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Degradation of Total Petroleum Hydrocarbon in Crude Oil Polluted Soil using Water Treatment Residuals from Fish Pond Effluents

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***Abstract**: This study aims to compare the effect of feed formulation on the degradation of total petroleum hydrocarbon using water treatment residuals from fish pond effluents. The remediation process was for varying treatments of two different nutrients (WTRs, A, and WTRs, B). The experiment was carried out in Department of Agricultural and Environmental Engineering workshop in Rivers State University, Port Harcourt, Nigeria. Soil samples with crude oil were bulk in five (5) Reactors (T1, T2, T3, T4, and T5) with three replications. The nutrient value of WTRs (A) and WTRs (B) such as nitrogen, potassium, phosphorus, as well total petroleum hydrocarbon (TPH) of treated soil were analyzed in the laboratory before and after treatment. In addition, the statistical tool used for analysis was F-test and TPH reduction of the treated soils were determined. Result showed that WTRs (A), and WTRs (B) have high NPK values. The result also revealed that TPH in the crude oil polluted soils were reduced drastically in all the treatment options (reactors) at the end of the remediation period of 60 days. TPH, percentage reductions were ranging from 93.59 to 95.90%, respectively in all treatment options for the period of 60 days. Also, F-test result showed a significant difference at 95% confidence levels. T3 was the most performing studied nutrient because of its high degradation efficiency. It is therefore recommended that WTRs (A), and WTRs (B) can be used for degradation of TPH in crude oil polluted soil.*

Keywords— **bioremediation, fish feed formulation, fish pond effluents, total petroleum hydrocarbon, water treatment residuals**

1. INTRODUCTION

The contamination of the soil part of environment by total petroleum hydrocarbons is becoming predominant across the world. It might be due to dependence on petroleum as a major source of energy, rapid industrialization, population growth and complete neglect to environmental health. According to Kumar et al. [1] that the estimate of natural crude oil seepage into the soil was quantified to be 600,000 metric tons per year with a range of uncertainty of 200,000 metric tons per year. The main cause of water and soil pollution were due to the release of hydrocarbons into the environment whether accidentally or due to human activities [2].

Total petroleum hydrocarbon as a product of crude oil has entered the environment through oil spillage. Crude oil pollution has been connected to a rise in the degradation of environmental soils, depositing many contaminants like hydrocarbons and heavy metals and also making the environment unfavorable for living things [3, 4]. Study by Ekemube et al. [5] reported that crude oil alters the physicochemical characteristics of the soil. Hence the increase in crude oil in the soil, the more physicochemical characteristics of soil change thereby causing imbalance in soil nature.

The Niger Delta region is chockfull with petroleum hydrocarbons-contaminated soils that need cost-effective and environment friendly, time efficient and simplified methods to remediate. On the other hand, fish farmers discharge pond effluents without treatment into nearby water bodies. This pollutes such water bodies by increasing organic nutrient level in the receiving water leading to algal bloom. With the economic water scarcity in Nigeria, it is expedient that water bodies be protected from pollution as much as possible. The dream of creating such items for the unsolvable environmental pollution circumstances of today becomes a reality with the application of locally sourced environmental remediation stimulants [3, 4]. Furthermore, study suggest that remediation should be adopted to regain the originality of the soil [5].

Bioremediation of contaminant impacted areas has become a major undertaking, with many different approaches and options available. The cost, long-term effectiveness/ permanence, and commercial availability of remediating materials must be considered when planning a remediation effort, as must the public general acceptance of them and their capacity to deal with potentially high pollutant concentrations that may have considerable toxicity and mobility. The remediation approach adopted must therefore consider all such points and strike a balance [6]. The process of bioremediation involves the use of microorganisms to detoxify or degrade environmental pollutants including petroleum hydrocarbons from soil, sediments and water owing to their diverse metabolic capabilities [7]. It has been reported by Ekemube et al. [7] changes in microbial activities pinpointed the highest hydrocarbon degradation supported by increase in total organic carbon and total nitrogen. Bioremediation technology is an evolving technology and it is believed to be a relatively cost-effective technology [9]. Bioremediation has been defined as the use of biological processes to degrade, break down, transform, and/or essentially remove contaminants or impairments from soil and water [10]. The need for plentiful, effective, low-cost materials for use in contaminated site remediation has therefore stimulated interest in finding additional uses for readily available by-products that might otherwise simply be discarded; in this study the utility of using water treatment residuals (WTRs) from fish pond effluents in the remediation of petroleum hydrocarbon impacted soils.

