontaminated soil only (control) + 0g cassava peel

This setup was allowed to stand for 1 week for proper acclimatization. Two seedlings of *Abelmoschusesculentus* (okra), raised in a nursery, were then transplanted into each experimental plot and monitored for 2 months. The morphological properties such as stem girth, number of leaves and stem length and microbial load were measuredat2 weeks interval while fresh and dry weight were measured at termination. Weeding weremanually controlled when necessary. At the conclusion of the experiment, soil samples from each treatment were sieved using a 2 mm mesh before the determination of soil microbiological and physicochemical properties.

Determination of Physicochemical Parameter

Chemical determination

Soil pH was determined electronically using a glass electrode pH meter (PHS. 25 Model). The soil was dried and sieved through a 2 mm sieve to remove coarse particles before analysis. Soil phosphorus and nitrogen content were determined using the Oxidation-Ascorbic acid and Kjeldahl methods, respectively (Stewart *et al*., 1974). Soil potassium and calcium content were measured using an atomic absorption spectrometer (AAS) following the digestion method. The cation exchange capacity (CEC) was obtained, and the mean soil CEC for the different treatments was calculated and expressed in meq/100g of the sample. The total hydrocarbon content (THC) was determined using the spectrophotometer method. A one gram (1g) sample of oven-dried soil was weighed and transferred into a test tube, followed by the addition of 10 ml of 99.9% chloroform. The test tube was corked and shaken for 15 seconds, then placed on a rack until a clear supernatant and sediment formed. The supernatant was read in a Shooter spectrophotometer at a wavelength of 420 nm, using pure chloroform as the blank. The concentration of THC was extrapolated from a standard graph plotted for Bonny Light and Bonny Medium crude oil.

The total organic carbon (TOC) was determined using the oxidation method. A one gram (1g) sample was weighed and transferred into a clean 250ml conical flask. Then, 5ml of potassium dichromate and 7.5ml of concentrated sulfuric acid were added. The mixture was heated on an electro-thermal heater for about 15 minutes to allow oxidation to occur. After heating, the mixture was allowed to cool to room temperature and then diluted to 100ml with distilled water. Subsequently, 25ml of this solution was titrated with ferrous ammonium sulfate using ferroin as an indicator. A blank was prepared and treated in the same manner. The titer value was recorded, and the total organic carbon was calculated based on this value:

formula.
$$\% \text{ TOC} = \frac{\text{Titre value of blank-titre value of sample} \times 0.2 \times 0.3}{\text{Weight of sample}}$$

Microbial determination

The total heterotrophic bacteria count (THBC) was analyzed using medium nutrient agar. To prepare the nutrient agar, 28g of powder was added to 1 liter of distilled water and autoclaved at 121°C for 15 minutes. The solution was then allowed to stand for about 45 minutes before being poured into sterilized Petri dishes and left to solidify. Any excess moisture was removed from the agar using a hot air oven set at 60°C. 1g soil sample was weighed and transferred into 9 ml of a sterile diluent for serial dilution. 0.1 ml aliquot of the diluted sample was aseptically inoculated onto duplicated agar surfaces using a sterile pipette. The inoculum was spread uniformly with a sterile glass rod and incubated at 37°C for 24 hours. Colony-forming units (CFU/g) were then calculated based on the resulting bacterial colonies.

Morphological determination

Shoot length (cm) was measured weekly using a centimeter rule, positioned from the stem's base at the soil surface to the terminal shoot apex. The number of leaves in each planting bag was counted and recorded, and stem girth was measured with a Vernier caliper. Fresh weight was measured immediately after harvest using a digital weighing balance (Ohaus, HSC4010). Dry weight was determined by the loss on drying method.

Data Analysis

The data generated were subjected to statistical analysis of variance (ANOVA) using Statistical Analysis System (SAS, 2002) to test the significance of cassava waste on soil characteristics and plant growth. Least Significant Difference (LSD) was used to analyze the data obtained.

RESULTS

Effect of Cassava Peels Waste on Soil Cation Exchange Capacity

The results established a high level of cation exchange capacity (CEC) in soils treated with cassava peel waste. The treatments with cassava peel waste notably enhanced the CEC across various experimental conditions. The highest CEC was observed in T5 (24.8 **meq** / 100), the unpolluted soil (double control), which did not receive any cassava treatment. This indicates the inherent high CEC of the unpolluted soil. Soils treated with different amounts of cassava peel waste (T1, T2, and T3) showed a significant increase in CEC compared to the control polluted soil (T4). This suggests that cassava peel waste effectively enhances the soil's ability to retain and exchange cations, potentially improving soil fertility and health. The lowest CEC was found in T4, the control polluted soil without any treatment. This underscores the detrimental impact of crude oil contamination on soil CEC. The differences in CEC levels within and between the various treatments were statistically significant at $p < 0.05$ as shown in Fig 1.

