p-ISSN 2822-1729, e-ISSN 2822-1737 Available online at https://www.nepjol.info/index.php/josem

Evaluation of Organic Treatments for Enhanced Bioremediation of Crude Oil Impacted Soil in Bayelsa State, Nigeria

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Abstract: The aim of this study was to evaluate organic treatments for enhanced bioremediation of crude oil impacted soil in Bayelsa State, Nigeria. Koroama community in Gbarain clan, Yenagoa local government area, Bayelsa State, Nigeria was randomly selected for the study. The experimental research design was adopted for this study, which was carried out for 28 days. The required soil samples were collected at a depth of 0 – 15cm from a 3 x 3m experimental plot developed in a farmland in Koroama community. Five sampled points, in the form of flat beds A, B, C, D and E respectively were randomly selected. Sampled beds A to D were simulated (contaminated) with 2.25kg of crude oil. The objective is to simulate conditions of a major crude oil spill. The crude oil contaminated soil samples were then allowed to condition for 6 days before treatment with 2kg organic treatments like goat manure (GM), poultry droppings (PD) and the combination of goat manure and poultry droppings (GM & PD). Bed E was unpolluted and untreated (control A) while Bed D was crude oil impacted and untreated soil (control B). The study showed that the impact of crude oil on the soil affects both the physical properties of the soil. The study also showed that the sampled organic treatments were all effective in restoring the physical properties of the crude oil impacted soil. At the end of the study, GM showed the highest TPH degradation rate (62.1%) followed by PD (57.1%) and the least, the combination of GM & PD (52.0%). Hence, the application of GM, PD and the combination of GM & PD are highly recommended for bioremediation of crude of impacted soil with special preference to GM.

Keywords: *Bioremediation, Crude oil, Oil pollution, Organic treatments, Soil*

Conflicts of interest: None
Supporting agencies: None

Received 22.09.2023; Revised 20.11.2023; Accepted 28.11.2023

Cite This Article: Asuka, E. & Hyginus, O. (2023). Evaluation of Organic Treatments for Enhanced Bioremediation of Crude Oil Impacted Soil in Bayelsa State, Nigeria. *Journal of Sustainability and Environmental Management*, 2(4), 231-240.

1. Introduction

Oil pollution is a worldwide threat to the environment and the remediation of oil-contaminated soils, sediments and water is a major challenge for environmental research (Chorom et al., 2010). The contamination of the environment (mainly terrestrial and aquatic) by crude oil is referred to as crude oil pollution and it is estimated that 80% of crude oil pollution is as a result of spillage (Odu, 1997). Oil spillage is perhaps, the most significant environmental consequence of oil exploration and constitutes the industry's gravest environmental hazards. The level of pollutants discharge into the environment in the form of oil spills poses serious environmental problems with significant, long-term impact on the environment, ecology and socio-economic life of local dwellers in affected areas (Singh and Lin, 2008; Eregha and Irughe, 2009).

In Nigeria, the oil and gas exploration activities are credited to the six years Bergheim's Corporation adventure for oil in Okitupupa area of southwestern Nigeria (Nlerum, 2010). The pioneering effort was interrupted by the outbreak of World War I (1914 - 1918) and at the end of the war no information was heard about the oil industry. In early 19th century, a sign of the occurrence of crude oil was observed when oil seepages were seen at Araromi in the present-day Ondo state. German businessman John Simon Bergheim in 1906 convinced the colonial office and the government of southern Nigeria based on his geological knowledge that petroleum existed in the region and that his company (the Nigerian Bitumen Corporation) could find it (Steyn, 2006). The company was then given prospecting rights for oil exploration in Nigeria. They officially started in 1903 when two companies; the Nigerian Properties Limited and the Nigerian and West African Development syndicate limited commenced exploration for coal, oil and bitumen. Their two concessions covered a territory of 400 m2 in the Agbabu-Mulekangbo area in the Lekki Lagoon region in 1937. An Anglo-Dutch consortium, Shell D'Arcy the fore-runner of Shell Petroleum Development Company (SPDC) was given the sole prospecting right for oil exploration. Unfortunately, like their predecessor, its activities were also interjected by yet another war, the Second World War (1939-1945), which stalled exploration in Nigeria for another ten years (Raji and Abejide, 2013).

