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Biostimulation potentials of pig dung and oil palm fruit chaff on a diesel fuel polluted soil

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ABSTRACT

The study was carried out to examine the biostimulatory effect of pig dung and oil palm fruit chaff on remediation of soil contaminated with diesel fuel. Different rates (0, 1 and 2kg) of pig dung and 1kg of oil palm fruit chaff and were applied to diesel fuel contaminated soils at (0, 1litre and 2litre /ha) of diesel fuel respectively were used. A total of twelve (12) treatments combination with three (3) replicates each summing to thirty-six (36) plots were used. The experiment was laid out in a randomized complete block design. The soil physicochemical parameters that were examined are pH, total organic content (TOC), nitrogen (N), carbon to nitrogen ratio (C:N), phosphorus (P) CEC, TPH and PAH. The results for soil physicochemical parameters showed significant variations ($P<0.05$) in the levels of pH, phosphorus, Cation Exchange Capacity, carbon to nitrogen ratio (C:N) associated with pollution and biodegradation occurring within the soils, the result shows high levels in total organic carbon (TOC) and Nitrogen. Soil analysis during the experiment revealed a general negative correlation coefficient implying enhanced remediation during the trial periods. The research has shown that pig dung and oil palm fruit chaff are good biostimulatory agent in the remediation and restoration of diesel fuel polluted soil.

Contribution/Originality: This study reveals the potentials of using Pig dung and palm fruit chaff to enhance biostimulation. There is paucity of information on research using these two available waste materials to solve the challenge of environmental degradation with crude oil. This research therefore elicits this area of research.

1. INTRODUCTION

In the Niger Delta, petroleum hydrocarbon environmental pollution results from the exploitation and processing of this mineral endowment of the region. Oil spills have crippled the livelihoods of the people of oil-bearing communities in the Niger Delta. The origin of this problem can be traced back to Nigeria's colonial period. According to Tolulope (2004) the very first oil spill in Nigeria occurred at Araromi in Ondo state, south western Nigeria in 1908 before the first successful oil well of commercial quality and quantity was found and drilled by Shell-BP at Oloibiri, Bayelsa State in 1956. The spill reported above according to Akande (2003) was natural seepage of oil from its deposit in the area. Following the discovery and successful drilling of oil in 1956 and subsequent increase in oil prospecting activities in Niger Delta, the spate of oil spill increased. From then till date, many major and minor oil spillages with disastrous consequences on the affected habitats have occurred.

Nonetheless, measures are being adopted in a bid to clean up the oil spill such as biological methods or bioremediation, chemical methods and physical methods. Bioremediation's role is to optimize conditions for natural microbes to degrade environmental pollutant. There are two main approaches to oil spill bioremediation, which are; bioaugmentation and biostimulation (Yakubu, 2007). Firstly, bioaugmentation deals with the use of beneficial microbes that have an affinity towards specific pollutants (Mckee & Mendelssohn, 1995; Venosa et al., 1996). Recently, biological techniques like phytoremediation are being evaluated for the remediation of sites contaminated with petroleum. Phytoremediation is the use of plants and/or associated microorganisms to remove contain or render harmful material harmless (Cunningham & Berti, 1993; Merkl, 2005; Schwab & Bank, 1999). It has been shown to be effective for different kinds of pollutants (contaminants) like heavy metals, radionuclides and broad range of organic pollutants (Schröder, Harvey, & Schwitzguébel, 2002). The second approach is known as biostimulation and it involves the aeration and addition of selected micronutrient and sometimes top soil to appropriate quantities (Shekwolo, 2005; Swannell, Lee, & McDonagh, 1996) i.e the modification of the environment to stimulate exiting bacteria capable of bioremediation. Different materials have been proposed by authors to be used for this purpose such as cow dung (Oriakpono, Okunwaye, & Helen, 2018) however, oil palm fruit chaff is another promising agricultural by-product. Oil palm fruit chaff isa by-product of palm oil milling constitutes enormous heap of waste in palm oil mills. Grounded oil palm fruit chaff is rich in some mineral nutrients (Udoetok, 2012). Because of this property, it was recommended by the worker for use in the clean up of hydrocarbon-polluted soil. Furthermore, it was reported to significantly improve soil aeration and water retention capacity (Gali, 2008). The use of pig dung on diesel fuel contaminated soils will also protect the soil structure; provide utilizable nutrients (Oriakpono et al., 2018). This study is therefore aimed at determining the effect of diesel on soil properties and the effectiveness of amending the polluted soil using oil palm fruit chaff. In addition, the study is structured to determine the potentials of the different mixtures of Oil palm fruit chaff and pig dung as amendment materials to ameliorate hydrocarbon content in diesel fuel polluted soil.