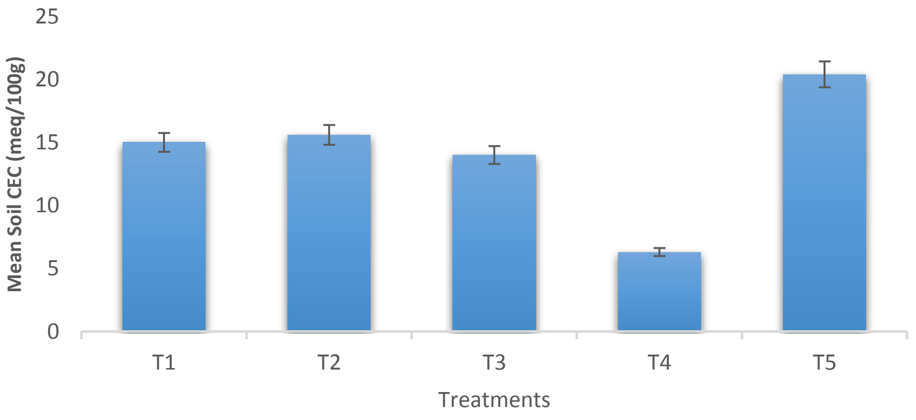

Fig 1: Effect of different levels of treatments on soil CEC

Effect of Cassava Peels Waste on Soil Potassium

There was an increase in soil potassium (K) content treated with cassava peel waste. The most substantial increase in potassium was observed in T3 (crude oil-contaminated soil with 300g of cassava peel waste). However, all soils treated with varying amounts of cassava peel waste (T1, T2, and T3) exhibited significant increases in potassium levels compared to the control treatments. The highest increase in potassium was recorded in T3 (32.3 mg/kg), which received 300g of cassava peel waste. This indicates that a higher amount of cassava peel waste significantly boosts the potassium content in the soil. Significant increases in potassium were also noted in T1 (100g cassava peel waste) and T2 (200g cassava peel waste), demonstrating the positive impact of cassava peel waste on soil potassium levels across different application rates. The lowest potassium levels were found in T4, the control polluted soil without any treatment. This highlights the adverse effect of crude oil contamination on soil potassium content. The differences in potassium levels within and between the various treatments were statistically significant at $p < 0.05$ as shown in Fig 2.

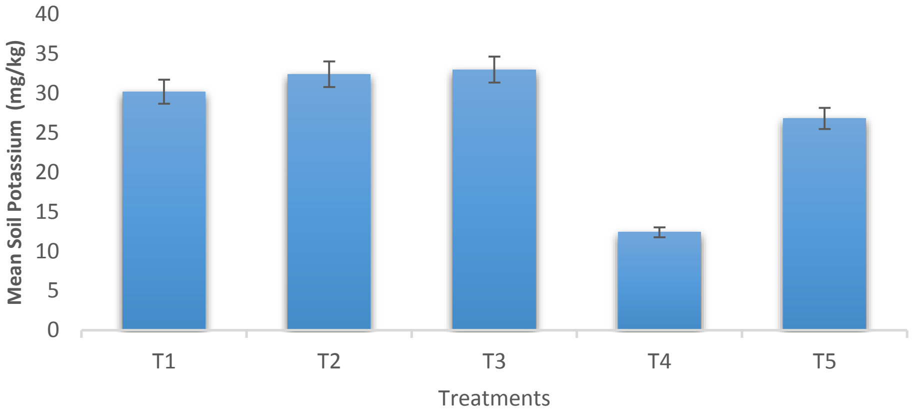

Fig2: Effect of different levels of treatments on soil potassium

Effect of Cassava Peels Waste on Soil Nitrogen

The lowest nitrogen levels were found in T4, the control polluted soil without any treatment. This highlights the negative impact of crude oil contamination on soil nitrogen content Significant increases in nitrogen were also observed in T2 (200g cassava peel waste) and T3 (300g cassava peel waste), confirming the positive effect of cassava peel waste on soil nitrogen levels across different application rates. The highest increase in nitrogen was recorded in T1 (4.92 mg/kg), which received 100g of cassava peel waste. This suggests that even a relatively small amount of cassava peel waste can significantly enhance soil nitrogen content. There were significant differences in nitrogen levels within and between the various treatments were statistically significant at $p < 0.05$ as shown in Fig 3

