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Effectiveness of African Palm (*Raffia Farinifera*) Substrate in the Bioremediation of Oil-Based Drill Cuttings

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***Abstract**: This study determines the effect of dry raffia palm substrate for degradation of oil-based drill cuttings bioremediation. The experiment was carried out at the Rivers Institute of Agricultural Research and Training (RIART) located in the Rivers State University, Port Harcourt. Samples of oil-based drill cuttings were bulk in eleven reactors with four replications (T1, T2, T3-T11). The physiochemical properties of the initial drill cuttings were analyzed. Also, the physiochemical properties of the oil-based drill cuttings of substrate such as. Total Petroleum Hydrocarbon, Benzene Toluene Ethylene Xylene and Polycyclic Aromatic Hydrocarbon were analyzed in the laboratory before and after treatments. Total Petroleum Hydrocarbon, Benzene Toluene Ethylene Xylene and Petroleum Aromatic Hydrocarbon reduction were drastically reduced in all treatment options at the end of 16weeks of remediation. Total Petroleum Hydrocarbon, Petroleum Aromatic Hydrocarbon and Benzene Toluene Ethylene Xylene rate of percentage reduction ranges from 83 to 84% in all the treatment option for the period of 16weeks. Results also displayed high coefficient of determination of (R^2) between the range of 0.9789 to 0.9974 in all the treatment option. The results of the ANOVA showed that significant difference at 95% and highly significant at 99% confidence level. Similarly, the coefficient of variation of every low percentage were revealed for the treatment option respectively. This confirmed that the experimental error was very low and reliable. It is however recommended that the dry raffia palm substrate should be used for bioremediation of oil-based drill cuttings respectively.*

Keywords: **Bioremediation, Biodegradation, Oil-Based Drill Cuttings and Dry Raffia Palm Substrate**.

1. Introduction

Nigeria is endowed with a variety of mineral resources, including petroleum. It is self-evident that the quest for crude oil entails a complex interaction of operations. Drilling of petroleum hydrocarbon wells, location of petroleum hydrocarbon deposit with the use of seismic surveys and geological mapping, and development of the petroleum hydrocarbon deposit to production level are most of these activities [1]. Nonetheless, drill bits influence the discharge of pollutants into the environment during drilling operations, resulting in significant volumes of drill cuttings that are harmful to the environment. According to [2], the waste generated during petroleum hydrocarbon exploration can be divided into two categories: liquid (water and oil) and solid (drilling mud and cuttings). Several drilling additives are suspected to be poisonous and should be avoided [1,6]. Drilling muds can be water-based, oil-based, or synthetic-based, depending on the number of heavy metals and hydrocarbons present. According to [3], oil-based drilling muds (OBM) are primarily related to unsaturated and saturated petroleum hydrocarbons, which can be as high as 45 percent and 60 percent, respectively. According to [1,4,7] drill cuttings and wasted drilling fluids account for roughly 2% of total waste volume, while other connected wastes such as produced formation water account for over 90% of total waste volume. During the drilling process, the cutting debris from crude oil drilling might amount to tens of thousands of tons. (1,3,5) noted that almost two million five hundred tons of debris from drilling operations are piled up in the Norwegian section of the North Sea. Drill cuttings have been observed to include a wide spectrum of inorganic and organic chemicals, even after cleaning, especially when oil-based muds are recycled. Onshore and offshore settings are two of the immediate physical environments that are directly affected by drilling waste disposal. Freshwater, dry land, and swampy environments all fall under the environmental onshore umbrella, and each has its own unique ecological characteristics and features Despite the fact that drilling muds (OBM or WBM) used for onshore oil well drilling are largely disposed of in reserved pits, due to the huge volume of drill wastes, the majority of cuttings and muds can end up in nearby soil and water bodies during run-off and precipitation. According to [3], some drilling pollutants are even dumped straight on farmland. Unlike on dry land, oil and waste contamination of freshwater lakes and swampy places are difficult to clean of contaminated oil by their very nature [1,5]. Drilling fluids, commonly known as drilling muds, are used to improve drilling operations by suspending cuttings, controlling pressure, stabilizing exposed rocks, providing buoyancy, cooling, and lubricating**.** Drilling fluids are used in the oil and gas industry for drilling bore holes and constructing oil wells, according to [4]. They are typically classified as either aqueous drilling muds or water-based muds (WBM) or non-aqueous drilling fluids such as oil-based muds or invert emulsions or synthetic based muds. Another class has been developed that replaces traditional oils with synthetic organic liquids designed to provide superior environmental performance. Water-based fluids contain clays, weighting agents, and other specialist chemicals in the aqueous phase whereas oil-based or synthetic-based fluids contain a hydrocarbon continuous phase with an emulsified internal aqueous "brine" phase in addition to clays, weighting agents, and other additives. Such fluids fulfill a wide variety of functions in drilling operations, including maintaining pressure in the formation of rocks and helping to protect and support the borehole wall, preventing collapse. They're also made to shield permeable zones from harm during drilling, which boosts hydrocarbon recovery rates. Drilling fluids also aid in the cooling and lubrication of the drill bit and drill string, as well as the removal of excavated rock (also known as "drill cuttings") from the borehole [4,5,7].

