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The Strength of Dry, Fresh and Decomposed Raffia Palm Trunk in the Bioremediation of Oil-based Drill Cutting

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Abstract

In this research, the impact of dry drill cuttings and compost tea on the environment's ability to degrade oil-based drill cutting contamination is investigated. The experiment was conducted in the research center located at the workshop of Agricultural and Environmental Engineering Department, Rivers State University, Port Harcourt. Oil-based drill cutting samples were placed in bulk in eleven reactors (T1, T2, T3-T11) with four replications. The original drill cuttings' physiochemical characteristics were examined. Additionally, before and after treatments, the physiochemical characteristics of oil-based drill cuttings were examined in the lab, including TPH, BTEX, PAH, pH, EC, N, P, K, OM, and BC. At the conclusion of 16 weeks of remediation, the decrease in TPH, BTEX, and PAH were significantly reduced in all treatment choices. The range of percentage reductions for TPH, PAH, and BTEX throughout a 16-week treatment period ranges from 86 to 91%. The results also showed that all treatment alternatives had strong coefficients of determination (R2) between the range of 0.8238 and 0.9992. The ANOVA findings revealed a significant difference at a 95% confidence level and was very significant at a 99% level. Similar to this, the treatment coefficient of variation for each low percentage was displayed. This demonstrated how little and trustworthy the experimental error was. The TPH, BTEX, and PAH models were developed. To determine the constant (β) in the projected models, the experimental test results were plotted against the time period. The models provided high concordance between experimental and anticipated data. The model utilized was a straightforward nonlinear regression, and it was graphically compared to the root mean square error (RMSE). High R2 coefficient of determination and low RMSE were found in the results. To forecast the rate of degradation of TPH, PAH, and BTEX in oil-based drill cuttings contaminated with petroleum hydrocarbon treated with fresh extract, respectively, the model (basic nonlinear regression) is nonetheless advised.

Keywords. Bioremediation, Biodegradation, Oil-Based Drill Cuttings, Dry, Fresh and Decomposed Raffia Palm Trunk.

INTRODUCTION

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The expansion of petroleum exploration and production, which has been the mainstream of the Nigerian economy, has caused agricultural land to become contaminated. Many of Nigeria's shorelines and terrestrial ecosystems in oil producing cities with sizable agricultural lands exhibit the characteristics of Oil-based drill cutting contamination from petroleum hydrocarbons has led to the eradication of soil and plant-supporting microorganisms (Nweke et al., 2023). Crude oil decomposition is hampered by soil nitrate reduction and organic carbon loss caused by oil-based drill cutting contamination with petroleum hydrocarbons.

Drill cuttings contaminated with oil causes plant roots to die, which prevents the plants from receiving water and other nutrients. Additionally, it causes the soil's water-plant interaction to explode. Drill cuttings generated from crude oil are generally paraffin-based and contain around 75% saturated petroleum hydrocarbons and 25% aromatic petroleum hydrocarbons.

Regardless of complexity, a variety of soil microorganisms may break down oil-based drill cuttings. This differs significantly from plants growing in uncontaminated soil conditions at levels below this hazardous limit. Oil-based drill cuttings have been evaluated and treated using a variety of physicochemical approaches, such as microwave drying, thermal desorption, and cuttings re-injection, but none of these have completely eliminated the bio-contaminant from the ecosystem.

Unfortunately, the approaches are frequently implemented in a way that has serious procedural and ecological problems, such as the potential for inadvertent discharge into the environment, a never-ending energy demand, excessive residues of pollutants, and luxury execution. Numerous biological techniques, such as composting (Ahmadi et al. 2017), bioaugmentation (El-Liethy et al. 2021), and biostimulation (Kogbara et al. 2017), have been researched to solve these problems.