2. MATERIALS AND METHODS

2.1. Study Area and Material

The experiment was conducted at the University of Port Harcourt. The venue is located in University Park popularly called Abuja Campus. It is 1.52 km by air off the East-West Road from Dan Etete Road junction. The University of Port Harcourt is located north-east of Rivers State. The experiment comprised of twelve (12) treatment combinations replicated thrice, for a total of thirty-six (36) plots. The diesel Oil was used in the experiment. It was obtained from Shell Petroleum Development Company (SPDC) of Nigeria. While dried oil palm fruit chaff realized after oil extraction were collected from a palm oil mill at Oil mill market Rivers State. It was blended into powder form. Pig manure used for this experiment was obtained from Alakahia slaughter Rivers state. The pig manure was collected, dried and crushed before use.

2.2. Treatments and Experimental Design

The experiments were laid out in 3 x 4 factorial arrangement fitted into a Randomized Complete Block Design (RCBD) and replicated three times. The replication was made up of twelve beds each carrying a treatment, after the preparation of beds the soil was left for two weeks and treated with three rates (0, 1 and 2L) of diesel oil. The diesel oil was spilled on the surface of the soil in simulating what generally occurs in case of oil spills. Two weeks after diesel oil pollution, three rates (0, 1 and 2kg) of air- dried, ground pig dung and 1kg of Oil Palm Fruit chaff were applied to polluted soils. The pig dung and Oil Palm Fruit chaff were thoroughly mixed with the soil using hand trowel to ensure uniform distribution within the soil. Each quantity of diesel oil served as a treatment with the 0ml treatment serving as the control.

2.3. Sampling

Soil samples were collected from the plots at three different times. First was before diesel oil application to ascertain the physico-chemical nature of the unpolluted soil. Second was 4 weeks after pollution and amendment (AP/A) and third was at the expiration of the experiment at 10 weeks. 50g of soil were collected at 0-15 cm depth using a soil auger. Table 1 presents the Chemical composition of pig dung.

Table 1. Chemical composition of pig dung.

S/No.	Parameters	Value
1	Organic Carbon (%)	30.2
2	Total Nitrogen (%)	2.11
3	Sodium (ppm)	0.20
4	Potassium (ppm)	0.52
5	Calcium (ppm)	2.40
6	Magnesium (ppm)	0.63
7	Available Phosphorus (ppm)	10.5
8	Ph	6.40
9	Hydrogen ion (H^+)	0.10
10	Microbial count (cfu/g)	12.50 x 10^1

Figure 1 Illustrates the Field experimental layout in a randomized complete block design (RCBD).

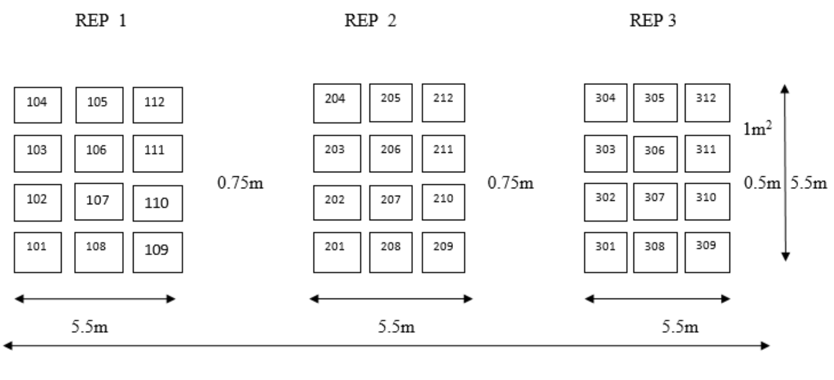

Figure 1. Field experimental layout in a randomized complete block design (RCBD).

