EJSIT
European Journal of Science, Innovation and Technology
ISSN: 2786-4936
www.ejsit-journal.com
Volume 3 | Number 5 | 2023

Influence of Solpawa SBR-X^tm Doses on Petroleum Hydrocarbon Contaminants in Sandy Soil at Different Depths

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ABSTRACT

This study investigated the effectiveness of Solpawa conditioner and Solpawa booster (an indigenous formulated nutrient) in the bioremediation of petroleum hydrocarbon contaminated soils (sandy). The bioremediation process was for combined effects for Solpawa conditioner and Solpawa booster. The experiment was carried out at Rivers Institute of Agricultural Research and Training (RIART) in Rivers State University, Nkpolu, Port Harcourt. Soil samples with crude oil were bulk in four (4) reactors (T_1, T_2, T_3, T_4) with three replications. The physiochemical properties of the initial soil conditions, Solpawa conditioner and Solpawa booster were analyzed in the laboratory. The physiochemical properties of bioremediated soil for Total Petroleum Hydrocarbon (TPH) were analyzed in the laboratory before and after bioremediation. The result showed that TPH degraded severely in all the treatment options at the end of the bioremediation period of 52 days. TPH percentage reduction ranged from 9.00 to 96.47 % in all treatment options for the period of 52 days for the three depths, respectively. Analysis of variance (ANOVA) result also revealed significance difference at 0.05 level of significance. Additionally, the developed multiple linear regression models were for TPH with Solpawa conditioner/water ratio of 1:4, 1:6, and 1:8 and Solpawa boaster. The multiple linear regression model showed good agreement between measured and predicted data. The models were validated with coefficient of determination (r^2), adjusted (r^2), and root mean square error (RMSE). Models' prediction achieved in this study can be categorized as almost good for high coefficient of determination (r^2), adjusted r^2 and low RMSE. It is therefore suggested that the model can be used for predicting TPH concentration for petroleum contaminated soils (sandy) remediated with different ratios of Solpawa conditioner/water and Solpawa boaster, with respect to the bioremediation period.

Key words: Solpawa nutrient, Sandy Soil, Crude Oil, Bioremediation

INTRODUCTION

The discovery of crude oil at Oloibiri, a village in Bayelsa State was in 1956 by Royal Dutch Shell, in the Niger Delta Region of Nigeria. The first commercial production started in 1958. Nwilo and Badejo (2005) reported that 606 oil fields exist in the Niger Delta, of which 360 are on-shore and 246 off-shore. Nigeria is the largest oil producer in Africa and the sixth largest in the world, averaging 2.7 million barrels per day (bbl/d) in 2006. Nigeria's economy is heavily dependent on its earnings from the oil sector, which provides 20% of GDP, 95% of foreign exchange earnings, and about 65% of budgetary revenues (Central intelligence Agency (CIA) World Fact Book, 2005).

Current oil exploration and production activities in Nigeria are concentrated in the Niger Delta region, a huge fertile wetland that covers a landmass of over 70,000 km^2, and cuts across 800 oil-producing communities. The region has a huge oil and gas reserve and accounts for 90 per cent of national exports and 70 per cent of government revenue. Geological records and research show that the region (both onshore and offshore areas) is particularly conducive for the formation and accumulation of oil and gas (Oguejiofor, 2008). Today, the oil industries are highly visible in the Niger Delta and have control over a large area in the region. The area is crisscrossed by thousands of kilometers of pipeline, punctuated by wells and flow stations. Much of the oil infrastructure is located close to the homes, farms, and water sources of communities (UK, 2018).