Fish pond waste water consists of excretory product of fishes and nutrients not totally exhausted by the fishes. The quantity and quality of waste generated and discharged into natural water bodies from fish ponds has recently indicated the need for different strategies to address water quality challenges in the environment [11]. The main cause of poor water quality is waste accumulation through hyper-nitrification resulting from excessive feeding rates and high nutrient dietary composition, both of which are common phenomena in intensive aquaculture systems [12]. High levels of nitrate and phosphate accumulation predispose fish to infestation by parasites and pathogens and also pose a threat to the environment [13]. Many aquaculture systems generate high amounts of wastewater containing compounds such as suspended solids, total nitrogen and total phosphorus [11].

Beneficial use of WTRs is therefore an attractive option that offers financial advantages and facilitates development of a more circular economy with greater levels of materials recycling. The use of WTRs in the bioremediation of contaminated soils has yet to be comprehensively investigated. Moreover, while a number of studies have investigated their effects on soil microbes following soil amendment with WTRs [14], very few, if any, have examined the influence of feed formulation on the bioremediation potentials of WTRs from fish pond effluents. Therefore, there is need for this study to restore contaminated soils. Hence, this study aims to compare the effects of two different feed formulation on the degradation of total petroleum hydrocarbon using water treatment residuals from fish pond effluents.

2. MATERIALS AND METHODS

2.1 Study Area Description

The experimental was carried out at the Teaching and Research Farm of Rivers State University, Port Harcourt, Nigeria. Port Harcourt is the capital of Rivers State and most especially the center of crude oil exploration in Niger Delta as well as Nigeria at large. The ambient environment (i.e., Port Harcourt metropolis) have a mean monthly relative humidity of 85% and a daily minimum temperature about 230c with a mean daily maximum temperature of 32^{o}c.

2.2 Study Area Description

The completely randomized design (CRD) was used in this study. The design was used to assign treatments to each of the reactors. A total of 15 reactors made up of 5 treatments labelled (T1 to T5) and a Control labelled T1 replicated thrice as shown in Tables 1 and 2.

Table 1: Experimental Material Mix Proportion

Reactors	Materials Mix Proportions	Mixed Ratios
T_1	4000 g of Soil + 500 ml of Crude oil + 0 g of WTRs	4:0.5:0
T_2	4000 g of Soil + 500 ml of Crude oil + 500 mg of WTRs(A)	4:0.5:0.5
T_3	4000 g of Soil + 500 ml of Crude oil + 1000 mg of WTRs(A)	4:0.5:1.0
T_4	4000 g of Soil + 500 ml of Crude oil + 500 mg of WTRs(B)	4:0.5:0.5
T_5	4000 g of Soil + 500 ml of Crude oil + 1000 mg of WTRs(B)	4:0.5:1.0

WTRs(A) = WTRs from feed A, WTRs(B) = WTRs from feed B

Table 2: Layout of the Completely Randomize Design for Crude Oil Contaminated Soil

Treatment	Levels of Treatment		
	Replicate 1	Replicate 2	Replicate 3
T_1	$T_{1,1}$	$T_{1,2}$	$T_{1,3}$
T_2	$T_{2,1}$	$T_{2,2}$	$T_{2,3}$
T_3	$T_{3,1}$	$T_{3,2}$	$T_{3,3}$
T_4	$T_{4,1}$	$T_{4,2}$	$T_{4,3}$
T_5	$T_{5,1}$	$T_{5,2}$	$T_{5,3}$

7 Treatments (T_1, T_2, T_3, T_4, and T_5) Each Replicated Three Times

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2.3 Sample Preparation

Soil samples were collected from different random spot per reactor using a hand dug auger capable of obtaining uniform cores of equal volumes to desired depth for the background check. The samples were put in amber coloured glass vials with no headspace to preserve the integrity of the sample in order to prevent volatilization. The sample was then stored in an ice box containing sufficient ice blocks, and transported to the laboratory for analysis in order to achieve background data. The sample preparation was strictly adhered to in line with Environmental Guideline and Standard of petroleum industry in Nigeria [15] for quality assurance.