Figure 2 Illustrates the Field experimental layout in a randomized complete block design (RCBD) Showing the different concentration of diesel oil, Pig Dung and oil palm fruit chaff.

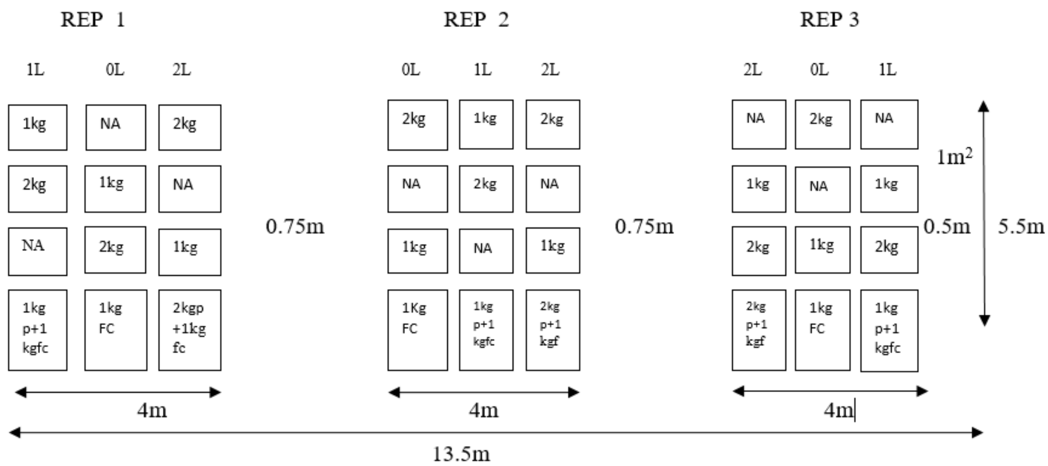

Figure 2. Field experimental layout in a randomized complete block design (RCBD) showing the different concentration of diesel oil, Pig Dung and oil palm fruit chaff.

2.4. Determination of Physiochemical Parameters

Soil Samples were collected, labelled, and then taken to the laboratory for analysis. The pH of the soil samples was determined by meter method using distilled water at a ratio of 1:1 with a glass electrode pH Meter (Hanna, HI 8314 model). Total Organic carbon was determined using titrimetric method by Walkley and Black (1934). The total Nitrogen, CEC and available phosphorous in the soil was determined by spectrophotometry method (Ogboghodo, Azenabor, & Osemwota, 2005). Soil conductivity was determined using a conductivity meter.

2.5. Statistical Analyses

The Assistat 7.6 beta statistical analysis software program for windows was used in the statistical analysis of data, the data was subjected to analysis of variance (ANOVA). Mean differences among treatments were evaluated with the Tukey Least Significant Difference t-test (LSD) test. Results were regarded significantly different at a significance level below ($P \leq 0.05$).

3. RESULTS

3.1. Total Petroleum Hydrocarbon Content (mg/kg)

Total Petroleum Hydrocarbon was observed to be below detecting limits (BDL) in samples uncontaminated with diesel fuel. The highest mean was (3692.12) in treatments (1 L of diesel fuel, NA of pig dung application). Similarly, the lowest mean (375.83) was recorded in (2 L of diesel fuel, 1kg of pig dung with 1kg of Oil Palm Fruit chaff application) Table 2.

3.2. pH

Soil pH ranged from (8.18 – 8.43) uncontaminated soil, (5.60 -8.18) 4 weeks AP/A and (6.90- 8.21) after 10 weeks Table 2. Highest mean of 8.21 was obtained from (after 10 weeks) in treatment (0 L of diesel fuel, no amendment of pig dung and oil palm fruit chaff application). While the lowest mean was recorded as (5.60) from (4 weeks AP/A) in treatments (1 L of diesel fuel, NA of pig dung and oil palm fruit chaff application). Statistical analysis of pH indicates there were statistically significant differences ($P<0.05$) in pH between the uncontaminated soil and soil samples collected 4 weeks AP/A and after 10 weeks.