Oil and gas activities and enormous oil installations deployed in the Niger Delta explains her vulnerability to the oil spill. The social and environmental costs of oil contamination have been extensive. These include destruction of wildlife and biodiversity, loss of fertile soil, pollution of air and drinking water, degradation of farmland and damage to aquatic ecosystems, all of which have caused serious health problems for the inhabitants of areas surrounding oil production. Oil spills in the Niger Delta have destroyed vegetation, mangrove forests, food/cash crops, fishing ground/marine life, reduces the nutrient value of the soil, induces land fragmentation, and sets communities on fire (UK, 2018). For example, a spill at Osama creek in Agbakabiriyai, near Nembe on February 28th, 1998, led to eight days of the fire, which razed down the entire community. This resulted in the destruction of about 400 houses, and the displacement of about 130,000 inhabitants (Okogbule-Wonodi, 2023). Also, a spill that occurred on 7th December 2008 in the Ikarama community caught fire on 1st of March 2009. The fire caused more damage to the environment, given these challenges, land as an economic power resource base becomes critical for the Niger Delta region. Without fertile soil and good water, indigenous communities in the region lose their mode of survival and are faced with the crisis of food shortages. Due to oil spillage, many waterways, land and marine systems in the region have been badly polluted and residents have been badly affected by the environment (Okogbule-Wonodi *et al*., 2023).

Because of these numerous reoccurrences, petroleum hydrocarbons enter the soil by an accidental or intentional release of petroleum products into the environment resulting from human activities like drilling, manufacturing, storing, transportation and waste management of oil. From several research, it was reported that petroleum hydrocarbon is easily absorbed in the soil surface, affecting the permeability and porosity of soil (Okogbule-Wonodi, 2023; Wang, 2009). Petroleum being a substance that is rich in carbon and a small number of nitrogen compounds, it altered structure of soil organic matter and its composition; and influence the C/N, C/P, salinity, pH and conductivity of soil (Li *et al.*, 2009). Also, heavy metals (nickel and vanadium) in petroleum mixtures and high concentrations of salt in oilfield output water destroy the soil environment (Saadat *et al*., 2014; Dindar, Şağban, & Başkaya, 2015).

Studies by Xu and Lu (2010), Zhu (2010), Shan *et al*. (2014) report that petroleum hydrocarbon hinders the normal growth of crops by reducing the germination rate and fertility as well as weakening the resistance to pests and diseases. Furthermore, the petroleum compounds react with inorganic nitrogen and phosphorus, limiting the nitrification and removal of phosphoric acid, then, the effective nitrogen and phosphorus in the soil decrease leading to the effect on the absorption of crops (Shen, 2011; Pinchin *et al.*, 2013; Liao *et al.*, 2015).

A lot of studies have been done on the restoration of petroleum hydrocarbon contaminated soil using several methods, but Bioremediation technology has shown to be more suitable to use for the remediation of petroleum contaminated soil as it is lower in cost, simple in-situ and ex-situ treatments, environmentally friendly, no secondary pollution, and removes most pollutants with high efficiency (Hill *et al.*, 2000; Liste & Alexander, 2000; Shen *et al.*, 2002).

Adenipekun (2008) defined Bioremediation as the enhancement of live soil organisms, such as fungi, bacteria, and plants to break down hydrocarbon and organic contaminants.

Inorganic fertilizer has also been utilized as Biostimulation agents throughout the world. One of such studies carried out by Chorom *et al.* (2010) investigated the efficacy of inorganic fertilizer (NPK) in enhancing microbial degradation of petroleum hydrocarbons in soil. Gas Chromatography results showed that normal paraffin and isoprenoid (Phitane and Pristane) decreased in the range 40-60% in all the treatment categories in less than 10 weeks. Addition of inorganic fertilizer improved the Carbon Nitrogen and Phosphorus (CNP) ratio of the test setup ultimately promoting microbial degradation. Solpawa SBR-X^{TM} Soil Remediation System (SSBRS) is principally developed for cleaning up and bioremediation processes which are particular about reducing pollutants within a short time (Okogbule-Wonodi *et al.*, 2023).

Pollution in the Niger Delta Region in recent times have gulped enormous resources as remediation of petroleum contaminants has largely been dependent on the use of imported nutrients. These imported nutrients are bought with forex bringing about huge financial burdens. The Solpawa SBX-X^{TM} is an indigenous remediation system which uses nutrients available indigenously for the bioremediation of soils contaminated by Petroleum Hydrocarbon in line with the Local Content initiative of the Nigerian Government (Okogbule-Wonodi, 2023).