For the experiment, about 4000 g of uncontaminated soil was mixed with 500 ml crude oil at the ratio (4:0.5) equivalent to selected concentrations accordingly. The crude oil sample of 500 ml was administered into each of the 4000 g of soil samples in the reactors through a perforated can. These mixes were in separate reactors for 3 days undisturbed before taken to the laboratory for analysis. On the 3rd day the WTRs(A) and WTRs(B) would be added into the contaminated soil at the rates of 500, 1000 and 1500 mg, respectively. Tilling was performed once a week. Soil samples was also collected from the reactors every 15 days and were taken to the laboratory for analysis. The properties that were analysed in the laboratory were total petroleum hydrocarbon (TPH) in crude oil polluted soil, respectively on a scale of concentrations in consideration of the DPR (2018) guidelines range of target and intervention values for TPH.

2.4 Laboratory Analysis

The following soil physicochemical parameters: nitrogen, potassium, phosphorus, and total petroleum hydrocarbon (TPH), were analyzed using standard method.

2.4.1 Nitrogen, Phosphorus and Potassium Analysis

Nitrogen was determine using the modified Kjeldahl method. Ascorbic acid method was used to estimate available phosphorus. While potassium content in the WTRs samples were analysed by flame atomic absorption spectrometry using a UNICAM-969 atomic spectrophotometer by measuring the light absorbance of the sample at the wavelength range of 357.9 – 228.8µm according to APHA method 3111C.

2.4.2 Total Hydrocarbon (TPH) Analysis

TPH of the samples were analysed in line with USEPA 8015 method using Gen Tech master G equipped with a split/ split less injector, J and W 30-meter DB-5column and an FID detector.

2.5 Statistical Analysis

The statistical method that was employed to analyze the data is F-test and it help to obtained an appropriate error term with single probability risk determined if the means considered are totally different and if the difference are beyond what is attributed to chance or experimental error sand difference will be considered as significant at $p \leq 0.05$. This was accomplished by use statistical software Microsoft excel 2021 version to determine if the F-statistic is statistically significant at 0.05.

2.6 Performance Comparison of WTRs (A) and WTRs (B) during the Bioremediation

Performance evaluation of WTRs(A) and WTRs(A) was determined using percentage reduction This was determined based on the initial and final concentration of the contaminant in the soil by using equation 1.

$$Biodegradation\ rate\ (\%) = \frac{\mathrm{Ci - Cf}}{\mathrm{Ci}} \times 100 \qquad (1)$$

Where:

% = percentage reduction

Ci = initial concentration of TPH (mg/kg)

Cf = final concentration of the treated TPH (mg/kg)

3. RESULTS AND DISCUSSION

3.1 Chemical Concentrations of WTRs using Different Feeds Formulation

Table 3 shows the TPH, and nitrogen phosphorus, and potassium (NPK) values of the of WTRs (A) and WTRs (B). The chemical compositions analyzed and used as indices for evaluation of level of nitrogen, phosphorus and potassium nutrient levels. Among the options, A (Blue crown feed) and B (Coppens feed), It was A that has the highest concentration of the NPK values followed by B (Table3).

Table 3: Chemical and Biological Composition of the Initial Soil Condition and Treatment

Treatment Options	Parameters (mg/Kg)			
	N	P	K	TPH
B	6.21	0.79	4.351	N/A
A	8.46	1.02	8.237	N/A

