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Physiochemical Properties and Some Microelement Levels of Crude-Oil Polluted Agricultural Soil Remediated with Palm Kernel Shell Powder and Poultry Manure

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***Abstract*— The efficacy of two organic amendments (palm kernel shell powder and poultry manure) in remediation of crude-oil polluted agricultural soilwith some physiochemical properties as evaluation criteria was assessed. The experiment comprised of eight cells each set up in triplicate totaling twenty-four cells in a completely randomized block design. The Ist set up with no pollution and no amendment was designated as positive control. Set up 2 which was polluted soil and no amendment was designated negative control.Three of the set up were designated groups (P100gPKSP, P200gPKSP and P400gPKSP) and were treated with varying doses of palm kernel shell powder. Another three set up were designated treatments (P100gPM, P200gPM and P400gPM) and were also treated with varying doses of poultry manure. The various set ups were designed to determine the effects of varying doses of the PKSP and PM in the remediation of the crude- oil polluted agricultural soil. Furthermore, the two controls were designed to determine the role played by the indigenous microorganisms and natural attenuation in the polluted and unpolluted soils respectively.**

***Index Terms*— Bio stimulation, Crude oil, Palm kernel shell powder, Poultry manure.**

I. INTRODUCTION

Crude oil pollution of agricultural land is thought to be a key contributor to Nigeria's decreased crop yield. The socio-economic and agricultural difficulties caused by crude oil contamination in the environment, particularly in petroleum rich areas such as Nigeria's Niger Delta region, have resulted in severe and unabated food insecurity. Crude oil polluted soils are a major source of surface and ground water contamination, and they are unsuitable for both agricultural and recreational purposes (Ikhajiagbe et al., 2013). The presence of crude oil pollution in soils may alter the physiochemical features of the soil, pore spaces may get clogged resulting to a loss in soil aeration, water infiltration, and an increase in bulk density which may impact plant development on such soils (Abosede., 2013). Some metals contain components that are required for the majority of redox reactions and are important for basic biological activities. Fe, Mn, Zn and Cu are crucial microelements in soils that plants require for many physiological processes and growth. For instance, Fe is an important part of haem proteins including cytochromes, catalase, and Fe-S proteins (for example, ferredoxin). Cu is necessary for photosynthetic electron transport proteins such as plastocyanin and cytochrome C oxidase required for respiration. On the other hand, Mn has a lower redox activity but plays vital roles in photosynthesis (for example O_2 evolution). Although Zn is not a redox active metal, it plays an important structural or catalytic role in a variety of proteins and enzymes. Ni is a constituent of urease, and some plant species require modest amounts of Ni. (Sirko, and Brodzik, 2000).

A range of deficiency symptoms appear when any of these metals are insufficient and plant growth is slowed. Regardless, excessive concentrations of these transition metals disrupt cellular functioning and affect metabolism in its natural state resulting in cellular damage and possibly plant death. Because an oil layer on the soil surface acts as a barrier between air and the soil, crude oil pollution can obstruct healthy soil aeration. Agronomic issues linked to crude oil contaminated soils have been recognized by several authors (Odu, 1972., Udo & Fayemi., 1975., Cooke & Westlake 1976., Bossert & Bartha 1984). In order to restore the contaminated environment to its natural condition, it is critical that the polluted environment be improved in order for the environment to be free of contaminants (Dixit et al., 2015) Biodegradation is the primary mechanism for removing spilled crude oil from a contaminated environment. Enhancing the biodegradation process by amending soil with organic or inorganic nitrogen rich nutrients is a successful method (Margesin, et al., 2007; Abioye et al, 2009).