Figure 1: Solpawa SBX^{TM} Soil Conditioner 102X and Soil Booster 101X

Solpawa SBR-X ™ is scientifically formulated soil bioremediation system proposed to have the ability to release nutrients into the sandy soil to stimulate microbial activities. This study investigates the bioremediation influence of Solpawa SBR-X^{TM} doses on petroleum contaminants in Sandy soil at different depths.

MATERIALS AND METHODS

Study Area Description

This study was carried out in the Niger Delta region of Nigeria. The Niger Delta region of Nigeria is located in the Southern part of Country and bordered to the south by the Atlantic Ocean and the East by Cameroon. The Niger Delta region cartographically and historically, originally consisted of modern day Bayelsa, Rivers, and Delta States, with Delta State being its core (Igoni, 2019) but in the year 2000 due to political classifications, six States were added by the Obasanjo administration bringing the total number of States in the region to nine (Otoabasi, 2011). The Six States added were, Abia, Akwa-Ibom, Cross River, Edo, Imo, and Ondo States. Researchers such as Akujuru *et al.* (2014) reported in studies conducted by Niger Delta Development Commission (NDDC), that the region occupies a surface area of about 112,110 square kilometers. It represents about 12% of Nigeria's total surface area. The region has about 450 km^2 coastlines and is the world's second largest delta and terminates at Imo River (Otoabasi, 2011). The region as 20,000 km^2 is the largest of all wetlands in Africa as well as the third largest globally (Anifowose, 2016).

Niger Delta region has three main vegetation are mangrove forest, freshwater swamp forest, and the savanna and stunted rain forests of the sand ridges and mainland margin. Its ecological zone has classified into four namely lowland rain forest, freshwater zone, mangrove swamp and coastal inland zones. This region is classified as tropical rainforest with ecosystem comprising myriads of species of flora and fauna, aquatics, and terrestrials (Uyigue & Agho, 2007). The Niger Delta region accommodates about 23% of Nigeria population's total population of over 140 million (NPC, 2006).

The region is the major source of timber and forest products and contains important areas of highly endangered wildlife with very high fishery and agricultural potentials, and Nigeria as oil and gas producing nation, solemnly depends on the Niger Delta, where most of its oil and gas industries are located.