Shell D'Arcy resumed its Nigerian operations again in 1946 after the war at Owerri, Okigwe and Umuahia, all in the Eastern region of Nigeria. Based on their initial exploratory work which showed that the most favorable oil yielding structures lay in Eastern Nigerian, two camps were then established on Pinnacle land at Owerri and Okigwe. The Owerri camp expanded very rapidly and developed into the operational headquarters of 24 Shell D'Arcy and remained so until it was moved to Port Harcourt in 1961(Steyn, 2006). In 1951, the joint venture drilled its first deep exploration well at Ihuo, near Owerri, which turned out to be a dry well. Between 1951 and 1956 it drilled eighteen explorations, appraisal and development wells. Oil and gas were discovered at Akata in the Calabar region in 1953, but the oil was very limited at this source. In January 1956 oil of commercial quantity was finally discovered by Shell D'Arcy (later Shell–British Petroleum) in the Niger Delta at Oloibiri oil field in the then Rivers State, now in the present day Bayelsa State, situated 72km West of Port Harcourt at a depth of about 36602.5176m (Kadafa, 2012). And a second oil field was later discovered at Afam in Rivers State (Vassiliou, 2009). By 1958, Shell British Petroleum had discovered oil in twelve areas of which Oloibiri, Afam, and Bomu were the most hopeful. In February 1958, Shell British Petroleum started exporting crude oil produced from Oloibiri and Afam oil fields to the company's terminal in Port Harcourt (Aniefiok et al., 2013).

After the Nigerian Independence in 1960 and the success of Shell British Petroleum other companies were invited to prospect for oil. Soon, forerunners of Agip/Eni, Chevron/Texaco, ExxonMobil, Total and others were active in search for oil both onshore and offshore. The climax of the era was the establishment of a national oil company that later became the Nigerian National Petroleum Corporation (NNPC) in 1977 and the admission of Nigeria into the Organization of Petroleum Exporting Countries (OPEC) in 1971 (United Nations Development Programme [UNDP], 2012; Andrews, 2015).

Today, the Niger Delta region is the centre of petroleum production and development activities in Nigeria. The region consists of 9 oil producing states: Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Ondo, Imo and Rivers (Okonkwo et al., 2015).

Due to oil exploration and exploitation activities, oil spills are regrettably common around the world. In Nigeria, oil spill incidents have occurred in various parts and at different times in the Niger Delta's aquatic and terrestrial environments. These spills have been associated with sabotage, corrosion of pipes, carelessness during oil production and oil tanker accidents (Nwilo and Badejo, 2005). The biggest spill incidents from Shell facilities between 2013 and 2020 in the Niger Delta were recorded in 2019, with a total of 190 crude oil spill incidents. Then between January and June 2020, a total of 6,117.2 barrels of crude oil was spilled from 72 spill incidents (Shell Nigeria, 2020). For instance, in March 2020, a total of 364 barrels of crude oil was spilled by the Shell Petroleum Development Company of Nigeria (SPDC) from 10 spill incidents. The 10 spill incidents took place in Imo, Rivers, Abia and Bayelsa States respectively. The affected facilities in these four States include: Obele Flow Station, 28″ Nkpoku-Ebubu Pipeline, 12″ Imo River2 – Ogale Pipeline, 20″ KoloCreek Pipeline, 4″ Etelebou Well 1S Flowline, 12″ Oguta to Egbema Pipeline, 28″ Nkpoku – Bomu Pipeline, 16″ Egbema – Assa Pipeline, and 14″ Okordia- Rumuekpe Pipeline. All the 10 leaks were recorded on land, while the volume of each spill ranges from 2 barrels to 150 barrels in each of the spill site (Sweet Crude Report, 2020). In March 15, 2016 the Etelebou Flow station, Shell facility at Ogboloma-Gbarain in Bayelsa State spilled 72 barrels of crude oil on land (Shell Nigeria, 2020).

The damage caused by oil spill depends on different aspects, including the chemical composition of the oil, location where the contamination occurs, how long the oil has been in the environment and how the oil is removed (De la Huz et al., 2011). Ogaji et al. (2005) noted that, as the oil spill penetrates to a depth of about 10-20cm which has a major role to play in agricultural activities, result in the loss of soil fertility and also, initiates environmental degradation. It alters the physiochemical properties of the soil, thereby making it impossible for the soil to produce at its optimal capacity due to the hardening of the soil structure by the oil (Ana, 2000; Wilford, 2004; Gesinde et al., 2008; Ezeonu, 2010).

Many studies have investigated the environmental pollution in the Niger Delta yet the pollution problems continue to occur (Sojinu et al., 2010). The potential dangers resulting from crude oil pollution have driven man into the search for different options of soil remediation of crude oil impacted soils. Several remediation methods have been employed for the remediation of crude oil impacted soils in the Niger Delta, but these efforts have yielded little or no success as they are either inappropriate for the environment and thus complete remediation is not achieved (Giadom and Tse, 2015).