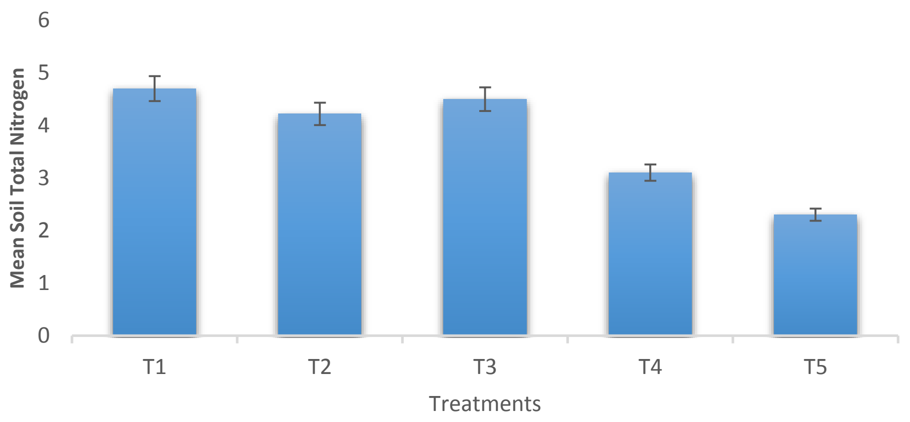

Fig3: Effect of different levels of treatments on soil total nitrogen

Effect of Cassava Peels Waste on Soil Phosphorus

The results indicate that phosphorus (P) levels significantly increased in soils treated with waste cassava, with the highest increase observed in the T3 (14.8 mg/kg) treatment. This suggests that cassava treatment positively affects phosphorus availability in the soil. In contrast, the control soil (T5), which was not treated, exhibited the lowest phosphorus levels. The statistical analysis confirms that there are significant differences in phosphorus levels both within the various treatments and between treatments, with a p-value of 0.05. This emphasizes the impact of cassava treatment on enhancing soil phosphorus as shown in Fig 4

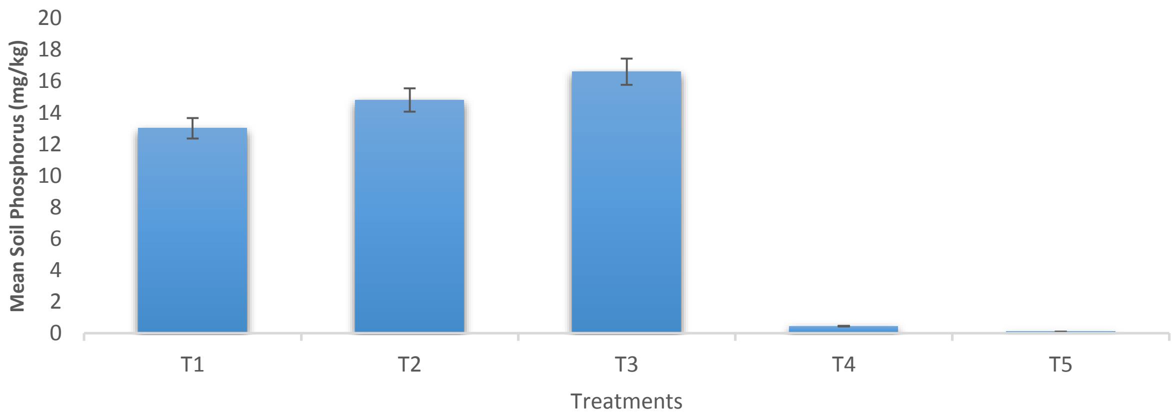

Fig4: Effect of different levels of treatments on soil phosphorus

Effect of Cassava Peels Waste on Soil THC

The results indicate a reduction in total hydrocarbon content (THC) with the application of waste cassava treatment, with the least reduction observed in the T3 (640.5mg/kg) treatment. Despite this reduction, soils treated with cassava exhibited a significant increase in THC compared to untreated soils. Notably, the highest THC levels were found in the control polluted soil (T4), which did not receive any treatment. Statistical analysis reveals significant differences in THC levels both within the various treatments and between treatments, with a p-value of 0.05. This underscores the influence of cassava treatment on altering THC levels in soil as shown in Fig 4.