In summary, these bioremediation approaches have convinced us that we are superior alternatives to physical and chemical treatments, both financially and in terms of biodegradability. However, the practice of adding cultured microorganisms for biodegrading oil-based drill cuttings or water contaminants (bioaugmentation), have successfully been used in numerous researches containing petroleum hydrocarbons biodegradation by bacteria. However, no proper information involving the use of agro-waste such like indigenous degradative substrate, fresh and decomposed raw-materials from raffia palm trunk for complete elimination of oil-based drill cuttings as reported in Nweke *et al*., 2023) has been used so far. In contrast, study by Ahmed *et al.*, 2021) applied earthworm as an organic waste for the treatment oil-based drill cuttings, and it yields excellent result. Similarly, (Akpofure, 2011) as cited in (Nweke *et al.*, 2023) did a research on the biodegradation potential of oil-based drill cuttings encapsulated with cement in the soil environment and there wer total detoxification of the contaminants from the environment. Following that, this study carries out a thorough analysis with the goal of determining the viability of raffia palm by-products like (subtract, fresh, and decomposed) for thorough bioremediation processes as well as finalizing several fungal strains, as part of the environmental management and ultimate removal of oil-based drill cuttings, according to Nweke et al. (2023) [1–5].

Meanwhile, raffia Palm are traditionally cultivated and practiced through farm plantation as well as family estate. This are possessed by individual families and being practiced by individual owners as well as land tenure system through inherence. Over the years, raffia palm had been exploited by palm wine tappers as cited in (Udofia *et al.*, 2017). Gift *et al*, (2017) in their studies revealed that Raffia palm produces sap known as palm wine. The product of Raffia palm is palm wine which is alcoholic in nature. The palm wine is a sweet native brewed hot drink with a substantial 10-12% sucrose of sugar. It is a clean whitish liquid and highly cherished by southern part of Nigerians, more especially, during the traditional marriage ceremonies and festival periods. The palm wine product can also be acquired from extra palm such as coconut palm and oil palm trees. Raffia palm is the best among all and can produce about 200-1212 liters of palm wine per annum as contain in (Dauda *et al*., 2019). The need to use subtract, fresh and decomposed raffia palm from Okoroagu-Etche of Rivers State to ameliorate the oil-based drill cuttings is essential in this study. Therefore, this research focuses to determine the strength of the combined effect of raffia palm subtract, fresh and decomposed in the bioremediation of oil-based drill cutting, also and its comparison [6–9].

MATERIALS AND METHODS.

The Study Area

The Rivers State University, Port Harcourt, Nigeria was the location/site where all experimental works were carried out. The Boskel Nigeria Limited in Rivers State, Nigeria's Niger Delta area, provided the oil-based drill cuttings. The experiment was carried out between the months of December 2022 to November 2023. The soil in the experimental region may be described as coastal plain sand and is made up of flat plains, with coordinates of (5°19'N, 6°28'E), the tropical rain forest serves as the area's vegetative cover [10, 11].

Experimental Design

The study's methodology was the Randomized Complete Block Design (RCBD). Eleven choices were considered as treatment methods, whilst the control group received no treatment at all. These options include two treatments using African raffia palm substrate and compost tea made from raffia palm larvae casts. All these biostimulants or derivatives were evaluated before being added to a 20-liter bucket of oil-based drill cuttings with set masses and fixed ratios at extremely low thermal conductivities. The contents were mixed thoroughly to get a composite mixture, thereafter, they were kept at room temperature except for control. Samples were taken every 4 weeks and analyzed for reduction in Total Petroleum Hydrocarbon (TPH), PAH and BTEX respectively [12, 13].