According to Balba (1993), the best option to correct our crude oil contaminated soil is adopting a long-lasting remediation method. Bioremediation is considered one of the most promising methods for dealing with a wide range of organic contaminants, particularly petroleum hydrocarbons. Bioremediation involves three principal approaches namely, natural attenuation (reliance on natural biodegradation activities and rates), which is sometimes called intrinsic bioremediation; biostimulation (stimulation of natural activities by environmental modifications such as fertilizer addition to increase rates of biodegradation); and bioaugumentation (addition of exogenous microorganisms to the hydrocarbon-impacted ecosystem to supplement the existing microbial population). These three principles for in-situ biodegradation have been applied several times at pilot and field scale levels with varying degree of success (Kaplan and Kitts, 2004; Chikere et al., 2009; Eziuzor and Okpokwasili, 2009; Gertler et al., 2009; Akpoveta et al., 2011). Several studies on bioremediation have been conducted for the remediation of crude oil impacted soils in Nigeria. Agarry et al. (2010) investigated the efficacy of biostimulation with animal manure versus chemical fertilizers in the developing country using Nigeria as study area. They revealed that organic treatment is a better option compared with the inorganic treatment. Apart from the fact that it is more effective, it is also considered to be cheaper and more environmentally friendly.

Ayolagha et al. (2013) studied the effect of remediation material on growth of maize (Zea mays) planted on Bonny light crude oil polluted inceptisols of Yenagoa, Bayelsa State. Remediation materials used for the study are poultry manure and cow dung (organic treatment), NPK and urea (inorganic treatment). In the cause of the study, they concluded that crude oil pollution adversely affects the soil but the condition could be improved and ameliorated by addition of soil nutrient supplement (bioremediates). And that poultry manure had the best performance across seasons compared to cow dung, NPK and urea in Bayelsa State.

Obiakalaije et al. (2015) studied crude oil contaminated soil from Isaka mangrove in Okirika local government area of Rivers state. The crude oil contaminated soil was treated with three different organic wastes (goat manure, poultry droppings and cow dung), for a period of 28 days. They concluded that, contaminated soil amended with goat manure have the highest percentage total petroleum hydrocarbon loss. And that, treatment of the crude oil polluted soil with the various organic waste stimulated higher microbial proliferation in soil.

However, it was observed that, studies conducted to enhance bioremediation of crude oil contaminated soil in the Niger Delta region is lacking in the area of the application of goat manure, poultry manure or droppings and their mixture. Their levels of efficacy compared to one another are yet to be ascertained. This study is informed by the afore-mentioned. It has becomes very necessary to evaluate and explore the feasibility of using goat manure, poultry droppings and their mixture for enhanced bioremediation of crude oil impacted soil in Yenagoa Local Government Area of Bayelsa State, Nigeria. Hence, the objective of this study is to determine the physical properties such as bulk density, porosity, permeability and soil moisture of the crude oil impacted soil before and after treatment with goat manure, poultry droppings and combination of both. And also establish a comparative recovery index of impacted crude oil sites from these treatments.

2. Materials and methods

Yenagoa LGA is the headquarters of Yenagoa which is the seat power of Bayelsa state. It lies along latitudes between 4o 48′00″ N and 5o 24′ 10″E; and longitudes between 6o 12′00″N and 6o 39′30″E. It is bounded by Rivers State on the North to East, Kolokuma/Opokuma LGA on the North West and West, Ogbia LGA on the South East and Southern Ijaw on the South west (Effiong et al., 2016). The LGA has an area of 706km² and a population of 353,344 comprising of 187,791 males and 165,553 females with an annual exponential growth rate of 2.9 as at the 2006 National (Obafemi, 2014).

The experimental research design was used for this study. A 3 x 3m experimental plot was developed in an agricultural farmland in Koroama Community, Gbarain clan, Yenagoa Local Government Area (Yelga), Bayelsa State, Nigeria. This falls within the Gbarain – Ubie Integrated Oil and Gas project area. This design enables us decide how the treatments was physically arranged and applied in the field. In this design, treatments was replicated but not blocked, which means that the treatments were assigned to plots in a completely random manner. Soil samples were randomly collected from the top surface soil at 0-15cm depth.

The experimental plot of 3 x 3m was delimited into a 1 x 1m sample matrixes and further delimited into a 0.33 x 0.33m sample matrixes. In this design, the soil was prepared for bioremediation by removing sticks and stones. Five sampled points, in the form of flat beds A, B, C, D and E respectively were randomly selected. Sampled bed A to D was then simulated (contaminated) with 2.25kg of crude oil. The objective is to simulate conditions of a major crude oil spill.

The crude oil simulated (contaminated) sampled beds were then allowed to condition for 6 days before treatment with organic treatments like goat manure (GM), poultry droppings (PD) and the combination of goat manure and poultry droppings (GM & PD). Bed A was treated with 2kg goat manure (GM), bed B was treated with 2kg poultry droppings (PD), bed C was treated with 2kg combination of goat manure and poultry droppings (GM & PD). Bed D was untreated (control B) while bed E was unpolluted and untreated (control A).