The use of inorganic fertilizer to restore damaged soil is not sustainable due to its scarcity among most farmers and the high cost of the few that are available (Agarry et al., 2010; Danjuma et al., 2012). The use of organic waste originating from plants and animals for bioremediation of crude oil polluted soil has been studied. (Danjuma et al., 2012; Adesodun, and Mbagwu, 2008; Agarry, S. E. and Ogunleye 2012.). Domestic poultry and agricultural animals such as chicken, ram, sheep, cow, goat are abundant in Nigeria. These farm animals produce large volumes of waste dung in abattoirs, which serve as disposal site for such manure. These wastes are regarded useless by the average person, nevertheless research has proven that they are useful material

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for modifying soil physiochemical characteristics and assisting in the long-term release of soil nutrients (Ofoegbu et al., 2015). According to Abulude et al., (2003), animal dung is nutritionally rich in protein, mineral, vitamins and energy and can enhance soil qualities particularly in agricultural farmlands, without poising a health danger to live biota. The addition of limiting nutrients to polluted soils to promote microbial growth is known as bio stimulation. Over time poultry manure has been utilized to boost soil fertility. It has also been shown to be effective in stimulating plant development in Nigerian soils that have been contaminated by crude-oil. (Okolo et al, 2005).

When poultry manure is applied to soils, it enhances the soil's structure, drainage and other physical characteristics (Chen and Jiang., 2014). It also boosts microbial activity and aids in the reduction of ecotoxicity in soils contaminated with crude oil (Okafor et al., 2016). According to Okolo et al., (2005), using poultry manure as organic fertilizer in polluted soil enhances biodegradation rates. Also, Ogboghodo et al., (2004) investigated the impact of poultry manure treatment on maize (*zea mays*) growth and soil parameters in crude oil polluted soils.

The oil palm tree is an important tree in Nigeria because of the value of crude palm oil, fronds, stems and leaves. As a result of the industry's size, there are a number of residues created alongside palm oil. Palm fruit fiber (PFF), palm oil mill effluent (POME), empty fruit bunch (EFB), and palm kernel shell (PKS) are among these, although oil palm is mostly grown for palm oil (PO) and palm kernel oil (PKO). Palm kernel shell (PKS) is a common type of plant material. Because of its environmentally favorable quality, PKS is referred to as one of the wastes resulting from oil palm processing that can be transformed into organic manure (Dagwa, &Ibhadode., 2006). In the early 1960s, Nigeria was one of the world's leading exporters of palm kernel products accounting for around 400,000 metric tons or 65 percent of global trade, resulting in a massive deposit of palm kernel shells in the country. In the country, managing the massive deposit of palm kernel shells remains a serious challenge (Koya, 2006; Oyebanji, 2012). Palm kernel shells are collected after the nuts are broken and the kernels are removed with the shells being generally discarded after the palm oil is extracted. Palm kernel is the dry fibrous and tough material that covers the palm nut and is left over after the rich outer cover is removed and the interior soft nut is removed. PKS is a natural fertilizer that is used to grow plants. Furthermore, decayed oil palm empty bunch has previously been reported to have a positive influence on the levels of pollutants in crude-oil polluted soil (Otaraku, & Anozie 2013).

The objective of this study is to evaluate the potential of palm kernel shell powder (PKSP) and poultry manure (PM) in the enhancement of physiochemical parameters in crude -oil polluted agricultural soil.