3.2 Effects of WTRs (A) on TPH

The effect of WTRs (A) on TPH concentration in the crude oil polluted soil is shown in Table 4. Also, Fig. 1 shows the graphical variation of TPH concentration in crude polluted soil with time for different treatment composted with WTRs (A) on the polluted soils. An examination of the Figure 1 showed that the TPH concentrations decreased with the presence of WTRs (A) and increase in number of days. The T1 was without amendment with any stimulant while T2 and T2 were amended with WTRs (A) that were different proportion by mass. The TPH concentrations contained in the various treatment (T2 and T3, respectively) ranged from 16384.10 to 863.13, and 16383.10 to 671.04 mg/kg for 3 to 60 days, respectively according to the order of reduction. This might be due to the presence of WTRs (A) introduced to the crude oil polluted soil, which has high content of nutrients. The F-test result for the effect of WTRs (A) on the TPH concentration was calculated using 95% confidence level (5% significant level). It is obvious that there was significant difference in the treatment means at 5% significance levels. This suggests that with 95% confidence, the difference in treatment means was due to the variation in the amount of WTRs (A) applied. This revealed that the higher the quantity of the nutrient the more effective it will degrade TPH in contaminated soil.

Table 4: TPH (mg/kg) Concentration of Soil Before and After Treatment

Period, Day	Treatment				
	T1	T2	T3	T4	T5
3	16382.1	16384.1	16383.1	16385.1	16380.1
15	13489.3	6145.49	4777.77	5892.52	4777.77
30	11892.9	3452.52	2684.14	3310.41	2684.14
45	9852.63	1726.26	1342.07	1655.07	1342.07
60	8858.53	863.13	671.04	827.54	671.04

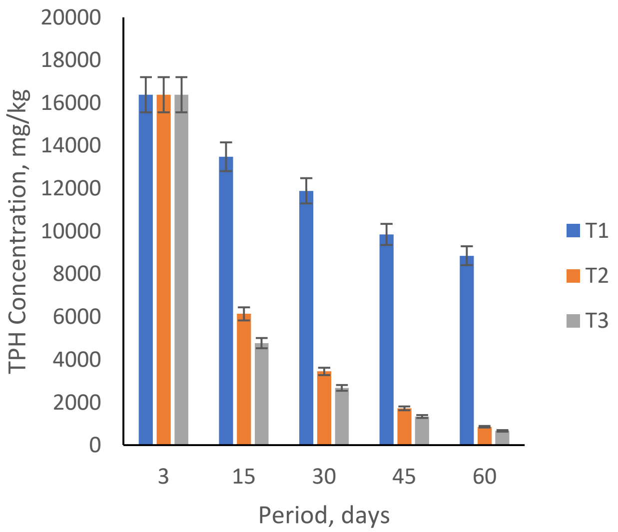

Fig. 1: Effect of WTRs (A) on TPH Polluted Soil

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3.3 Effects of WTRs (B) on TPH

Table 4 illustrates the impact of WTRs (B) on the TPH concentration in the soil that has been contaminated by crude oil. Additionally, Fig. 2 displays a graphic representation of the time-dependent fluctuation of TPH concentration in crude polluted soil for various treatments (T4, and T5) composting WTRs (B) on the polluted soils. When WTRs (B) was present and the number of days increased, the TPH concentrations reduced, as seen in Figure 2. WTRs (B) was used to amend the T4, and T5 while no treatment was given to T1. The treatment given the T4 and T5 were applied at different ratios. According to the order of reduction, the TPH concentrations in the different Treatments (T4, and T5, respectively) of the reactors varied ranging from 16583.10 to 827.54, and16383.10 to 671.04 mg/kg for 0 to 60 days, respectively. The F-test result for the effect of WTRs (B) on the TPH concentration was computed using 95% confidence level (5% significant level). It is obvious that there was significant difference in the treatment means at 5% significance levels. This suggests that with 95% confidence, the difference in treatment means was due to the variation in the amount of WTRs (B) applied. This revealed that the higher the quantity of the nutrient the more effective it will degrade TPH in contaminated soil.