Before simulation of the sampled beds with crude oil, 2kg of unpolluted and untreated soil sample 1 (control A) was collected from bed E at a depth of 0 - 15cm depth and sent to the laboratory for test. After simulation with crude oil and 6 days conditioning period on day 0, 2kg of crude oil impacted soil sample 2 without treatment was collected from bed D at 0 - 15cm depth and sent to the laboratory for test.

Hereafter, on day 0, 2kg of crude oil impacted and treated soil samples were collected at the depth of 0 - 15cm from bed A (sample 3), B (sample 4) and C (sample 5) respectively and then sent to the laboratory for test.

Again, on day 14, 2kg of crude oil impacted and treated soil samples were collected at the depth of 0 - 15cm from bed A (sample 6), B (sample 7) and C (sample 8) respectively and then sent to the laboratory for test. Again, on day 28, 2kg of crude oil impacted and treated soil samples were collected at the depth of 0 – 15cm from bed A (sample 9), B (sample 10) and C (sample 11) and then sent to the laboratory for test. In order to test for natural attenuation, 2kg of crude oil impacted and untreated soil (sample 12) was also collected from bed D at the depth of 0 – 15cm on the same day 28 and sent to the laboratory for test.

Two sets of control experiment were set up. Control A comprising of 2kg unpolluted and untreated soil (bed E). Control B comprising of 2kg crude oil impacted and untreated soil (bed D).

In order to avoid anaerobic condition, the sampled bed A, B, C and D were thoroughly mixed every 3 days. The respective sampled soils were observed and analyzed on a two week basis (14 day interval) for residual total petroleum hydrocarbon (TPH) respectively. This enabled us determine the extent of total petroleum hydrocarbon reduction over time for a particular treatment method.

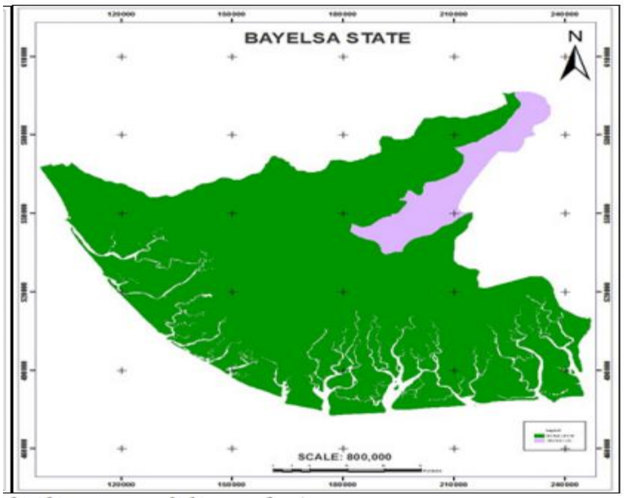

Figure 1.1: Bayelsa State showing Yenagoa Local Government Area (LGA)

In order to determine the physical properties of the sampled soils for this study, bulk density; porosity; permeability and soil moisture were analyzed using recommended protocols.

The methodology encompasses the determination of key soil properties, including bulk density, porosity, permeability, and soil moisture content. For bulk density, 50g of soil is heated, cooled, and weighed in a density bottle, with the bulk density calculated from the weight difference. Porosity is assessed by measuring water volume in a crushed soil sample, with the porosity calculated as a percentage. Permeability, indicating water passage through soil, is determined using a falling head permeability test with air-dried soil layers. Lastly, soil moisture content is gauged by heating 10g of dried soil, weighing before and after, and calculating moisture content as a percentage. This comprehensive methodology provides valuable insights into soil characteristics critical for understanding soil behavior and quality.

3. Results and discussion

3.1. Physical properties of soil before and after crude oil pollution

Bulk density (Pb) (g/ml)

The study as shown in Table 3.2, Figure 3.1 and Figure 3.2 respectively, revealed that bulk density significantly increased in the soil from 1.24g/ml (control A) before the impact of crude oil on the soil, to 1.27g/ml (control B) after the impact of crude oil on the soil. Furthermore, after the application of sampled organic treatments on the crude oil impacted soil as shown in Table 3.2, Figure 3.1 and Figure 3.2 respectively, bulk density, significantly reduced in all treatments compared to that of the polluted soil without treatment (control B) (1.27g/ml). They revealed that bulk density of polluted soil treated with GM on day 14reduced to 1.17g/ml and on day 28 reduced to 1.12g/ml respectively. That treated with PD on day 14reduced to 1.13g/ml and on day 28 reduced to 1.05g/ml respectively. While that treated with the combination of GM & PD on day 14 reduced to 1.10g/ml and on day 28 reduced to 1.09g/ml respectively.