As a result, the hydrocarbon content and heavy metal content of onshore drilling wastes are prone to contaminate the environment, with serious health consequences. However, as stated by [1,6], this is dependent on the nature, quantities of heavy metals, hydrocarbons, and trace elements. Drill cuttings and mud disposal have been reported to be of ever-increasing concern, particularly among academics in the international community, due to their multiple detrimental consequences on health, safety, and the environment (HSE), Nigeria cannot be an exception.

Another study by the Environmental Investigation Agency (EIA,) found that environmental management of oil-based drill cutting has been a subject of concern for several crude oil producing businesses in Nigeria, owing to the huge amount created and its environmental repercussions. As documented in the [1,2], inappropriate treatment of drill cuttings has resulted in environmental consequences. [5], for example, found that it increases turbidity of surface water bodies and has an ugly nature on sea-bottom (benthic) habitats. According to [6], drill cuttings are generally classified as hazardous to the environment. Regardless of technology advancements, a developed drilling concept has its own set of technical hurdles, process needs, and environmental concerns.

The drilling fluid carries rock debris to the surface, where the cuttings are collected using solids-control equipment, according to the manufacturer [4]. When oil-based or synthetic-based drilling fluids are employed, the discharged cuttings typically have a hydrocarbon concentration of 10-15%, as well as residual salt and weighing material from the internal phase. While properly managed drill cuttings have been securely disposed of for many years, untreated drill cuttings can have a significant influence on the receiving environment, prompting the establishment of more stringent disposal rules around the world [7].

However, the hydrocarbon concentration of the drilling fluid is often viewed as the main contaminant, which has raised serious concern to many Nigerians. African palm, otherwise known as *raffia farinifera*, originated from Africa, where it plays an important role in the ecosystem. The cultivation of *raffia farinifera* always occurs in family estates and farms, which is traditionally practiced through planting system especially in Etche, Ikwerre Local Government Areas South-Eastern part as well as South-South of Nigeria, more especially in Rivers State, where it is in abundant. They are mainly grown around the wetlands more especially the flood plains and the river valleys. Their presence has led to the growth and development of other plant and animal species, which are linked to a complex web of feeding relationship. African palm (*Raffia Farinifera)* and other palms species have been exploited in wine industries according to [8]. This study, on the other hand, investigated African palm *(raffia farinifera's)* substrate bioremediation capacity. As a result, the goal of this study was to determine the potential of African palm substrate for remediation application [1]

2. Materials and Methods

2.1 Study Area Description

The experiment was conducted at the Rivers Institute of Agricultural Research and Training (RIART), located at Rivers State University, Port Harcourt, Nigeria. The oil-based drill cuttings were obtained from the Boskel Nigeria Limited, in Rivers State, Niger Delta region of Nigeria. The experiment was carried out on 21st of August 2020 to 21st of December 2020. The experimental area is made up of flat plains with soil characterized as coastal plain sand. The climatic condition is that of a humid tropical climate with an average rainfall of about 2100mm of which 70% of rain falls between April and September. The randomized complete block design (RCBD) was used in this study. The experimental bioreactor contains 20 liters. Four liters were marked each provided for different treatment options. The vegetative cover is the tropical rain forest with longitude and latitude of (5°19'N, 6°28'E).