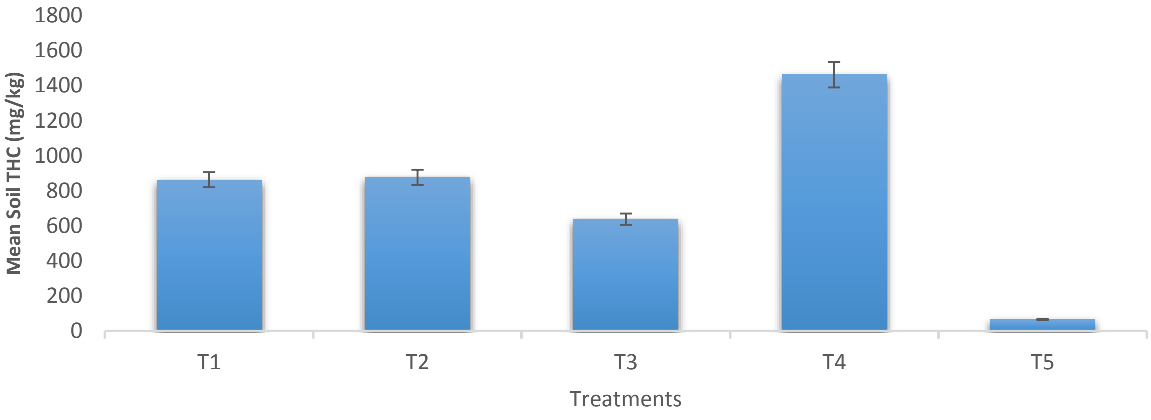

Fig4: Effect of different levels of treatments on soil THC

Effect of Cassava Peels Waste on Soil TOC

The results indicate a reduction in total organic carbon (TOC) with waste cassava treatment, with the smallest decrease observed in the T1 treatment. Interestingly, soils subjected to various levels of cassava treatment demonstrated a significant overall increase in TOC compared to untreated soils. The highest TOC levels were recorded in the control polluted soil (T4), which did not receive any cassava treatment. Statistical analysis confirms significant differences in TOC levels both within the treatments and between treatments, with a p-value of 0.05. This highlights the complex impact of cassava treatment on soil TOC dynamics.

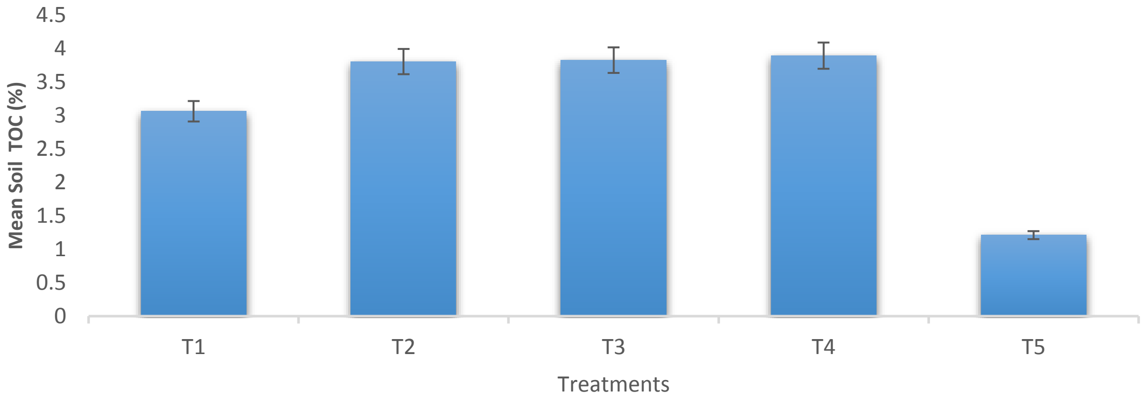

Fig6: Effect of different levels of treatments on soil TOC

Plant Height

An increase in the height of *Abelmoschusesculentus* was found with different levels of cassava treatment at various weeks. The highest increment in height was recorded at T1 for 2 weeks, T3 for 4 and 8 weeks and T2 for 6 weeks as shown in Table 1.