The impact of crude oil on the soil did not have significant influence on bulk density at the different stages between when the soil was impacted/polluted without treatment (control B) and before the soil was impacted/polluted (control A) as shown in Table 3.2, Figure 3.1 and 3.2 respectively. When control B was compared with control A, bulk density increased by 2.4%. This is worthy of note that crude oil increased bulk density. This observation is in agreement with the study conducted by Kayode et al. (2009) where they evaluated the effect of pollution with spent lubricating oil on the physical and chemical properties of soil. They found out that soil pollution with crude oil and spent lubricating oil increased bulk density. So also is the study of Abosede (2013) evaluating effect of crude oil pollution on some soil physical properties. She found out that bulk density of the crude oil polluted soil increased by 7.1% when compared with the unpolluted soil (control) and that this might have resulted from the blockage of pores spaces with the pollutant. In affirmation to this, Klamerus-Iwan et al. (2015) studying the influence of oil contamination on physical and biological properties of forest soil after chainsaw use, also revealed that soil contamination with chainsaw mineral oil increased the soil bulk density, with simultaneous deterioration of total porosity and air-filled porosity.

On the other hand, the reduction in bulk density after the application of sampled organic treatments on the crude oil impacted/polluted soil compared to the crude oil impacted/polluted soil without treatment (control B) with value of 1.27g/mlas shown in Table 3.2, Figure 3.1 and

Figure 3.2 respectively, revealed that GM, PD, and the combination of GM & PD are effective in restoring crude oil impacted/polluted soil. However, the application of PD is best in reducing the bulk density level in the polluted soil, followed by the application of the combination of GM & PD and the least is the application of GM. This is in agreement with the findings of Asai et al. (2009) revealing that organic amendments can significantly reduce soil bulk density, prevent soil compaction, and increase soil porosity and aggregate stability

Porosity (Pt) (%)

Simultaneously, the study as shown in Table 3.2, Figure 3.1 and Figure 3.2 respectively, revealed that the soil porosity (Pt) was 70% (control A) before the impact of crude oil on the soil but after the impact of crude oil on the soil (control B), porosity significantly reduced to 34%. However, after the application of sampled organic treatments on the crude oil impacted/polluted soil, porosity significantly increased in all treatments compared to that of control B (34%) as shown in Table 3.2, Figure 3.1 and Figure 3.2 respectively. They revealed that porosity of the crude oil impacted soil treated with GM on day 14 increased to 60% and on day 28 increased to 68% respectively. And that treated with PD on day 14 increased to 42.5% and on day 28 increased to 45% respectively. While that treated with the combination of GM & PD on day 14 increased to 48% and on day 28 increased to 60% respectively.

The study as shown in Table 3.2, Figure 3.1 and 3.2 respectively revealed that revealed that as bulk density of the crude oil impacted/polluted soil (control B) increased compared to that of control A, so also porosity of the crude oil impacted/polluted soil (control B) significantly reduced by 51.4% compared to that of control A. This implies that crude oil reduces soil porosity. This observation is in agreement with the study conducted by Kayode et al. (2009) where they evaluated the effect of pollution with spent lubricating oil on the physical and chemical properties of soil. They found out that soil pollution with crude oil and spent lubricating oil reduces soil porosity in soil capillary. So it is with the study of Abosede (2013) evaluating effect of crude oil pollution on some soil physical properties. She found out that total porosity of the crude oil impacted/polluted soil reduced by 8.5% when compared with the unpolluted soil (control) and that this might have resulted from the blockage of pores spaces with the pollutant. Also in agreement with this, is the study conducted by Klamerus-Iwan et al. (2015) on the influence of oil contamination on physical and biological properties of forest soil after chainsaw use. They found out that soil contamination with chainsaw mineral oil increased the soil bulk density, with simultaneous deterioration of total porosity and air-filled porosity.

On the other hand, the study as shown in Table 3.2, Figure 3.1 and 3.2 respectively revealed that porosity significantly increased respectively after the application of sampled organic treatments on the crude oil impacted/polluted soil compared to that of control B (34%). It revealed that at the end of the study on day 28, GM, PD, and the combination of GM & PD are effective in restoring crude oil impacted/polluted soil. However, the application of GM is best in improving the porosity level of the polluted soil, followed by the application of the combination of GM & PD and the least is the application of PD. This is in agreement with the findings of Asai et al. (2009) revealing that organic amendments can significantly reduce soil bulk density, prevent soil compaction, and increase soil porosity and aggregate stability.

Permeability (cm/hr)

Permeability (cm/hr) as shown in Table 3.2, Figure 3.1 and Figure 3.2 respectively revealed that soil permeability was 0.80cm/hr before the impact of crude oil on the soil (control A) but after the impact of crude oil on the soil (control B) permeability significantly reduced to 0.50cm/hr. On the other hand, after the application of sampled organic treatments on the crude oil impacted/polluted soil, permeability significantly reduced in all treatments compared to that of control B (0.50cm/hr.) but increased as the study progressed from day 14 to day 28 as shown in Table 3.2, Figure 3.1 and Figure 3.2 respectively. They revealed that crude oil impacted/polluted soil treated with GM increased from 0.20cm/hr. on day 14 to 0.24cm/hr. on day 28 respectively. And that treated with PD increased from 0.10cm/hr. day 14 to 0.15cm/hr. on day 28 respectively. While that treated with the combination of GM & PD increased from 0.03cm/hr. on day 14 to 0.05cm/hr. on day 28 respectively.