i. *Oil Based Drill Cuttings:* 180 liters of untreated oil-based drill cuttings were used for the research with high TPH, TPAH and BTEX content. Thereafter, the untreated oil-based drilling cuttings samples were treated with the different raffia palm substrates at different treatment levels using a mix ratio of 2:1 according to Okparanma *et al*. (2018) and Nweke et al., (2023).
ii. *Extract Raffia Palm Trunk:* The extracted raffia palm used in this research was formed by cutting the raffia palm trunk log into (2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, and 20.0) pieces and was later placed on a mild steel plate (receptacle), which was then placed on a hydraulic press machine for the extraction of fresh (palm wine). At 7.5 tons, the first reading produced 1.5 L of fluid in 60 minutes interval, and the total fluid generated amounted 160 tons (i. e. 32 liters) at 1280 minutes at the end. The extracted palm wine contain yeast that was mixed with oil-based drill cuttings at pre-determined optimal activation temperature and time respectively.
iii. *Decomposed Raffia Palm Trunk:* The hand towel was used in preparing mixture of decomposed and oil-based drill cutting. The mixture was in accordance with the provisions of BS12-1991.
iv. *Dry Raffia Palm Trunk:* Dry used in the study was obtained from raffia palm trunk locally, by cutting down the trunk into different log. The log was crushed into pieces with the use of axe, thereafter, it was transferred and placed on a strong metal iron where it was grinded into fine size by the use of hammer. The grinded substrate was air dried daily at an interval of 30 days to obtain oven drying. The substrate was passed through a sieve analysis to obtain fine aggregate using US Sieve no. 60.
v. *Compost Tea Raffia palm Trunk:* Compost tea as the name implies is an organic liquid fertilizer generated from raffia palm larva cast through the uppermost top of the raffia palm trunk. The collected larva cast was immersed in 400 liters of water where it was later turned into compost tea that served as source of irrigation. The oil-based drill cuttings and compost tea were mixed together at a mix ratio of 2:1 according to Okparanma *et al*, (2018) and Nweke et al., (2023) [14–16].

ANOVA Equation

$$\text{RSS} = \frac{1}{t}\sum R^2 - \text{C.F} \tag{1}$$

$$\text{C.F} = \frac{(GT)^2}{rt} \tag{2}$$

GT= Grand Total

$$\text{TSS} = \frac{1}{r}\sum T_i^2 - \text{C.F} \tag{3}$$

$$\text{ESS} = \text{Total S.S} - \text{RSS} - \text{TSS} \tag{4}$$

$$\text{Total S.S} = Y_{11}^2 + Y_{12}^2 + \ldots\ldots Y_{tr}^2 - \text{C.F} \tag{5}$$

$$\text{RMS} = \frac{RSS}{r-1} \tag{6}$$

$$TMS=\frac{TSS}{t-1} \quad (7)$$

$$EMS=\frac{ESS}{(r-1)(t-1)} \quad (8)$$

Statistical Analysis

The single factor experimental analysis of variance (ANOVA) was used on the various replications of the experimental cells in order to determine the percentage reduction of TPH, PAH and BTEX. Simple non-linear regression model analysis was adopted to evaluate the relationship between time (in weeks) and some measured oil-based drill cutting characteristics since bioremediation is a time dependent process while simulation cum root mean square were used for comparison on the classification of the difference between two treatment means as significance and non-significance at 5% and 1% level of probability. This analysis followed the procedure described by several authors.

RESULTS AND DISCUSSIONS

Total Petroleum Hydrocarbon (TPH

Table 1 shows the reductions in percentage in respect to TPH as a result of addition of dry, fresh and decomposed as well as microorganisms' augmentation.

Figure 1 shows the TPH concentration against time (weeks) in oil-based drill cuttings bioremediation. The result shows that the concentrations of TPH reduced with increase in the number of weeks.

Table 1. Effects of Dry, Decomposed and Fresh Raffia Palm Trunk on Oil-based Drill Cutting Bioremediation

Period (week)	Parameter									
	Ph	EC (us/cm)	N (mg/kg)	P (mg/kg)	K (mg/kg)	OM (mg/kg)	TPH (mg/kg)	PAH (mg/kg)	BTEX (mg/kg)	BC (10^5cfu/g)
0	6.75	3509.43	175.49	140.49	152.58	58.49	15967.90	128..07	1.00	6.15
4	6.59	1929.79	96.49	77.19	83.90	32.16	8780.55	66.50	0.57	9.25
8	6.24	1190.32	59.52	47.61	51.75	19.84	5415.94	34.88	0.26	43.87
12	6.13	739.93	37.00	29.60	32.17	12.33	3366.69	26.88	0.20	24.12
16	6.08	492.37	24.62	16.69	21.41	8.21	2240.28	17.00	0.13	14.88

EC–Electrical Conductivity, N–nitrogen, P–Phosphorus, K–Potassium, OM–Organic Matter, TPH–Total Petroleum Hydrocarbon, PAH–Polycyclic Aromatic Hydrocarbon, BTEX-BC–Bacteria Count