II. MATERIALS AND METHOD

Experimental Design

A fallowed agricultural land located at Obio-Kpor Local Government Area of Rivers State was identified, cleared of bushes and a soil surface area measuring $15.39m^2$ (5.7m × 2.7m) was further sub-divided into eight (8) smaller experimental cells of size measuring 0.3m × 0.3m ($0.9m^2$) each with a spacing of 0.3m between the respective cells. The cells measuring 0.3m × 0.3m were prepared using a hoe and were adequately ridged from each other to forestall pollutant migration. Shallow drains were also constructed in the spacing between cells with a view to preventing treatment from one cell flowing into the other either by surface runoff or interflow. The experiment comprised of eight cells each set up in triplicate totaling twenty-four cells in a completely randomized block design. The first cell was left in its natural state and served as a positive control. The second cell was polluted and devoid of amendment serving as negative control, while the remaining six plots were polluted and amended with the organic amendment material (poultry manure and palm kernel shell powder). Each cell of $0.9m^2$ size was artificially polluted with 500 mls of Escravous light crude oil having a specify gravity of 0.866. The crude oil was obtained from Warri Refining and Petrochemical Company (WRPC), Delta State. The crude oil was carefully measured and sprinkled equally on each cell using a fine hose and a watering container. Using a garden fork, the oil was then incorporated into the soil and the polluted cells were left undisturbed for a period of two weeks for proper infiltration of the crude-oil, after which the amendment material (palm kernel shell powder and poultry manure with varying doses of 100g, 200g and 400g) were applied using the method of (Obasi et al., 2013; Ayotamuno et al, 2006). The amended soils were remediated using palm kernel shell powder and poultry manure for a period of three months.

The amended soils were tilled using a plastic shovel to enable proper aeration and mixing of the amendment material and microbes with the polluted soil. Composite soil samples between 0-30cm were collected using soil auger for laboratory analysis before contamination with crude oil, two weeks after contamination, 1 MAT, 2 MAT and 3 MAT of crude oil polluted soils on a monthly basis.

Collection of Amendment materials

The following materials were used to amend the polluted soil in the course of this study.

1. Palm kernel shell powder (PKSP)
11. Poultry manure

The palm kernel shells were obtained from a local food vendor at NTA Road Mgbuoba while the poultry manure was obtained from a poultry farm at NTA Road, Mgbuoba.

Preparation of the amendment materials.

Palm kernel shell powder

The palm kernel was obtained from a local food vendor at NTA Road, in Obio - kpor Local Government Area. The palm kernel had previously been boiled, the husk removed and oil extracted. The palm kernel shells were properly dried under direct sunlight for a period of three weeks before cracking in order to separate the shells from the kernel. Thereafter it was ground with local mortar and pestle with the help of several hands. This took a period of 2 months. In order to obtain the palm kernel shell powder, the ground palm kernel was sieved through a 2mm standard mesh sieve. and thereafter, some samples were sent to the laboratory for analysis of chemical composition, e.g., nitrogen, phosphorus, potassium, pH etc. as shown in Table 1. This was done in order to ascertain the remediating potential of the palm kernel shell powder.

Poultry manure

The poultry manure was dried in the sun for three weeks and afterwards it was ground into powdered form. After passing the ground poultry manure through a 2mm standard mesh filter, some powdered poultry manure samples were sent to the laboratory for analysis of its minerals content such as carbon, nitrogen and phosphorus, etc.

Laboratory Analyses

All reagents employed for this study were of analytical grades with high purity.

Microelement analyses was conducted by microwave digestion method as described by (Mwegoha & Kihampa., Rashid et al, 2016). Two and a half grams of finely powdered soil was transferred into a crucible and mixed with 10 mL of aqua regia comprising of HCl and HNO_3 (3:1) and digested at 95°C for 1 hr. After cooling, the digest was diluted to 50 mL using dH20 and allowed to settle overnight and thereafter filtered. The concentrations of Cu, Fe, Zn and Mn were determined by atomic absorption spectrometry (SensAA).

The soil organic matter was determined by “loss of weight on ignition method” as described by (Motsara and Roy). Five grams of sieved (2mm) soil was placed unto a crucible. The crucible containing the soil was placed in a drying oven and dried at 105°C. After 4 hours, the crucible was removed, cooled in a desiccator and weighed. Again, the crucible with the dried soil was placed in a muffle furnace and dried at 400°C. After 4 hours, the crucible was removed, cooled and reweighed and the organic matter was thereafter calculated.