Soil Moisture (%)

For soil moisture (%), the study as shown in Table 3.2, Figure 3.1 and Figure 3.2 respectively, revealed that soil moisture was 40.27% before the impact of crude oil on the soil (control A) but after the impact of crude oil on the soil (control B) soil moisture significantly reduced to 39.68%. However, after the application of sampled organic treatments soil moisture significantly increased in all treatments compared to that of control B (39.68%) as shown in Table 3.2, Figure 3.1 and Figure 3.2 respectively. They revealed that crude oil impacted soil treated with GM on day 14 increased to 45.94% and on day 28 increased to 46.53% respectively. And that treated with PD on day 14increased to 51.49% and on day 28 increased to 49.66% respectively. While that treated with the combination of GM & PD on day 14increased to 49.14% and on day 28 increased to 49.40% respectively.

The observed decrease in soil moisture content in control B (39.68%) compared to that of control A (40.27%) as shown in Table 3.2, Figure 3.1 and 3.2 respectively shows that crude oil reduces soil moisture. This is in agreement with the study of Devatha et al. (2019) investigation of physical and chemical characteristics on soil due to crude oil contamination and its remediation. They revealed that soil mixed with crude oil samples shows a decrease in the moisture content proportionally with the contamination concentration which may be due to the polar and nonpolar reaction of the soil. As crude oil is a nonpolar liquid which will absorb the soil moisture content in the soil and decrease the amount of moisture content in the soil. Control B has a significant effect on the liquid limit and plastic limit of the soil. Also in line with the study is that of Ohanmu et al. (2018) the impact of crude oil on physicochemical properties and trace metals of soil before and after planting of two pepper species (Capsicum annum L and C. frutescens L) in Edo State, Nigeria. They found out that moisture content was significantly reduced (P<0.05) with increase in crude oil concentration. As the crude oil impacted soil had reduced water infiltration and percolation in the soil. Furthermore Devatha et al. (2019) found out that crude oil in the soil caused the micro-structural transformation of the soil, as it forms lumps which could glue together with soil particles so as to reduce the influence of water particles.

Then the significant increase in soil moisture content after the application of organic treatments on the crude oil polluted soil compared to that of control B (39.68%) as shown in Table 3.2, Figure 3.1 and 3.2 respectively is an indication that the sampled organic treatments: GM, PD, and the combination of GM & PD are effective in restoring crude oil impacted/polluted soil. However, the application of PD is best in improving soil moisture content in the polluted soil, followed by the application of the combination of GM & PD and the least is the application of GM.

3.2. Effect of crude oil on physical properties of crude oil impacted soil

As shown in Table 3.2, Figure 3.1 and 3.2 respectively the study revealed that after the impact/pollution of crude oil on the soil, the crude oil impacted/polluted soil increased in bulk density by 2.4% (1.27g/ml) and the reduced in porosity by 51.4% (34%), permeability by 37.5% (0.50cm/hr) and soil moisture by 1.5% (39.68%) respectively when compared to their respective values of control A (unpolluted soil). This is an indication that crude oil adversely affects physical properties of impacted/polluted soil. This is in line with the study of Abosede (2013) evaluating effect of crude oil pollution on some soil physical properties. She found out that in crude oil polluted soil, porosity; permeability reduces and then bulk density increases, which might have resulted from clogged pore spaces, thereby reducing aeration and water infiltration and subsequently affecting plant growth. And that oils that are denser than water might reduce and restrict soil permeability.

Also in line with this study is the finding of Kayode et al. (2009) when they evaluated the effect of pollution with spent lubricating oil on the physical and chemical properties of soil. They found out that, the presence of crude oil and spent lubricating oil in the soil adversely affected the physical properties of soil.

So also is the study conducted by Wang et al. (2013) when they studied the effects of crude oil contamination on soil physical and chemical properties in Momoge wetland of China. They revealed that crude oil contamination detrimentally affect the physical properties of soil. As it adversely affects the marsh water use efficiency by lowering the soil water content, which could be especially critical in the Momoge National Natural Reserve where the semi-arid conditions lead to the water supply being relatively limited.

Also Imasuen et al. (2014) after studying the impact assessment and bioremediation of oil contaminated soil in Koko and Ajoki Communities, Niger Delta Nigeria affirmed that soil contamination with petroleum affects the physical properties of soil. As soil contaminated with petroleum reduces the organic content of the soil, thereby reducing soil fertility.