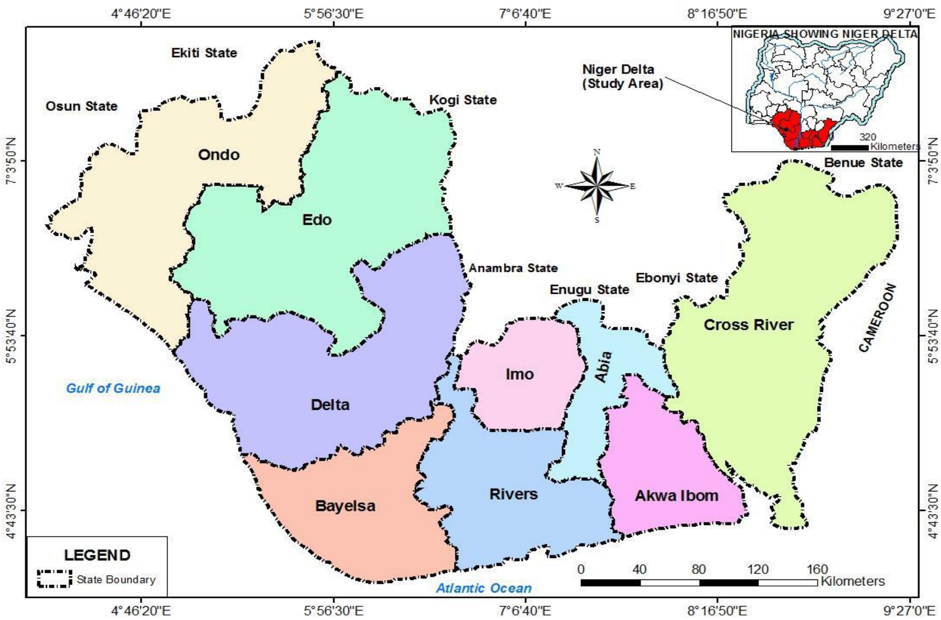

Figure 2: Map of Niger Delta Region of Nigeria Sowing States

Source: https://jackjessi.wordpress.com, 2020

Sample Collection

Three different soil classes were collected from three different locations (Rumuduru, Igrita and Elingbu areas all in Obio-Akpo Local Government Areas in Rivers State), in the Niger Delta Region of Nigeria.

Crude oil was collected from an oil and gas exploration and exploitation company in the region. The crude oil samples were managed in accordance with the guidelines of the Department of Petroleum Resources (DPR, 2002). The *Solpawa* SBR-X™ was collected from SOLPAWA Bioremediation Products Company Lagos, Nigeria.

Experimental Design

This experiment was conducted during the peak of raining season in the middle of August to the ending of October 2021. The 3 X 4 factorial experiment in a randomized complete block design (RCBD) was used in this study. For this experiment, the setup consisted of 12 reactors labelled N_0C_1, N_1C_1, N_2C_1, N_3C_1, N_0C_2, N_1C_2, N_2C_2, N_3C_2, N_0C_3, N_1C_3, N_2C_3 and N_3C_3 including the controls N_0C_1, N_0C_2, and N_0C_3. The experimental reactor 1 m^3 (1000 L) which was divided into four treatments of 12 reactors each. Randomization was achieved using the draw lot approach as described by Gomez and Gomez (1983).

Sample Preparation

Twelve (4) reactors of 1 m^3 (1000L), sandy soil and three Solpawa® additional levels were used. Each reactor was charged with 1000 kg of sandy soil and a condition of heavy spill was simulated by homogenizing the soil with 0.03132 m^3 (32.32L) (Ayotamuno *et al.*, 2006). One of the reactors served as the control. The other three mixes were left undisturbed for 7 days before being taken to the laboratory for analysis. On the 7th day Solpawa Soil Conditioner (SSC) mixed with water at the ratio of 1:4, 1:6 and 1:8 was administered into the contaminated soil in the different reactors with exception of the control. These were allowed for 14 days undisturbed to allow the conditioner to infiltrate into the contaminated soil and samples were collected at different depths of 0.3, 0.6, and 0.9 m from the reactors before taken to the laboratory for analysis. On the 14th day another treatment was given to the soil samples in the reactors. This treatment was the addition of Solpawa booster to the reactors at the ratio of 1:12 (20 kg of Solpawa booster and 240 kg of soil). Soil samples were then collected from the reactors and taken for analysis. Two days after the 14th day, water was applied to the different reactors and soil pH was checked and samples were collected for laboratory analysis. This was carried out for 14 days at an interval of 2 days each for 40 days.

The property analyzed in the laboratory was, total petroleum hydrocarbon (TPH).

Statistical Analysis

A two way Analysis of variance (ANOVA) was used to determine the significance of the difference in the mean values of each treatment of TPH during the experiment. This was done based on the F-test. Differences were considered significant if $F_{computed} > F_{table}$ at 5% and 1% significance levels. The ANOVA was implemented using Microsoft Excel 2019.

RESULTS AND DISCUSSION

Prior to contamination of each of the soil samples were collected using soil corer for particle size distribution (PSD) analysis. The result of the uncontaminated soil indicated the relative content of soil particles of various sizes such as sand, silt, and clay in the soil (Figure 2). From the results, it was revealed that the soil texture Sand according to United State Department Agriculture (USDA) textural classification of soil using TAL for windows a software used by the USDA to classify soil types (Figure 3).