The method described by (Motsara, and Roy) was employed for the determination of the soil samples pH using a calibrated pH meter. Firstly, the pH meter was calibrated using buffer solutions of pH 4, 7 and 9. The buffer solutions were placed in beakers and the electrode was inserted alternatively in the beakers containing the buffer solutions while adjusting the pH. The instrument was ready for use to test the samples when it indicated pH as per the buffers. This was followed by measuring 10 g sample into a 50-mL beaker and 20 mL distilled water added. The soil was allowed to absorb the distilled water without stirring and thereafter stirred thoroughly for 10 seconds using a glass rod. The suspension was further stirred for 30 minutes and the pH of the soil sample read using the pH meter.

Statistical Analysis

Results of the study are expressed as means ± standard deviation of triplicate determination. To ascertain a significant difference between the groups, statistical analysis was carried out using one-way analysis of variance (ANOVA). Data between groups were analyzed by the Tukey’s test using Statistical Package for the Social Science (SPSS®) Version 20 statistics software at 95% ($p< 0.05$) confidence level.

III. RESULTS AND DISCUSSION

The results of the microelement of the treated soils groups are presented in Tables 1-4

The result of copper levels of the remediated soils is shown in table 1 below. The observed copper levels in the amended soils compared to the corresponding baseline values, 3 MAT may be related to increase in the quantity of organic matter (Reed & Martens., 1996). According to (Mengel, & Kirby, 2001), organic matter limits availability of copper by the reduction of soil mineral fixation and leaching.

The result of iron levels of the remediated soils is shown in table 2. Iron level was observed to be lower in soils remediated with P100gPKSP and P400gPKSP whereas soils remediated with P200gPKSP, P100gPM and P200gPM had higher iron levels compared to the corresponding baseline values 3 MAT. The former observation may be linked to degradation and utilization of Fe by the soil microorganisms (Das and Chandran, 2011). Research work by (Ogbo & Okhuoya, 2011) shows that iron recorded low bioavailability level both in crude oil polluted soil without and with fungal treatment.

The result of zinc levels of the remediated soils is shown in table 3 below. The decreased zinc levels observed in both the unpolluted and remediated soils compared to the corresponding baseline values, 3 MAT could be attributed to the active role played by natural attenuation and the amendment materials respectively in creating a suitable and favorable environment for the biodegradation and subsequent utilization of. Zn. According to Alloway (1995), organic matter has been reported to form stable compounds with micro elements such as zinc. This complexation results to its unavailability. Furthermore, as soil pH increases, the availability of Zinc reduces due to lower Zn mineral solubility and increased Zn absorption by negatively charged colloidal soil particles. Soil pH is the most important factor which controls Zn availability. The decrease in zinc availability 3 MAT could be linked to the increase in pH after the application of the amendments observed in this study.

The result of manganese levels of the remediated soils is shown in table below 4. The remediated soils showed decreased values compared to the corresponding baseline values. This indicates that manganese was adequately mobilized into environmental segments enhancing its extraction. Furthermore, the decrease in manganese observed in the amended groups 3 MAT was due to the degradation and utilization of Mn by the microorganisms. The observed increase in manganese level of the polluted soil 3 MAT could be due to its non-biodegradable nature. Heavy metals are non-biodegradable and persist in the environment (Kapahi, and Sachdeva., 2019). At 3 MAT, the percentage reduction of the remediated soils, calculated as: % reduction = [Baseline of Parameter in consideration] - [3 MAT] / Baseline × 100, is shows that soils amended with P200gPM had the lowest values for copper (77.72%) and Zinc (17.12%) whereas soils treated with P400gPKSP had the lowest values for iron (2.75%) and manganese (34.51%).