Table 1: Height (cm) of *Abelmoschusesculentus* (okra), in various cassava waste treatment option

S/N	Treatment Application	Wk2	Wk4	Wk6	Wk8
T1	Crude oil-contaminated soil + 100g cassava peel waste	15.3	16.8	21.0	26.5
T2	Crude oil-contaminated soil + 200g cassava peel waste	10.5	18.7	26.3	31.2
T3	Crude oil-contaminated soil + 300g cassava peel waste	11.2	19.6	22.8	36.9
T4	Crude oil-contaminated soil + 0g cassava peel waste	5.3	6.8	6.9	7.3
T5	Uncontaminated soil only + 0g cassava peel waste	14.3	21	28.6	33.8

Number Leaves

Increase in the number of leaves was recorded with various levels of treatment application and time. Increase in number leaves was highest at 100g, 200g and 300g treatment application as compared to control at 2 weeks. The highest at 4 weeks was recorded at T3, while 6 weeks and 8 weeks were recorded at T2 and T1 respectively.

Table 2: Number leaves of *Abelmoschus esculentus* (okra), in various cassava waste treatment option

S/N	Treatment Application	Wk2	Wk4	Wk6	Wk8
T1	Crude oil-contaminated soil + 100g cassava peel waste	3	4	7	22
T2	Crude oil-contaminated soil + 200g cassava peel waste	3	8	14	17
T3	Crude oil-contaminated soil + 300g cassava peel waste	3	10	12	16
T4	Crude oil-contaminated soil + 0g cassava peel waste	2	2	4	6
T5	Uncontaminated soil only + 0g cassava peel waste	3	7	9	18

Stem Girth, Fresh and Dry Weight.

The results in table 5, recorded a corresponding increase in stem girth with various treatment application. The least decrease in stem girth was found in T4 at various weeks. Result in Table 6 also suggest an increase in plant fresh and dry weight with treatment application. The least decrease was also reported in crude oil contaminated soil with 0g cassava peel amendment (T4)

Table 3: Stem girth (mm) of *Abelmoschus esculentus* (okra), in various cassava waste treatment option

S/N	Treatment Application	Wk2	Wk4	Wk6	Wk8
T1	Crude oil-contaminated soil + 100g cassava peel waste	0.2	0.32	0.35	0.38
T2	Crude oil-contaminated soil + 200g cassava peel waste	0.22	0.31	0.43	0.45
T3	Crude oil-contaminated soil + 300g cassava peel waste	0.25	0.3	0.34	0.49
T4	Crude oil-contaminated soil + 0g cassava peel waste	0.1	0.1	0.2	0.21
T5	Uncontaminated soil only + 0g cassava peel waste	0.2	0.28	0.34	0.4

Table 4: Fresh and Dry weight (g) of *Abelmoschus esculentus* (okra plant), in various cassava waste treatment option

S/N	Treatment Application	Fresh weight	Dry weight
T1	Crude oil-contaminated soil + 100g cassava peel waste	16	10
T2	Crude oil-contaminated soil + 200g cassava peel waste	14	9
T3	Crude oil-contaminated soil + 300g cassava peel waste	18	12
T4	Crude oil-contaminated soil + 0g cassava peel waste	7	4
T5	Uncontaminated soil only + 0g cassava peel waste	15	11

Microbial Load

Increase in microbial load was recorded across treatment option. A gradual increase in microbial load was recorded across number of weeks. Highest increase in hydrocarbon utilizing bacteria was found at week 6 and 8 for T1while T2 and T3 showed highest increment in microbial loadT2 and T3 at week 2 and 3 respectively.

Table 5:HUBC (CfU g-1) in various cassava waste treatment option

S/N	Treatment Application	WK2	Wk4	Wk6	Wk8
T1	Crude oil-contaminated soil + 100g cassava peel	6.2×10^4	12.6×10^4	24×10^4	26×10^4
T2	Crude oil-contaminated soil + 200g cassava peel w	7.4×10^4	17.2×10^4	22×10^4	22.65×10^4
T3	Crude oil-contaminated soil + 300g cassava peel	7.31×10^4	16.45×10^4	21×10^6	21.76×10^4
T4	Crude oil-contaminated soil + 0g cassava peel	2×10^6	3×10^4	3.4×10^4	5×10^4
T5	Uncontaminated soil only + 0g cassava peel waste	6.9×10^6	9×10^4	11×10^6	16.01×10^4