3.3. Cation Exchange Capacity (meq/100g)

The cation exchange Capacity (CEC) value range from (3.71 – 4.37) uncontaminated soil, (0.83 – 3.73) 4 weeks AP/A and (2.52 – 3.75) after 10 weeks. The mean for the control groups are (3.71, 3.73 and 3.75) respectively. Statistical analysis indicates there were statistically significant differences ($P<0.05$) between the treatment groups on the same column as found in the uncontaminated soil, 4 weeks AP/A and after 10 weeks. Results are shown in (Table 2).

3.4. Total Organic Carbon

Soil TOC ranged from (2.52 – 3.61) uncontaminated soil, (2.53 -6.31) 4 weeks AP/A and (2.58- 4.98) after 10 weeks (Table 2). Highest mean of 4.98 was obtained from (after 10 weeks) in treatment (1L of diesel fuel, 2 kg of pig dung application). While the lowest mean was recorded as (2.52) from (uncontaminated soil) in treatments (0L of diesel fuel, NA of pig dung and oil palm fruit chaff application). Statistical analysis of TOC indicates there were statistically significant differences ($P<0.05$) in TOC between the uncontaminated soil and soil samples collected 4 weeks AP/A and after 10 weeks.

3.5. Nitrogen

Total nitrogen (TN) content is presented in (Table 3). It has a higher value of (8.39) after planting is done in Treatments (1L of diesel fuel, 1 kg of pig dung with 1 kg of oil palm fruit chaff and 2L of diesel fuel, 1 kg of pig dung with 1 kg of oil palm fruit chaff application) compared with those of the other treatments and a lower value of (0.43). There were statistically significant differences (P<0.05) between the treatment groups on the same column as found in the uncontaminated soil, 4 weeks AP/A and after 10 weeks.

3.6. Carbon/Nitrogen Ratio

In the C: N ratio content, the lowest ratio (5: 1) were found in all samples of uncontaminated soil and after 10 weeks while the highest ratio (6: 1) were found in samples collected 4 weeks AP/A. Details of carbon to nitrogen ratio result are shown in (Table 3).

3.7. Phosphorus (mg/kg)

The result for phosphorus is presented in Table 3. It had a mean value range of (19.19-21.25) uncontaminated soil, (P<0.01) in all samples collected and analysed 4 weeks AP/A and (10.22-19.34) after 10 weeks. There were statistically significant differences (P<0.05) between the treatment groups on the same column as found in the uncontaminated soil, and after 10 weeks.

3.8. Electrical Conductivity

Effects of the remediation on conductivity are shown in Table 3. Conductivity was low in Treatment (0L of diesel fuel, NA of pig dung and oil palm fruit chaff application) 4 weeks AP/A, but high in treatment (2L of diesel fuel, 1 kg of pig dung and 1 kg of oil palm fruit chaff application) uncontaminated soil. Statistical analysis for electrical conductivity indicates there were statistically significant differences (P<0.05') in electrical conductivity between the uncontaminated soil, soil 4 weeks AP/A and after 10 weeks.

Table 2. Effect of bioremediation on TPH, pH, CEC and TOC.