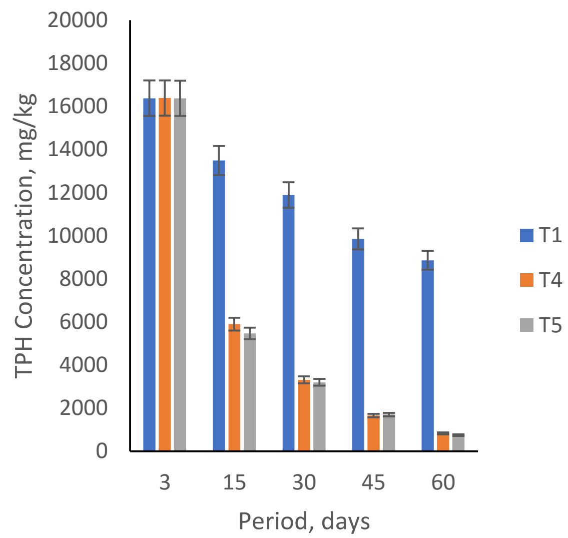

Fig. 2: Effect of WTRs (B) on TPH

3.4 Comparison of the Effects of the Variant Treatment Options on TPH

Fig. 3 showed the graphical comparison of the effects of the nutrients (WTRs (A), and WTRs (B) used in this study. T2 and T4 both received equal proportion of WTRs likewise T3 and T5 (see Figure 3, and 4, respectively). The study result revealed that T3 with WTRs (A) performs the best at the end of the sixtieth day of the remediation period. This was ranged from 0.00 to 95.90%. In addition, the treatments were compared using percentage reduction of TPH and the end of remediation period. The result of the percentage reduction is presented in Table 5. The result showed that T3 with WTRs (A) accomplishes the best in the degradation of TPH at the end of the 60 days of the remediation period. From the findings of this this study, it has been deduced that WTRs (A) is the most performance nutrient among the studied brand.

Table 5: TPH **Percentage Reduction on the Effects of WTRs (A) and WTRs (A)**

Period, day	Treatment				
	T1	T2	T3	T4	T5
3	0	0	0	0	0
15	17.66	62.49	70.84	64.04	66.64
30	27.40	78.93	83.62	79.80	80.50
45	39.86	89.46	91.81	89.90	89.64
60	45.93	94.73	95.90	94.95	95.43

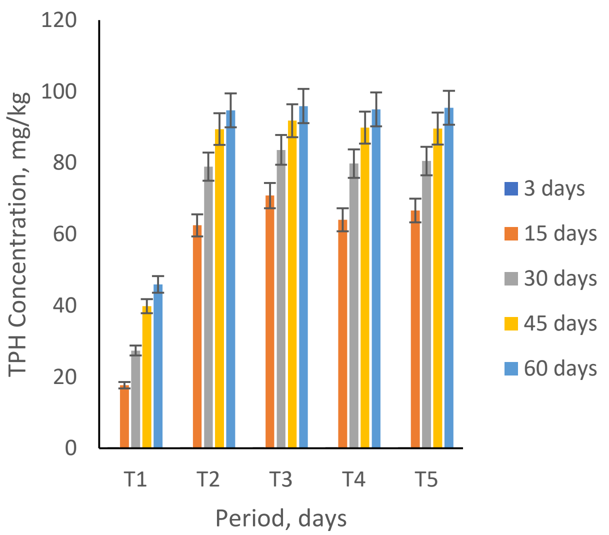

Fig. 3: Comparison of TPH Percentage Reduction on Variant Treatment

4. CONCLUSION

This study was based on degradation of total petroleum hydrocarbon in crude oil polluted soil using water treatment residuals from fish pond effluents. Test results of the analysis support the following conclusions. Cell A (WTRs) has the highest nutrient value (NPK) than Cell B (WTRs), there were no recorded concentration of TPH respectively. After treatment, the TPH concentrations dropped from 16382.12 to 8858.53 mg/kg, 16384.10 to 863.13 mg/kg, 16383.13 to 671.04 mg/kg, 16385.10 to 827.54 mg/kg, and 16380.12 to 1048.34 mg/kg in T1, T2, T3, T4, and T5, respectively. The effect of WTRs (A), and WTRs (B) product influenced the biodegradation of TPH in all the five points in the studied reactors. This is because of their high fertility nature. These biostimulants degraded TPH within the range of 93.59 to 95.90%, respectively. WTRs (A) was the best performing nutrient that enhanced the degradation of TPH in the crude oil polluted soil. This is because of its high TPH degradation efficiency ranging 95.90%.