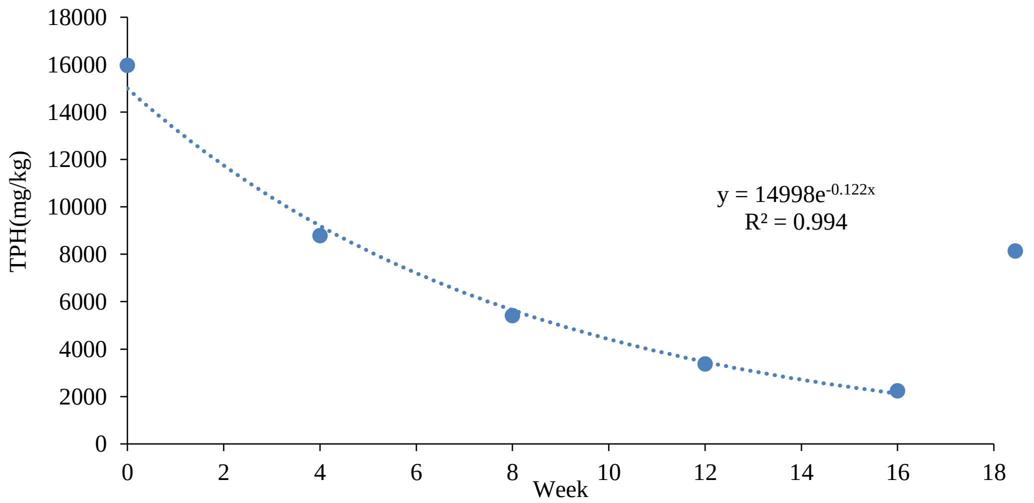

Figure 1. TPH Effect of Dry, Fresh and Decomposed Raffia Palm Trunk on Oil-Based Drill Cuttings Bioremediation.

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Figure 2 demonstrates that, during the 0 and 16 weeks of the degradation, the concentration of TPH decreased by 0, 45.01, 66.08, 78.92, and 85.97 percentage points, with an average reduction of 7154.27 mg/kg of TPH. The percentage reductions were brought about by the addition of dried, fresh, and decomposed raffia palm trunk to the oil-based drill cuttings bioremediation, which has a very high phosphorus concentration. This backs with the findings of Amajuoyi & Wemedo (2015), who found that the addition of oil palm ash to diesel results in an excess of phosphorus that makes TPH more easily degraded. Additionally, it backs up the studies by Njoku et al. (2016) and Chinwendu et al. (2021), which demonstrated how microorganisms in oil-based drill cuttings might increase deterioration. The association between the concentration of TPH and the remediation time (0, 4, 8, 12 and 16 weeks) is shown in Figure 1 [17].