Treatments	TPH			pH			CEC			TOC		
	Uncontaminated soil	4 weeks AP/A	After 10 weeks	Uncontaminated soil	4 weeks AP/A	After 10 weeks	Uncontaminated soil	4 weeks AP/A	After 10 weeks	Uncontaminated soil	4 weeks AP/A	After 10 weeks
0(NA)	BDL	BDL	BDL	8.19^{bA}	8.18^{aA}	8.21^{aA}	3.71^{bA}	3.73^{aA}	3.75^{aA}	2.52^{bA}	2.53^{bA}	2.58^{bA}
0(1kg)	BDL	BDL	BDL	8.24^{bA}	8.03^{aC}	7.28^{aB}	3.86^{bA}	0.83^{aC}	2.70^{aB}	3.55^{bC}	6.20^{bA}	4.23^{bB}
0(2kg)	BDL	BDL	BDL	8.34^{bA}	8.05^{aC}	7.23^{aB}	3.91^{bA}	0.83^{aC}	2.53^{aB}	3.50^{bC}	6.13^{bA}	4.74^{bB}
0(1kgP/1kgPFC)	BDL	BDL	BDL	8.36^{bA}	6.33^{aC}	7.96^{aB}	4.37^{bA}	0.84^{aC}	3.67^{aB}	3.61^{bC}	6.27^{bA}	4.71^{bB}
1L(NA)	BDL	3692.12	610.25	8.18^{aA}	5.60^{bC}	6.90^{aB}	3.79^{bA}	0.83^{bC}	2.59^{bB}	3.44^{aC}	6.24^{aA}	4.76^{aB}
1L(1kg)	BDL	3246.92	556.66	8.37^{aA}	6.39^{bC}	7.78^{aB}	3.79^{bA}	0.84^{bC}	2.61^{bB}	3.57^{aC}	6.29^{aA}	4.74^{aB}
1L(2kg)	BDL	3189.64	566.62	8.40^{aA}	6.54^{bC}	7.71^{aB}	3.98^{bA}	0.89^{bC}	2.68^{bB}	3.55^{aC}	6.25^{aA}	4.98^{aB}
1L(1kgP/1kgPFC)	BDL	3007.43	432.58	8.43^{aA}	6.69^{bB}	8.02^{aA}	4.04^{bA}	0.90^{bB}	3.58^{bA}	3.61^{aB}	6.31^{aA}	4.10^{aB}
2L(NA)	BDL	3137.4	677.3	8.37^{aA}	5.94^{bC}	7.04^{aB}	4.03^{aA}	0.88^{bC}	2.52^{abB}	3.48^{aC}	6.20^{aA}	4.62^{aB}
2L(1kg)	BDL	3390.77	607.31	8.38^{aA}	6.41^{bC}	7.71^{aB}	4.23^{aA}	0.85^{bC}	2.61^{abB}	3.52^{aC}	6.24^{aA}	4.74^{aB}
2L(2kg)	BDL	3548.99	528.82	8.39^{aA}	6.60^{bC}	7.73^{aB}	4.33^{aA}	0.86^{bC}	3.39^{abB}	3.50^{aC}	6.26^{aA}	4.72^{aB}
2L(1kgP/1kgPFC)	BDL	3244.67	375.83	8.41^{aA}	6.74^{bB}	8.18^{aA}	4.37^{aA}	0.87^{bC}	3.75^{abB}	3.60^{aC}	6.20^{aA}	3.83^{aB}

Note: $^{a-b}$ Different letters in the same column indicate significant difference ($P<0.05$)
$^{A-C}$ Different letters in the same row indicate significant difference ($P<0.05$).

Table 3. Effect of bioremediation on nitrogen, C:N, phosphorus, and conductivity.

Treatments	Nitrogen			C:N			P			Conductivity		
	Uncontaminated soil	4 weeks AP/A	After 10 weeks	Uncontaminated soil	4 weeks AP/A	After 10 weeks	Uncontaminated soil	4 weeks AP/A	After 10 weeks	Uncontaminated soil	4 weeks AP/A	After 10 weeks
0(NA)	0.48^{aA}	0.49^{bA}	0.47^{cA}	5:01	6:01	5:01	19.19^{b}	19.19^{b}	19.34a	19.39bA	19.39aA	19.42aA
0(1kg)	0.50^{aC}	8.38^{bA}	4.58^{cB}	5:01	6:01	5:01	20.18^{b}	<0.01	12.26a	19.41bA	11.21aC	14.44aB
0(2kg)	0.53^{aC}	8.30^{bA}	4.55^{cB}	5:01	6:01	5:01	20.61^{b}	<0.01	11.62a	19.91bA	11.70aC	14.23aB
0(1kgP/1kgPFC)	0.54^{aC}	8.37^{bA}	3.83^{cB}	5:01	6:01	5:01	20.92^{b}	<0.01	13.17a	20.69bA	12.10aC	14.84aB
1L(NA)	0.44^{aC}	8.33^{aA}	4.71^{bB}	5:01	6:01	5:01	19.94^{a}	<0.01	10.61b	19.45aA	10.96bC	14.01bB
1L(1kg)	0.48^{aC}	8.32^{aA}	4.54^{bB}	5:01	6:01	5:01	20.81a	<0.01	13.04b	20.36aA	11.70bC	14.64bB
1L(2kg)	0.53^{aC}	8.31^{aA}	4.54^{bB}	5:01	6:01	5:01	20.69a	<0.01	12.56b	20.52aA	11.54bC	13.77bB
1L(1kgP/1kgPFC)	0.54^{aC}	8.39^{aA}	3.65^{bB}	5:01	6:01	5:01	21.25a	<0.01	13.14b	20.77aA	11.91bC	15.12bB
2L(NA)	0.43^{aC}	8.34^{aA}	4.97^{aB}	5:01	6:01	5:01	20.30ab	<0.01	10.22c	19.92aA	10.90bC	14.27bB
2L(1kg)	0.47^{aC}	8.36^{aA}	4.64^{aB}	5:01	6:01	5:01	20.29ab	<0.01	12.05c	20.28aA	11.42bC	13.75bB
2L(2kg)	0.49^{aC}	8.34^{aA}	5.23^{aB}	5:01	6:01	5:01	20.69ab	<0.01	10.93c	20.77aA	11.73bC	14.57bB
2L(1kgP/1kgPFC)	0.52^{aC}	8.39^{aA}	3.94^{aB}	5:01	6:01	5:01	20.91ab	<0.01	13.02c	20.81aA	11.92bC	15.53bB