5. References

[1] Kumar, A., Bisht, B. S., Joshi, V. D., & Dhewa, T. (2011). Review on Bioremediation of Polluted Environment: A Management Tool. International Journal of Environmental Sciences, vol.1, no. 6, pp. 1079 - 1093, 2011.

[2] Hartley, W., Riby P., & Waterson, J. (2016). Effects of Three Different Biochars on Aggregate Stability, Organic Carbon Mobility and Micronutrient Bioavailability. Journal of Environmental Management. vol. 181, pp. 770 – 778.

[3] Ekemube, R. A., & Walter-Duru, V. A. (2023). Brackish Water as Biostimulant in the Degradation of Total Petroleum Hydrocarbon and Polycyclic Aromatic Hydrocarbon in Crude Oil Polluted Soil. International Journal of Academic Engineering Research (IJAER), vol. 7, no. 6, pp. 63 – 71.

[4] [Walter-Duru, V. A., & Ekemube, R. A. (2023). Evaluating the Potentials of Costus afer Juice for Bioremediation of Crude Oil Contaminated Soil. International Journal of Academic and Applied Research (IJAAR), vol. 7, no. 6, pp. 58 – 66.

[5] Ekemube, R. A., Emeka, C., Nweke, B., Atta, A. T., & Opurum, A. N. (2022). Evaluation of Simulated Petroleum Hydrocarbon on the Physicochemical Properties of Soil. Research Journal of Ecology and Environmental Sciences, vol. 2, no. 4, pp. 195 – 210.

[6] Abdullahi, M. Soil Contamination, Remediation and Plants: Prospects and Challenges, pp: 525-546). Soil Remediation and Plants, Elsevier.

[7] Agarry, S. E. (2018). Evaluation of the Effect of Inorganic and Organic Fertilizers and Activated Carbon on Bioremediation of Soil Contaminated with Weathered Crude Oil. Journal of Applied Science and Environmental Management, vol. 22, no. 4, pp. 587 – 595.

[8] Ekemube, R. A., Davis, D. D., Dumkhana, B. D., & Amgbara, T. O. (2021). Combined Effects of Spent Mushroom Substrate (SMS) and NPK Fertilizer in the Remediation of Crude Oil Polluted Soil. International Journal of Academic Engineering Research (IJAER), vol. 5, no. 2, 22 – 27.

[9] Chien, H. Y., Kao, C. M., Juo, C. L., Yang, & Huang, P. Y., C. C. (2008). Application of Enhanced Bioremediation to Clean up Diesel Oil Contaminated Soils. Laboratory Microcosm Study. Journal of Biotechnology, vol. 136, pp. 66 -82.

[10] Dindar, D., Sagban, F. O. T., & Baskaya, H. S. (2013). Bioremediation of Petroleum Contaminated Soil. Journal of Biological and Environmental Science, vol. 7, no. 19, pp. 39 – 47.

[11] Adekanmi, A. A., Adekanmi, S. A., & Adekanmi, O. S. (2020). Biological Treatment of Fish Pond Waste Water by Coelastrum morum, a Green Microalgae," International Journal of Engineering and Information Systems (IJEAIS), vol. 4, no. 4, pp. 62-77, 2020

[12] Shimeno, S., Shikata, T., Hosokawa, H., Masumoto, T., & Kheyyali, D. (1997). Metabolic Response to Feeding

Rates in Common Carp, Cyprinus carpio. Aquaculture, vol. 151, pp. 371- 377.

[13] Jana, B. B., & Jana, S. (2003). The Potential and Sustainability of Aquaculture in India. Journal of Applied Aquaculture, Vol. 13, 283 – 316, 2003.

[14] Garau, G., Silvetti, M., Castaldi, P., Mele, E., Deiana, P., & Deiana, S. (2014). Stabilising Metal (Loid) in Soil with Iron and Aluminium-Based Products: Microbial, Biochemical and Plant Growth Impact," Journal of Environmental Management, vol. 139, pp. 146 - 153.

[15] Department of Petroleum Resources (DPR) (2018). "Environmental Guidelines and Standards or the Petroleum Industry in Nigeria (Revised Edition)". Department of Petroleum Resources of Nigeria, Ministry of Petroleum and National Resources Abuja, Nigeria.