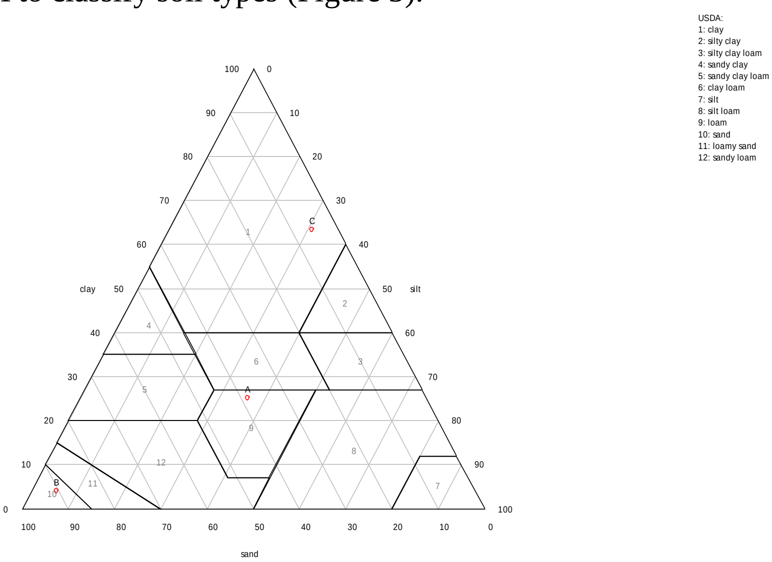

Figure 3: USDA Soil Texture Triangle

Fertilizing Value of Solpawa Conditioner and Booster

The initial NPK characteristics determined were used as indices for evaluation of the fertilizing value (i.e., remediation potential) of the Solpawa products. Table 1 shows the NPK values of the Solpawa conditioner and booster. As can be observed in the Table 1, the Solpawa booster (granular form) had a higher fertilizing value than the conditioner (liquid form). Compared with the recommended fertilizer value of 3: 2.5: 0.5 (N: P: K) for materials, both the booster and conditioner far exceeded these typical values. This suggests that both Solpawa booster and conditioner are excellent candidates for remediation purposes, which justifies the use of the products for remediation works.

Table 1: NPK Values of Solpawa Conditioner and Solpawa Booster

Properties	Solpawa Conditioner	Solpawa Booster
N (mg/kg)	103.560	261.450
P (mg/kg)	1.241	7.592
K (mg/kg)	180.903	569.191

Effect of Different Doses Solpawa on TPH at 30, 60 and 90cm Depth of Sandy Soils

Effects of Solpawa doses on the change in TPH concentration and 30days of remediation in Sandy soil is shown in (Table 2). Also, Figure 4 shows the variation of TPH concentration in Sandy soil with time at 30, 60 and 90 cm soil depths at different doses of Solpawa. An examination of the Figure 2 showed that the TPH concentrations decreased with reduction in Solpawa conditioner to water ratio administered to the contaminated Sandy soil over time and also in presence of oxygen. It might be so because at the depths of 30, 60 and 90 cm, the presence of oxygen speeds up the degradation of TPH more than it does at depths where oxygen is less in supply. The TPH reduced by 3.00,00, 10.00, 9.00 and 8.00% for the depth of 0.3, 0.6 and 0.9 m in T_1, T_2, T_3 and T_4 respectively (Table 2). The TPH concentrations contained in the reactors ranged from 17025.30 to 12012.20 mg/kg at the depth of 30 cm, 17876. 57 to 2091.57 mg/kg at depth of 60 m, and 18949.16 to 3793.62 mg/kg at the depth of 90 cm for 7 days after contamination, 12 days after Solpawa conditioner (ASC), 10, 20, 30 and 40 days after Solpawa booster (DSB), in T_1, T_2, T_3, and T_4 respectively according to their degradation rate. The TPH percentage reduction due to the presence of Solpawa conditioner and booster was significant (Table 2). These ranged from 0 to 92.88 % in T_1, T_2, T_3, and T_4 at the depths of 30cm, 60cm and 90cm m for day 7, 12 ASC, 10, 20, 30 and 40 DSB, respectively as shown (Figure 4). This might be due to the Solpawa conditioner and booster. The ANOVA result for the effect of different doses of Solpawa conditioner and boaster on the TPH concentration revealed that there was significance difference in the treatment means at 5% significance levels. This suggests that with 95% confidence, the difference in treatment means was due to the difference in Solpawa conditioner and booster applied.