DISCUSSION

Soil contamination by crude oil is a significant environmental concern, particularly in regions with extensive oil extraction activities. The presence of crude oil in soil not only hampers plant growth and soil fertility but also poses severe risks to groundwater quality and the broader ecosystem. Traditional remediation methods, such as mechanical removal and chemical treatments, can be costly and environmentally disruptive. Consequently, there is a growing interest in innovative and sustainable approaches for soil remediation. One such promising method is the use of agricultural waste, particularly cassava waste, for bioremediation (Abosede 2013). Increase in soil physicochemical, microbial and morphological properties was recorded optimal with application of various concentrations of cassava waste in a polluted soil. The highest increment in soil potassium content in 300g cassava waste amendment could be attributed to macro nutrient content in waste cassava peel. Cassava peels are rich in several essential nutrients, including potassium. Potassium is a vital plant nutrient involved in various physiological processes such as enzyme activation, photosynthesis, protein synthesis, and regulation of water uptake and movement within the plant. The peels contain potassium in a form that is readily available for microbial and plant uptake. When cassava peels are applied to soil, they undergo decomposition through microbial activity. During this decomposition process, the organic matter in the peels breaks down, releasing the contained nutrients into the soil. Potassium, being one of these nutrients, becomes available in the soil solution where it can be taken up by plants or contribute to the soil's overall fertility. Additionally, 300g, there is likely an optimal balance between the amount of organic material and microbial activity. This balance ensures efficient decomposition without overwhelming the soil system, leading to a consistent and significant release of potassium. Studies have demonstrated that the addition of cassava peel amendments to soil significantly increases the potassium content. Onwudike *et al*. (2016) who reported that soil treated with 300g of cassava peel showed the highest increase in potassium content compared to other amendment levels. This result also agrees with the report of Amadi *et al* (2023) who observed high concentration of essential soil nutrient present in biostimulants (organic waste) making it available for plant optimal productivity through the breakdown process facilitated my hydrocarbon eaters (HUBC).The highest soil CEC recorded at T5 (uncontaminated soil) as compared to other treatment option. This could be attributed the hydrocarbons pollutant, can disrupt the soil structure and its chemical properties. These contaminants can bind to soil particles and organic matter, blocking the negatively charged sites that would otherwise hold nutrient cations. This results in a lower CEC. The presence of pollutants can also lead to the alteration of clay minerals, reducing their effectiveness in cation exchange. Some pollutants may cause clay minerals to aggregate or become less reactive, further diminishing the soil's CEC. Furthermore, higher CEC in unpolluted soils is primarily due to the greater presence of organic matter, intact and reactive clay minerals, and stable pH levels, all of which enhance the soil's ability to hold and exchange cations. Similar result was also report in a study by Adebayo and Nwankwegu (2018) examined the effects of crude oil pollution on soil properties, including CEC. They found that unpolluted soils exhibited significantly higher CEC compared to polluted soils, attributing the difference to higher organic matter content, intact clay minerals, and stable pH levels in unpolluted soils. Increase in the concentration of phosphorus and nitrogen is understandable since the added biostimulants contain a good amount of the aforementioned nutrient. Nitrogen and phosphorus could be made available during microbial disintegration. Studies have shown that moderate levels of organic amendments can significantly enhance nutrient availability. The findings corroborated with Agbo *et al.* (2019) who reported that the application of 100g of cassava peel waste resulted in increased levels of nitrogen and phosphorus in the soil, compared to untreated and heavily treated soils. Polluted soils often have reduced microbial activity and degraded soil structure due to the presence of contaminants. These factors limit the natural nutrient cycling processes, resulting in lower levels of available nitrogen and phosphorus. In a study by Abdulfattah *et al*. (2016), crude oil-polluted soils showed significantly lower nutrient levels compared to amended soils, highlighting the negative impact of pollutants on soil fertility.