Note: $^{a-b}$ Different letters in the same column indicate significant difference (P<0.05).
$^{A-C}$ Different letters in the same row indicate significant difference (P<0.05).

Information:

NA = No amendment.

1kg= 1kg of Pig dung.

2kg=2kg of Pig dung.

1kgP/1kgPFC=1kg of Pig dung and 1kg of Palm oil fruit chaff.

0= No diesel fuel.

1L= 1Litre of diesel fuel.

2L= 2 Liters of diesel fuel.

BDL= Below detecting limits.

4. DISCUSSION

4.1. Effects of Remediation on Soil Physico-Chemical Properties

Contamination caused by petroleum and its derivatives is the most important problem in the environment. The addition of diesel fuel brought about acidity in the soil samples analysed 4 weeks AP/A but the growth of *Abelmoschus esculentus* reduced the acidity produced by the addition of diesel fuel on the soil. Results from this study indicate there were statistically significant differences ($P<0.05$) in pH between the uncontaminated soil and soil samples collected 4 weeks AP/A and after 10 weeks indicating that there is an effect of amendment. pH of soils decreased as a result of degradation of diesel fuel. This decrease in the pH of soil with degradation of diesel fuel could be due to accumulation of organic acids produced during degradation in the soil (Merkl, 2005) or the production of acid radicals through nitrification. However, since soil bacteria survive better in neutral than in acidic soils, the increase of the soil pH towards neutral condition means more favourable conditions for soil bacteria. Many researchers have reported that bacteria play good role in the degradation of diesel fuel (Van Hamme, Singh, & Ward, 2003). This means that as observed in this study, growth of *Abelmoschus esculentus* can enhance the bacteria population in diesel fuel polluted soil and thereby lead to higher degradation of diesel fuel in the soil.

Statistical analysis of TOC indicates there were statistically significant differences ($P<0.05$) in TOC between the uncontaminated soil and soil samples collected 4 weeks AP/A and after 10 weeks. The total organic carbon of soil improves the binding processes in the soil. Such binding reduces water drainage, degradation of pollutants, carbon sequestration and soil resilience also improves water retention ability of soil. The increase in TOC in this study is due to the addition organic fertilizer (pig dung). This report is in line with the works of Oriakpono et al. (2018) and Ogboghodo et al. (2005) they said that the increase is due to the microbial mineralization of the diesel fuel and the cow dung. The TOC content had a positive relationship between soil and contaminant concentrations ($P> 0.05$) as organic carbon concentrations increased with increase in diesel concentrations.