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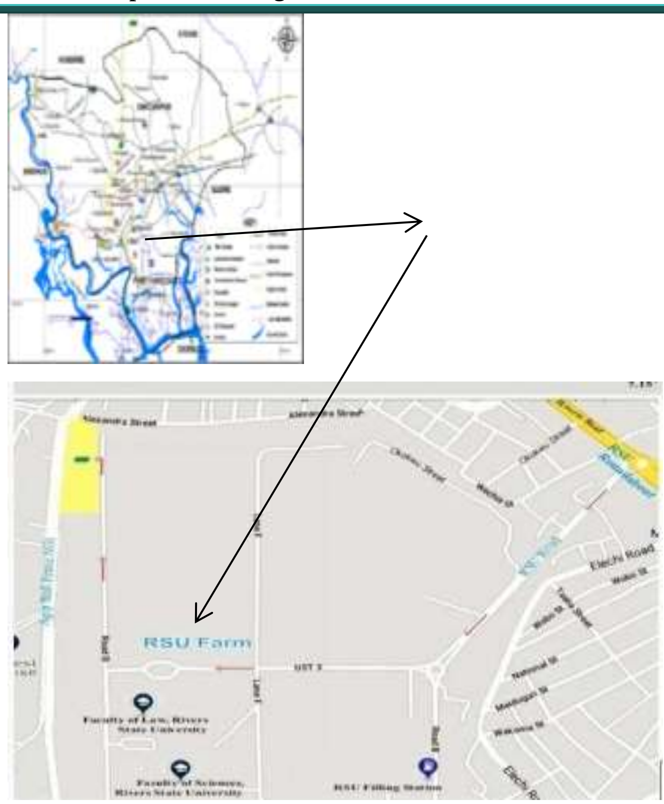

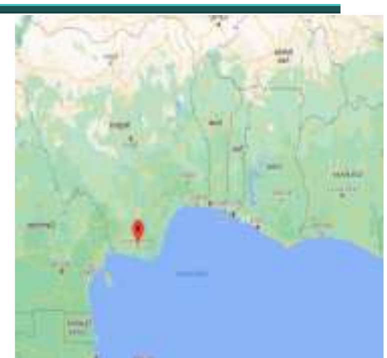

Dry Raffia Palm

ANOVA Equation

$$RSS = \frac{1}{t}\sum R^2 - C.F \quad (1)$$

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

GT= Grand Total

$$TSS = \frac{1}{r}\sum T_i^2 - C.F \quad (3)$$

$$ESS = Total\ S.S - RSS - TSS \quad (4)$$

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

$$RMS = \frac{RSS}{r-1} \quad (6)$$

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

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

2.2 Source of Bio-stimulant Used.

The dry raffia palm substrate as an amended material used for the study contain in (rector 1). Dry Raffia palm substrate was collected from Raffia palm trunk located at Okoroagu in Etche Local Government. There were Eleven treatment options (consisting of ten treatment options involving dry *raffia* palm and compost tea from raffia palm trunk all were used as treatment materials while the control was left untreated. Compost tea which serves as tea for irrigation that enhanced tilling for aeration. All these bio-stimulants or derivatives were tested and filled in 20 Liters of bucket at very low thermal conductivities containing fixed masses of the oil-based drill cuttings according to their fixed ratios. The content was mixed thoroughly to get a composite mixture thereafter they were safeguard and kept at room temperature except for control.

Samples were taken every 4weeks and analyzed for reduction in total petroleum hydrocarbon (TPH), total polycyclic aromatic hydrocarbon (PAH) and benzene toluene ethylene and xylene (BTEX) in the ratio of 2:1

2.4 Statistical Analysis

The single factor experimental analysis of variance (ANOVA) was used to performed on the various replications of the experimental cells to determine the percentage reduction of TPH, PAH and BTEX. This was done based on the F-test. Differences were considered significant if $F_{computed} > F_{table}$ at 5% and 1% significance levels. The experiment was carried out using the Randomized Complete Block Design (RCBD).