The decrease in Total Hydrocarbon Content (THC) and Total Organic Carbon (TOC) in crude oil-polluted soil following cassava waste treatment can be explained by several mechanisms related to the bioremediation and nutrient dynamics influenced by the amendment. These findings seems accurate since cassava waste serves as an organic amendment that provides additional nutrients and organic matter to the soil. This enrichment stimulates the growth and activity of hydrocarbon-degrading microorganisms, such as bacteria and fungi, which are essential for breaking down crude oil pollutants hence resulting in THC and TOC reduction. This finding agrees with Onwudike *et al*. (2016) who demonstrated that the application of cassava peel powder significantly increased the microbial population capable of degrading hydrocarbons, leading to a notable reduction in THC in contaminated soils. This result also agrees with Agbo *et al.* (2019) who observed that cassava waste application led to improved nutrient availability, which in turn boosted microbial degradation of crude oil, resulting in lower THC levels. The increase in morphological character such as plant height, number of leaves, stem girth, fresh weight, and dry weight following soil amendment with cassava waste can be attributed to several beneficial effects that cassava waste has on soil health and plant growth. These effects include improved soil fertility, enhanced nutrient availability, and increased microbial activity, which collectively support better plant development. Cassava waste is rich in essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K). When added to the soil, it provides these critical nutrients, which are crucial for plant growth and development. Nitrogen promotes vegetative growth. According to Agbo *et al.* (2019), the application of cassava peel waste significantly improved soil nutrient levels, leading to better plant growth parameters, including increased plant height, number of leaf, and biomass. The result obtained is in agreement with Adebayo and Nwankwegu (2018) who reported that soil treated with organic amendments like cassava waste showed improved soil structure and water retention, which contributed to increased plant growth and biomass. Onwudike *et al*. (2016) observed that cassava waste application increased microbial populations in the soil, leading to improved nutrient availability and enhanced plant growth. Abdulfattah et al. (2016) reported that plants grown in soil amended with organic wastes like cassava peels exhibited enhanced root growth, which was associated with increased plant height, stem girth, and overall biomass. With an increased HUBC, the efficiency of hydrocarbon degradation improves. Hydrocarbon-degrading bacteria break down crude oil components into less harmful substances, leading to a reduction in Total Hydrocarbon Content (THC) and overall soil pollution. Adebayo and Nwankwegu (2018) found that higher levels of HUBC in soils treated with cassava waste led to more effective bioremediation of crude oil contaminants, demonstrating the role of increased microbial populations in accelerating the cleanup process.

CONCLUSION

Cassava waste has demonstrated significant potential in ameliorating the impact of crude oil pollution on soil through a multifaceted approach that enhances soil health and accelerates bioremediation processes. The application of cassava waste in crude oil-polluted soils offers a sustainable and effective solution for soil remediation. By enhancing soil nutrient content, improving soil structure, stimulating microbial activity, and supporting plant growth, cassava waste contributes to the restoration of soil health and the acceleration of bioremediation processes. This approach not only mitigates the environmental impact of crude oil pollution but also promotes agricultural productivity and ecosystem recovery. The positive outcomes observed in various studies underscore the efficacy of cassava waste as a valuable tool in soil restoration and pollution management.

REFERENCES

Abdulfattah, A.A., Saima, J., Arif, M. and Rawand, S, (2016). Effects of crude oil spillage on phytochemical properties of soil. *Journal of Environment and Earth Science* 6(6): 27 – 32.

Abosede, E.E. (2013). Effect of crude oil pollution on some soil physical properties. *Journal of Agriculture and Veterinary Science* 6(3): 14 - 17

Adebayo, A. S., &Nwankwegu, A. S. (2018). "Impact of Organic Amendments on Soil Structure and Plant Growth." *Journal of Soil Science and Environmental Management*. 2(1): 23-37.

Agbo, B.E., Ogar, A.V., Itah, A.Y., Brooks, A.A. and Akonjor, M.A. (2019). Assessment of the effects of cassava mill effluent on the soil and its microbiota in Biase local government area of Cross river state, Nigeria. *World Journal of Advanced Research and Reviews*, 1(2):34–44.

Agbogidi, O.M., Edokpiawe, S., Okpewho, O.P. and Ogbemudia, C.O. (2023a). Effects of cassava processing wastewater on the performance of maize (*Zea mays* L.). *Nigerian Journal of Science and Environment*, 21(1): 358-368

Akoroda, M.O. and Ekanayake, I.J. (2005). Root crops and poverty alleviation. Proceeding of International Society of Tropical Root Crops – Africa Branch, Lilongwe, Malawi. Pp. 54-60.

Amadi, A., Dickson, A. A., &Maate, G. O. (1993). Remediation of oil polluted soils: Effect of organic and inorganic nutrient supplements on the performance of maize (Zea mays L.). *Water, Air, and Soil Pollution*, 66(1-2), 59-76.

Amadi. N, F.B.GTanee and OkogbuleF.N.C. (2023). Biostimulating effect of plantain peels(waste) on soil chemical properties, microbial loads and growth of *Cyperusiria*(Linn)in a heavymetal polluted soil. *International Journal of Advance. Resource Biological. Science*. 10(5): 157-167. DOI: http://dx.doi.org/10.22192/ijarbs.2023.10.05.013.