Also in agreement with the above assertions, is Ohanmu et al. (2018) in their study of the impact of crude oil on physicochemical properties and trace metals of soil before and after planting of two pepper species (Capsicum annum L and C. frutescens L) in Edo State, Nigeria. They revealed that crude oil reduces the physical properties of the soil, as the moisture content was significantly reduced (P<0.05) with increase in crude oil concentration. According to Aislabie et al. (2004) crude oil-contaminated soils are generally more hydrophobic than pristine sites.

3.3. Comparative total petroleum hydrocarbon (TPH) recovery index of goat manure (GM), poultry droppings (PD) and the combination of GM & PD

The significant decrease in TPH concentration in all the sampled treatments at different day intervals compared to that of control B (5012.71mg/kg) as shown in Table 3.3, Figures 3.3 & B respectively, can be attributed to the fact that both the GM and PD are rich in nitrogen (N), phosphorus (P), potassium (K) values as shown in Table 3.1. According to Vidali (2001); Nwogu et al. (2015) these are the basic building blocks of life, which stimulates microbial growth and allowed microbes to synthesize the necessary enzymes needed to break down the petroleum hydrocarbon contaminants in crude oil polluted soils. This implies that at the end of the study on day 28, sampled organic treatments: GM, PD, and the combination of GM & PD are effective in restoring crude oil impacted/polluted soil.

However with the significant decrease in TPH concentration in all the sampled treatments at different day intervals compared to that of control B as revealed in Table 3.3 and Figure 3.4 respectively implies that GM with a recovery index of 41.4% compared to that of PD with 31.5% and that of GM & PD with 30.0% on day 14 has the highest recovery index, followed by PD and then the least is the combination of GM and PD. While GM with a recovery index of 62.1% compared to that of PD with 57.1% and that of GM & PD with 52.0% on day 28 has the highest recovery index, followed by PD and then the least is the combination of GM & PD.

The consistent and faster recovery of the crude oil impacted/polluted soil with GM compared to PD and that of the combination of GM & PD may be attributed to the fact that GM has a more balanced pH and less salt. This affects plant nutrient availability and favourable for microbial activities that contribute to the availability of nitrogen, sulphur, and phosphorus in soils; which synthesizes the necessary enzymes needed to break down the petroleum hydrocarbon contaminants. And that GM is much drier than poultry droppings, allowing it to compost faster with better aeration (USDA – NRCS, 1998, n.d; Vidali, 2001; Zundel, 2016; Agri-Farming, 2021).

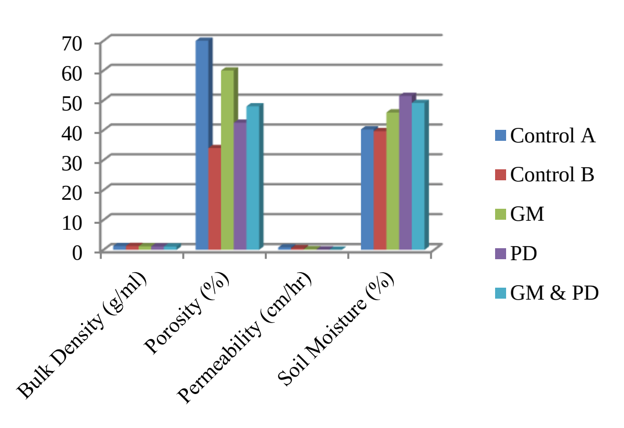

Figure 3.1: Physical properties of sampled soil at day 14

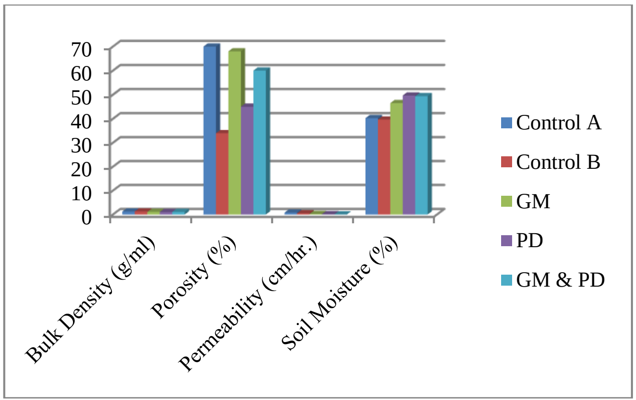

Figure 3.2: Physical properties of sampled soil at day 28

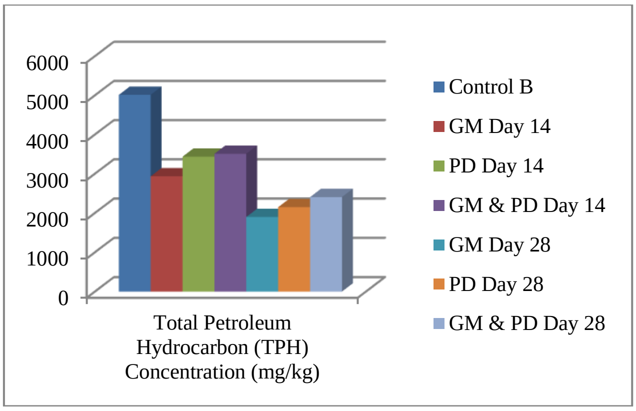

Figure 3.3: Comparative recovery rate of crude oil polluted/impacted site and amendment with organic treatments in MG/KG