3.RESULTS AND DISCUSSIONS

Table 1: Effects of Dry Filtrate Raffia Palm Trunk on Oil-based Drill Cuttings Bioremediation

Period (weeks)	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	3507.43	175.47	140.38	152.58	58.49	15967.90	128.07	1.00	7.56
4	6.60	1935.12	96.76	77.40	84.14	32.25	8804.81	75.64	0.64	12.38
8	6.30	1440.76	72.04	57.63	62.64	24.01	6555.46	43.79	0.38	43.87
12	6.15	990.28	49.51	39.61	43.06	16.50	4505.77	39.89	0.28	24.19
16	6.07	604.93	30.25	24.20	26.30	10.08	2752.41	21.27	0.16	18.01

Table 2: Percentage Reduction in TPH, TPAH & BTEX of Dry Raffia Palm Trunk in Bioremediation of Oil Based Drill Cuttings

Parameters (mg/kg)	Period (Weeks)				
	0	4	8	12	16
TPH	0	45	59	72	83
TPAH	0	12	26	45	76
BTEX	0	36	62	72	84

3.1 Total Petroleum Hydrocarbon (TPH)

The dry raffia palm trunk effect on the TPH concentration in oil-based drill cuttings bioremediation is shown in Table .1. Also, Figure 1 displayed the TPH concentration against time (weeks) on oil-based based drill cuttings bioremediation. The result shows that the concentrations of TPH reduced with increase in the number of weeks. Between the 0 to 16 weeks of the degradation, there are 0, 45, 59, 72 and 83 percentage reduction on TPH concentration with average of 7717.19mg/kg of TPH respectively. Table.2 and Figure.1 shows the reductions in percentage in respect to TPH because of addition of microorganisms' augmentation. The reductions in percentage were because of addition of dry raffia palm trunk into the oil-based drill cuttings bioremediation which possesses very high content of phosphorus as shown in Table1. This agrees with the findings of [9] that the addition of oil palm ash in diesel leads to the abundant of phosphorus that aids to the degradation of TPH in this study as well as the work of [1,17,10] which typified the ability of microorganisms in oil-based drill cuttings contaminated environment (soil) that enhances degradation. Figure.1 also illustrates the relationship between the concentration of TPH and remediation period (0, 4, 8, 12 and 16 weeks).

The coefficient of determination, R^2 is 0.9816 at the 16 weeks of remediation used in the study. The ANOVA result for the effect of dry raffia palm on the TPH concentration as contained in the study. 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 raffia palm applied.

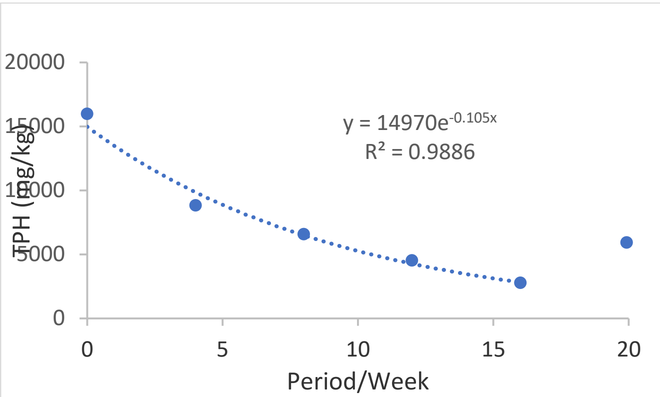

Fig.1: TPH Effects of Dry Raffia Palm Trunk on Oil-Based

3.2 Polycyclic Aromatic Hydrocarbon (PAH)

The chemical concentration of PAH as shown in Table 1 which is presented graphically in Figure 2. Figure 2 show the total polycyclic aromatic hydrocarbon (PAH) chemical concentration of bioreactor containing treatment T_1. Before the treatment commenced at the initial stage of remediation, there was an increase in the level of PAH. The result shows that the concentration of PAH in the oil-based drill cuttings bioremediation decreased as the dry raffia palm trunk was introduced. This decreases in PAH concentration, (Figure.2) illustrates the relationship between the concentration of PAH and the bioremediation period (0, 4, 8, 12 and 16 weeks). The coefficient of determination, R^2 is 0.9788 at the 16 weeks of remediation used in the study. The result of the ANOVA for the effect of dry raffia palm substrate on the concentrations of PAH as used in the study. It is apparent that there were significant differences in the treatment means 5% level at 1% significant levels.

This suggests that with 99% confidence, the difference in treatments means was due to the substrate applied. This shows PAH percentage reductions of 0, 42, 65, 73 and 84 % with an average of 61.73 for weeks 0, 4, 8, 12 and 16 as indicated in Table.2. The decrease of the PAH in the oil-based drill cuttings contamination after 16 weeks of bioremediation could be because of the incidence of high phosphorus content in dry raffia palm trunk which prompted an increase in the degradation rate of PAH on the oil-based drill cuttings bioremediation [11]. Also, this is like the findings of [1 12,13,14] which revealed that organic waste enhanced reduction of PAH in oil-based drill cutting bioremediation to minimum level.