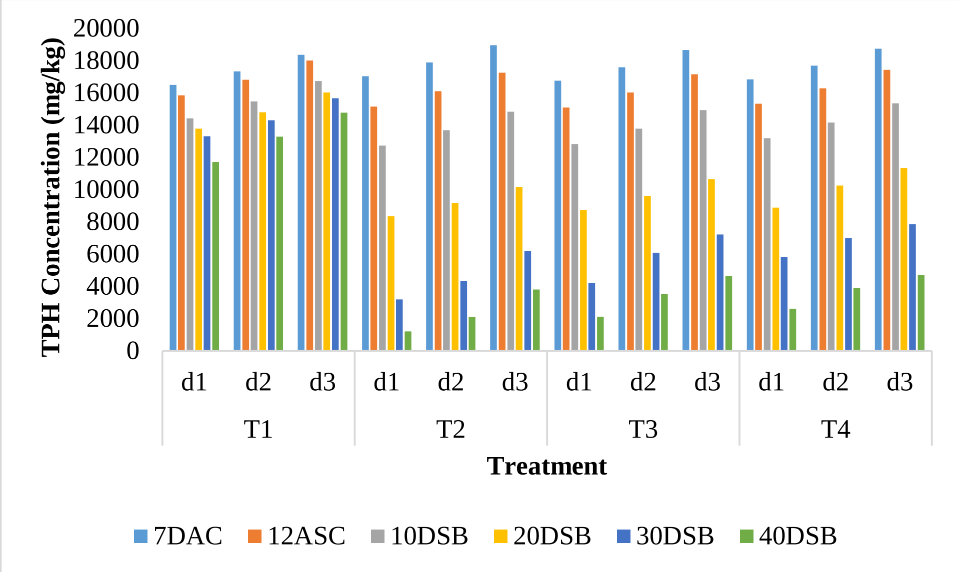

Figure 4: Effects of Solpawa dosages on TPH Concentration in Sand Soil

Table 2: Mean Results of TPH (mg/kg) Concentration in Contaminated Sand Soil Treated with Solpawa

Period (days)	T_1			T_2			T_3			T_4		
	d_1	d_2	d_3	d_1	d_2	d_3	d_1	d_2	d_3	d_1	d_2	d_3
7	16501.5	17326.6	18366.2	17025.3	17876.6	18949.2	16757.1	17595	18650.7	16839.9	17681.9	18742.8
12	15841.4	16806.8	17998.9	15152.5	16088.9	17243.7	15081.4	16011.4	17158.6	15324.3	16267.4	17430.8
10	14415.7	15462.2	16738.9	12728.1	13675.6	14829.6	12819.2	13769.8	14928	13178.9	14152.6	15339.1
20	13782.1	14790	16019	8333.88	9170.68	10173.8	8747.21	9606.85	10638.3	8888.1	10248.4	11330
30	13306.8	14285.8	15659	3182.03	4344.01	6207.74	4222.79	6084.34	7206.61	5823.24	6994.96	7843.86
40	11722.7	13277.4	14759.1	1212.2	2091.57	3793.62	2111.39	3522.51	4632.82	2605.13	3904.16	4706.32

CONCLUSION

Solpawa conditioner and booster influenced the biodegradation of (TPH) in the hydrocarbon petroleum contaminated sandy soil. This Solpawa conditioner degraded TPH up to 11, 11, and 9.01 %, after 12 days of remediation for the depths of 30cm, 60cm and 9cm In addition, Solpawa boaster degraded TPH up to 92.88, 92.88, and 92.63 %, after 40 days of remediation for the. ANOVA results also showed that there was significant difference among the treatments 0.3, 0.6 and 0.9 m.

ACKNOWLEDGEMENTS

The authors are grateful to SOLPAWA Bio-Remediation Products Limited for granting our request to release the products for this research.

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