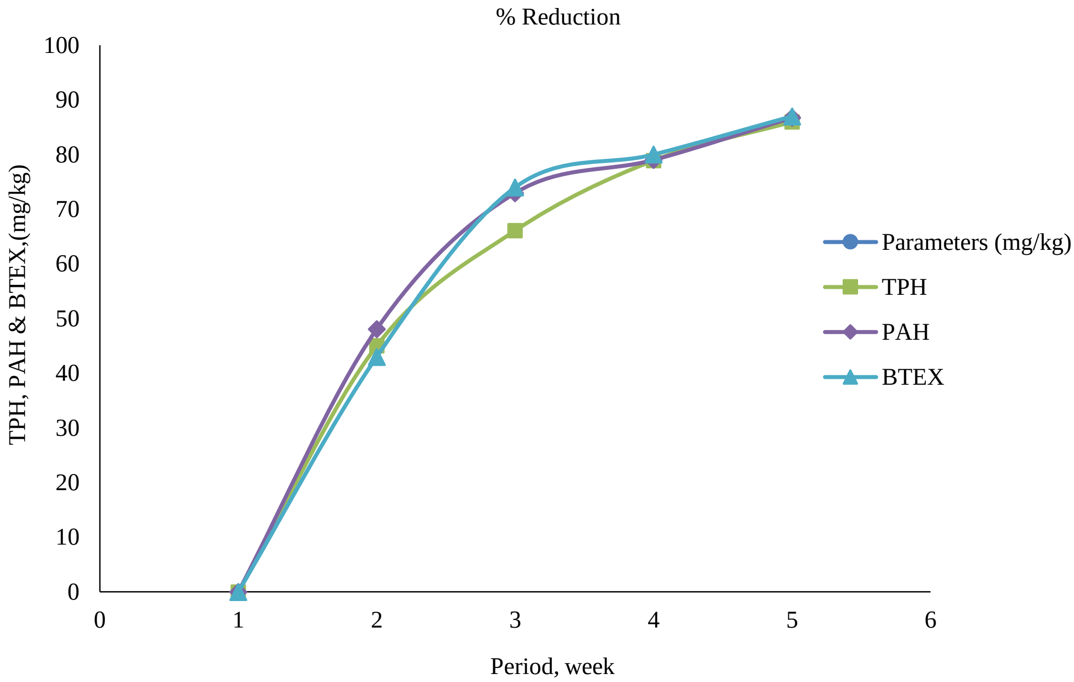

Figure 2. Percentage Reduction of TPH, PAH and BTEX Effect of Dry, Fresh and Decomposed Raffia Palm Trunk on Oil-Based Drill Cuttings Bioremediation.

Polycyclic Aromatic Hydrocarbon (PAH)

Before the treatment commenced at the initial stage of remediation, there was an increase in the level of TPAHs. Then the results shows that the concentration of TPAHs in the oil-based drill cuttings bioremediation decreased as the dry, fresh and decomposed raffia palm trunk was introduced.

The decrease in TPAHs concentration in Figure 3 illustrates the relationship between the concentration of TPAHs and the bioremediation period (0, 4, 8, 12 and 16 weeks).

It is apparent that there were significant differences in the treatment means 5% level at 1% significant level. This implies that there is 99% certainty that the application of dry, fresh, and decomposing raffia palm caused the variation in treatment means. This displays TPAHs percentage decreases of 0.48.08, 72.6, 79.1, and 86.73% with an average of 54.67 mg/kg for weeks 0 through 16, respectively. The presence of high phosphorus content in dry, fresh, and decomposed raffia palm trunk may have caused an increase in the rate of TPAHs degradation in the oil-based drill cuttings bioremediation, which may have led to a decrease in the PAHs in the oil-based drill cuttings contamination after 16 weeks of bioremediation (Latifa, et al. 2018). Also, this is similar to the findings of Christopher *et al*. (2016), Bright *et al*. (2017), and David *et al*. (2017) which reported that organic waste enhanced reduction of PAHs in oil-based drill cutting contamination to minimum level [18–20].

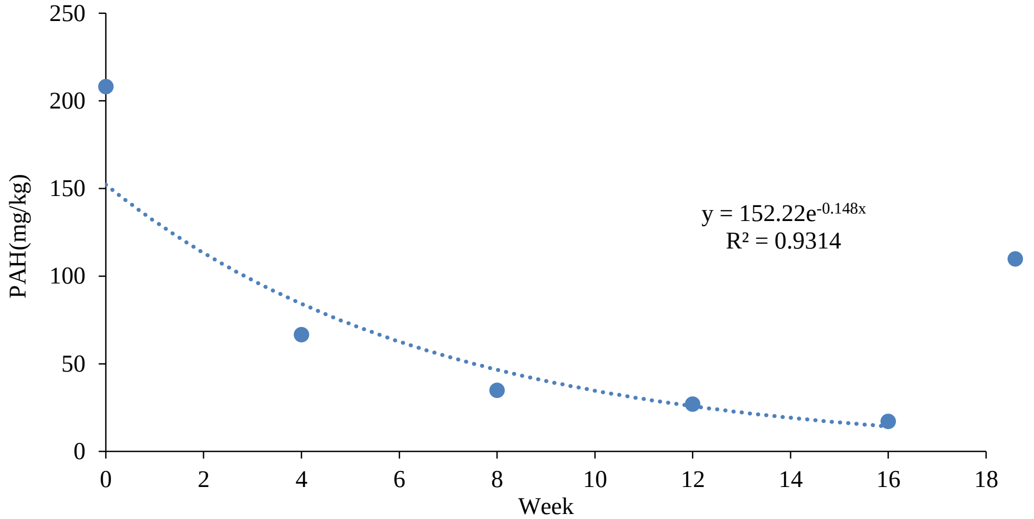

Figure 3. PAH Effect of Dry, Fresh and Decomposed Raffia Palm Trunk on Oil-Based Drill Cuttings Bioremediation.