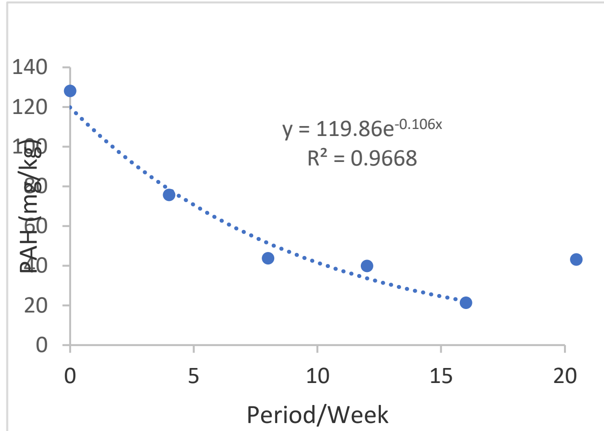

Figure 2: PAH Effects of Dry Raffia Palm Trunk on Oil-Based Drill Cuttings bioremediation

3.3 Benzene Toluene Ethylbenzene Xylene

BTEX known as benzene toluene ethylbenzene and xylene refers to very volatile organic compound which occurs 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 effects of dry raffia palm trunk on benzene toluene ethylbenzene and xylene as shown in Table1. The relationship between the concentration of BTEX and the bioremediation period is shown in Figure 3.

The coefficient of determination, R^2 is 0.9974 at the 16 weeks of remediation used in the study. The result of the ANOVA for the dry raffia palm trunk effect on the concentration of BTEX as contained in the study. It is apparent that there were significant differences in the treatment means 5% level at 1% significant levels. This suggests that with 99% confidence, the difference in treatments means was due to the dry raffia palm trunk applied. The concentration of BTEX reduction ranges from 1.00, 0.64, 0.38, 0.28, and 0.16 for an average of 0.49 weeks 0, 4, 8, 12 and 16 in Table.1 respectively. The percentage reduction for BTEX were 0, 36, 62, 72 and 84% for 0, 4-, 8-, 12- and 16-weeks as shown in Table.2. Figure 3 shows that the concentrations of BTEX reduced as the number of weeks increases. This finding agrees with the work of [1,15,16] respectively.

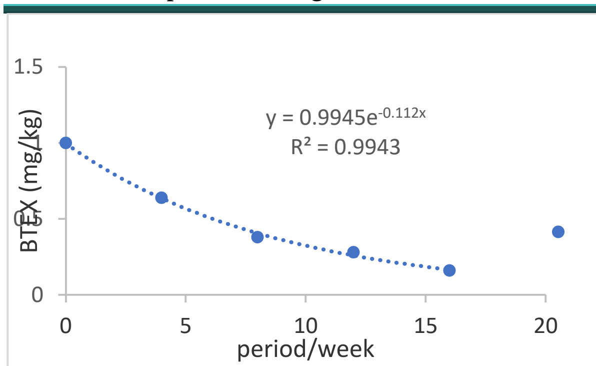

Figure.3: BTEX Effects of Dry Raffia Palm Trunk on Oil-Based Drill Cuttings bioremediation

4. CONCLUSION:

Dry raffia palm influenced the degradation of all parameters (TPH, BTEX, PAH), in oil-based drill cuttings contamination. It is because of very high content of composition of nutrients (NPK). The dry raffia palm can degrade (TPH, BTEX, PAH) to about 83, 84 and 84% respectively, and the coefficient of determination (R^2) are 0.9816, 0.9788 and 0.9974 respectively. Similarly, it's coefficient of determination ranges from 0.9816 to 0.9824 with other physiochemical parameters for phosphorus, nitrogen, potassium, organic matter, bacteria count, electrical conductivity, and pH after 16 weeks of bioremediation.

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ABREVATION

r = Replication
t = Treatment
SS = Sum of Squares
d/f = Degree of Freedom
MS = Mean Squares
RSS = Replication Sum of Squares
TSS = Treatment Sum of Squares
ESS = Error Sum of Squares
RMS = Replication Mean Squares
TMS = Treatment Mean Squares
EMS = Error Mean Squares

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