Total petroleum hydrocarbon (TPH) was found to be below detectable limit (BDL) in all uncontaminated soils collected and analysed before contamination. The TPH content of diesel fuel contaminated soil showed clearly that there is a reduction in the concentration of petroleum hydrocarbon in soil at the end of the experiment. This is in agreement with the report of Efe and Elenwo (2014) which revealed that plants are capable of reducing the concentration of petroleum hydrocarbon in petroleum hydrocarbon impacted soil. Similar reduction was also reported by Basumatary, Saikia, and Bordoloi (2012). This may be due to biological degradation of diesel fuel constituents occurring in the soil (Rhykerd, Crews, McInnes, & Weaver, 1999). TPH is one of the constituents of diesel fuel that is easily biodegradable or utilized by plant during an oil spill (Basumatary et al., 2012).

Result of this experiment indicates that plants are good agents for bioremediation of diesel fuel polluted soils and further established that okra has the potential of enhancing the removal of TPH from diesel fuel polluted soil (Ogboghodo et al., 2005). The result for the Poly Aromatic Hydrocarbon (PAH) above shows significant difference across the rows and column which shows that remediation took place. Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilisers and other ameliorants (Hazelton & Murphy, 2007).

There were statistically significant differences ($P<0.05$) between the treatment groups on the same column as found in the uncontaminated soil, 4 weeks AP/A and after 10 weeks indicating no effect of amendment. There was significant reduction of CEC in samples collected and analysed 4 weeks AP/A when compared with the control groups this could be attributed to the addition of diesel fuel but increased in samples collected and analysed after 10 weeks meaning that the addition of organic fertilizer increased the CEC of the soil. For soil nitrogen, the study shows a significant difference at ($p<0.05$) in uncontaminated soil and there was significant difference after 10 weeks and 4 weeks AP/A. Reason was that, the material used in the remediation process (pig dung and palm oil fruit chaff) is a product which is seen to have high nitrogen content, therefore leading to presence of many bacteria after remediation. Nitrogen is a substance that is been added to the soil either through natural processes or by fixation by microorganisms, that increases the nitrogen content of the soil. The result for the soil nitrogen in this study is in accordance with similar research carried out by other authors (David, Kii, & Youdeowei, 2009). The phosphorus content in the study shows significant different at the end of the experiment which shows that bioremediation has taken place. It could be seen that they are needed by bacteria for their high proliferation since a high bacteria count was recorded. The soil phosphorus was below detectable limits (<0.01) in soil samples collected 4 weeks AP/A i.e after contamination and remediation indicating that the diesel fuel pollution had serious effect on the level of soil phosphorus. Though there was increase at the end of the experiment indicating that the remediation process that is going on is indeed improving the soil phosphorus level. The available phosphorus obtained in soils from this study may be taking as agricultural limitations since the values were below 20 mg/kg which is the maximum tolerable limit of P for soils as stipulated by Holland, Allen, Barten, and Murphy (1989).

The addition of diesel fuel, pig dung and palm oil fruit chaff brought about an increase C: N ratio 4 weeks AP/A but reduced at the expiration of the experiment. The result of C: N ratio may be attributable to the increase in microbial activity of the carbon utilizing agent since microbes are known to be heavy carbon utilizers (Aprill & Sims, 1990).

Soil electrical conductivity (EC) is a measurement that correlates with soil properties that affect crop productivity, including soil texture, cation exchange capacity (CEC). As salt content increases, so does Electrical conductivity. There were statistically significant differences (P<0.05') in electrical conductivity between the uncontaminated soil, soil 4 weeks AP/A and after 10 weeks. Anions, metallic ions and carbonic acids contribute to electrical conductivity diesel fuel polluted soils and were found to increase with increasing concentration of remediating agent (Oriakpono et al., 2018; Wang, Feng, & Wang, 2009).

5. CONCLUSION

The indiscriminate disposal of diesel fuel from refineries, oil pipes, into water drains, gutters, farmlands and open plots are common practices by oil servicing companies. The findings of this study indicate that pig dung or palm oil fruit chaff proven to be a good biostimulatory agent in the remediation and restoration of diesel fuel polluted soil.

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Institutional Review Board Statement: The Ethical Committee of the University of Port Harcourt, Nigeria has granted approval for this study on 12 October 2022 (Ref. No. UPH/CEREMAD/REC/MM66/013).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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