Benzene Toluene Ethylbenzene Xylene (BTEX)

BTEX known as benzene toluene ethylbenzene and xylene is refers to as very volatile organic which occurred naturally in sea water, crude oil, petroleum deposit and forest fire resulting from volcanic eruption of gas emission as it readily evaporates when warm or hot in climatic region leading to very higher concentrations especially in the vapour phase. The relationship between the concentration of BTEX and the bioremediation period is shown in Figure 4. It is apparent that there were significant differences in the treatment means 5% level at 1% significant level. This suggests that with 99% confidence, the difference in treatments means was due to the dry, fresh and decomposed raffia palm applied. The concentration of BTEX reduction ranges from 1.00, 0.57, 0.26, 0.20, and 0.13 for weeks 0, 4, 8, 12 and 16. The percentage reduction for BTEX were 0, 43, 74, 80 and 87% with an average of 0.48 for 0, 4, 8, 12 and 16 weeks [21, 22].

As the number of weeks increased, Figure 4 demonstrates how the amounts of BTEX decreased. The research by Onakughotor et al. (2014), Nweke et al. (2023), and Anna et al. (2016) are all in agreement with these findings.

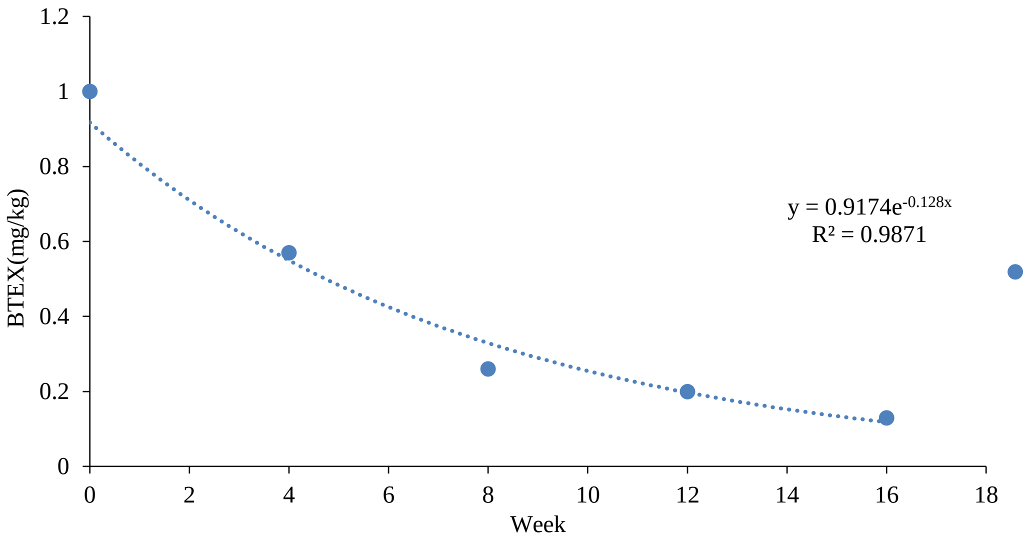

Figure 4. BTEX Effect of Dry, Fresh and Decomposed Raffia Palm Trunk on Oil-Based Drill Cuttings Bioremediation.

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CONCLUSION

Through the enhancement of microbial activities in the contaminated environment (soil), the combined effect of dry, fresh, and decomposed raffia palm as a bio-stimulants in the bioremediation of oil-based drill cuttings contamination resulted in the reduction of the pollutants TPH, TPAH, and BTEX to about 99%. This is because the stimulants include (NPK), which is readily accessible. After 16 weeks of bioremediation, the stimulants degraded TPH, TPAH, and BTEX at 86, 87, and 87%, respectively. Additionally, the coefficients of determination (R2) for these degradations were 0.994, 0.9314, and 0.9871, respectively. Other physiochemical parameters, including phosphorus, nitrogen, potassium, organic matter, bacteria count, electrical conductivity, and pH were also determined.

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