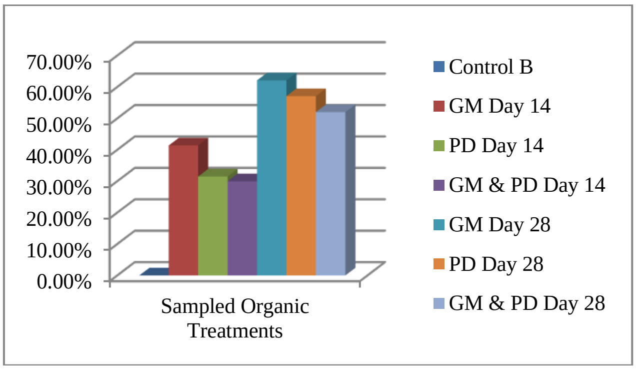

Figure 3.4: Comparative recovery rate of crude oil polluted/impacted site and amendment with organic treatments in %

Table 3.1: Nutrient composition of organic treatments

S/No	Organic Treatments	Nutrient Values		
		Nitrogen (N) (%)	Phosphorus (P) (mg/kg)	Potassium (K) (mg/kg)
1	Poultry Droppings (PD)	1.60	441.7	4,777.4
2	Goat Manure (GM)	1.35	128.5	2,942.7

Table 3.2: Physical properties of sampled soil

S/No	Parameters	Unpolluted Soil (Control A)	Polluted Soil Without Treatment (Control B)	Sampled Soils After Amendment With Organic Treatments					
				2kg Goat Manure (GM)		2kg Poultry Droppings (PD)		1kg Goat Manure + 1kg Poultry Droppings	
				Day14	Day28	Day14	Day28	Day14	Day28
1	Bulk Density	1.24	1.27	1.17	1.12	1.13	1.05	1.10	1.09

	(g/ml)								
2	Porosity (%)	70	34	60	68	42.5	45	48	60
3	Permeability (cm/hr.)	0.80	0.50	0.20	0.24	0.10	0.15	0.03	0.05
4	Soil Moisture (%)	40.27	39.68	45.94	46.53	51.49	49.66	49.14	49.40

Table 3.3: Comparative recovery rate of crude oil polluted/impacted site and amendment with organic treatments

Parameters	Crude Oil Concentration Levels in the Soil Before and After Amendment with Organic Treatments									
	Crude Oil Polluted Soil without Treatment (Control B)	Goat Manure (GM)			Poultry Droppings (PD)			Goat Manure + Poultry Droppings		
		Day 0	Day 14	Day 28	Day 0	Day 14	Day 28	Day 0	Day 14	Day 28
Total Petroleum Hydrocarbon (TPH) (mg/kg) / (%)	5012.71 (0.0%)	5012.71 (0.0%)	2935.14 (41.4%)	1899.98 (62.1%)	5012.71 (0.0%)	3434.85 (31.5%)	2148.89 (57.1%)	5012.71 (0.0%)	3510.00 (30.0%)	2406.55 (52.0%)

4. Conclusion

The results in this study showed that the impact of crude oil on the soil affects the physical properties of the soil. As it increased bulk density and reduced porosity, permeability and soil moisture respectively compared to that of the unpolluted soil.

However, after the application of the organic treatments like goat manure (GM), poultry droppings (PD), and the combination of goat manure and poultry droppings (GM & PD) respectively, the results in the study showed that the organic treatments were all effective in restoring the physical properties of the crude oil impacted soil, thereby restoring the fertility of the crude oil impacted soil.

The results of the study also showed that goat manure (GM), poultry droppings (PD), and the combination of goat manure and poultry droppings (GM & PD) are all effective in the degradation of total petroleum hydrocarbon (TPH) in the crude oil impacted soil, thereby restoring the fertility of the soil.

This implies that, at the end of the study goat manure (GM) showed the highest total petroleum hydrocarbon (TPH) degradation of 62.1% followed by poultry droppings (PD) with 57.1% and the least, the combination of goat manure and poultry droppings (GM & PD) with 52.0%. Hence, goat manure (GM) has highest recovery index, followed by poultry droppings (PD) and the least is the combination of goat manure and poultry droppings (GM & PD).

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