Ana, G. R. E. E., Sridhar, M. K. C., &Emerole, G. O. (2009). Environmental risk factors and health outcomes in selected communities of the Niger Delta area, Nigeria. Perspectives in Public Health, 129(4), 183-187.

Blake, G.R. and Hartge, K.H. 1986. Bulk density. In: Klute, A., (Ed.,), Methods of Soil Analysis, Part 1— Physical and Mineralogical Methods, 2nd Edition, Agronomy Monograph 9, American Society of Agronomy—Soil Science Society of America, Madison, 363-382.

Brady, N. C., & Weil, R. R. (2016). *The Nature and Properties of Soils*. Pearson.

Chindah, A. C., &Braide, S. A. (2000). The impact of oil spills on the ecology of the Niger Delta. Proceedings of the *International Seminar on the Petroleum Industry and the Nigerian Environment*, 9-15.

Coleman, D. C., Callaham, M. A., &Crossley, D. A. (2017). *Fundamentals of Soil Ecology*. Academic Press.

Dike B.U. and Nwachukwu, B.A (2003). Analysis of Nigerian Hydrometeorological Data. *Nigerian Journal of Technology*, 22 (1): 29-38.

Egharevba, F., &Ataga, A. E. (2003). Effects of sawdust mulch and bio-fertilizer on soil properties and yield of cassava (ManihotesculentaCrantz) in a degraded soil of the humid tropics. *African Journal of Biotechnology*, 2(10), 442-445.

Ekundayo, J. A., Oyenekan, J. A., &Nwokoye, I. C. (2012). Biodegradation of petroleum pollutants by microorganisms isolated from soil in the Niger Delta area of Nigeria. *African Journal of Biotechnology*, 11(26), 6734-6744.

Food and Agriculture Organization (FAO). (2015). *Status of the World's Soil Resources*. FAO.

Ijeomah, H. M., Aiyeloja, A. A., &Ogezi, E. A. (2013). Degradation of Niger Delta environment: Perspectives on its natural resource, agriculture and rural development potentials. *Journal of Agriculture and Social Research*, 13(2), 1-10.

Lal, R. (2004). Soil carbon sequestration to mitigate climate change. *Geoderma*, 123(1-2), 1-22.

Nawbueze, T.U. and Odunsi, F.O. (2007). Optimization of process conditions from cassava (*Manihotesculenta*) Lafun production. *Journal of Biotechnology*, 6(5): 603-611.

Nwilo, P. C., &Badejo, O. T. (2005). Oil spill problems and management in the Niger Delta. *International Oil Spill Conference*, 567-570.

Obioh, I. B., Eze, C. L., &Abiye, O. E. (2012). Impact of gas flaring on the air quality in the Niger Delta. *International Journal of Environmental Studies*, 69(6), 912-920.

Ogunwande, G. A., Osunade, J. A., &Ogunjimi, L. A. O. (2008). Process optimization of thermophilic composting of urban waste. *Journal of Soil Science and Environmental Management*, 2(3), 101-111.

Okerentugba, P. O., &Ezeronye, O. U. (2003). Petroleum degrading potentials of single and mixed microbial cultures isolated from rivers and refinery effluent in Nigeria. *African Journal of Biotechnology*, 2(9), 288-292

Okoye, R. and Onuoha, S. (2023). Effect of cassava processing wastewater on the bacteriological quality of soil in Aba, Abia State, Nigeria. *American Journal of Life Science Researches.* 11(1): 33-53.

Oladunjoye, I. O., Ojebiyi, O. O., &Amao, S. R. (2010). Effect of feeding processed cassava (Manihotesculentacrantz) peel meals on the performance characteristics, egg quality and blood profile of laying chicken. *Agricultural and Biology Journal of North America*, 1(4), 617-620.

Onwudike, S. U., Asawalam, D. O. and Ano A. O. (2016). Influence of Agro-waste on soil properties, growth and yield of Maize (Zea mays L.) in an acid utisol of Owerri, Imo state. *Nigerian Journal of Soil Science*, 26. 279-294

Uyigue, E., &Agho, M. (2007). Coping with climate change and environmental degradation in the Niger Delta of southern Nigeria. Community Research and Development Centre (CREDC), Nigeria.

Weil, R. R., & Brady, N. C. (2016). *Elements of the Nature and Properties of Soils*. Pearson.