Table 1: Copper levels (mg/kg) of palm kernel shell powder and poultry manure treated soils

GROUP	BASELINE	MONTH 3	% R 3 MAT
Unpolluted Control	141.34±23.08	3.44±0.65*	N/A
Polluted Control	361.63±29.51^{a}	68.24±4.65^{a,*}	N/A
P100gPKSP	152.62±17.44^{b}	17.41±1.05^{a,b,*}	88.59
P200gPKSP	119.57±10.83^{b}	13.66±0.52^{a,b,*}	88.58
P400gPKSP	118.34±10.70^{b}	13.59±0.53^{a,b,*}	88.52
P100gPM	102.58±5.73^{a,b}	18.71±1.29^{a,b,*}	81.76
P200gPM	73.43±1.93^{a,b}	16.36±0.48^{a,b,*}	77.72
P400gPM	310.40±17.34^{a}	37.32±3.01^{a,b,*}	87.98

Values are mean ± standard error of triplicate determination. ‘a’ is significant at $p<0.05$ when compared with the unpolluted control. ‘b’ is significant at $p<0.05$ when compared with the polluted control. ‘*’ is significant at $p<0.05$ when compared with the corresponding baseline values.

Note: MAT= Months after Treatment; % R =Percentage Reduction, NA=Not Applicable, P100gPKSP = Polluted + 100g Palm Kernel Shell Powder; P200gPKSP = Polluted + 200g Palm Kernel Shell Powder; P400gPKSP = Polluted + 400g Palm Kernel Shell Powder; P100gPM= Polluted + 100g Poultry Manure; P200gPM= Polluted + 200g Poultry Manure; P400gPM = Polluted + 400g Poultry Manure

Table 2: Iron levels (mg/kg) of palm kernel shell powder and poultry manure treated soils

GROUP	BASELINE	MONTH 3	% R 3 MAT
Unpolluted Control	735.37±19.71	659.38±33.87*	N/A
Polluted Control	691.41±22.92	653.15±27.93*	N/A
P100gPKSP	887.55±34.70^{a,b}	670.28±17.47*	24.47
P200gPKSP	585.56±48.85^{a,b}	712.52±26.55*	N/A
P400gPKSP	725.54±28.93	705.60±20.22	2.75
P100gPM	543.55±24.84^{a,b}	651.54±29.15*	N/A
P200gPM	529.50±43.43^{a,b}	675.40±43.13*	N/A
P400gPM	753.71±30.15	637.40±21.33*	15.43

Values are mean ± standard error of triplicate determination. ‘a’ is significant at $p<0.05$ when compared with the unpolluted control. ‘b’ is significant at $p<0.05$ when compared with the polluted control. ‘*’ is significant at $p<0.05$ when compared with the corresponding baseline values.

Note: MAT= Months after Treatment; % R =Percentage Reduction, NA=Not Applicable, P100gPKSP = Polluted + 100g Palm Kernel Shell Powder; P200gPKSP = Polluted + 200g Palm Kernel Shell Powder; P400gPKSP = Polluted + 400g Palm Kernel Shell Powder; P100gPM= Polluted + 100g Poultry Manure; P200gPM= Polluted + 200g Poultry Manure; P400gPM = Polluted + 400g Poultry Manure

Table 3: Zinc levels (mg/kg) of palm kernel shell powder and poultry manure treated soils

GROUP	BASELINE	MONTH 3 MAT	% R 3 MAT
Unpolluted Control	331.40±17.21	70.51±2.27*	N/A
Polluted Control	384.70±23.08	385.43±24.44^{a}	N/A
P100gPKSP	319.28±11.11^{b}	142.32±5.81^{a,b,*}	55.42
P200gPKSP	249.57±17.65^{a,b}	174.44±11.30^{a,b,*}	30.10
P400gPKSP	291.28±23.13^{b}	153.57±11.65^{a,b,*}	44.28
P100gPM	288.47±17.18^{b}	169.31±5.71^{a,b,*}	41.31

P200gPM	185.30±11.60^{a,b}	153.58±5.87^{a,b,*}	17.12
P400gPM	202.19±11.39^{a,b}	130.72±2.86^{a,b,*}	35.35

Values are mean ± standard error of triplicate determination. ‘a’ is significant at *p*<0.05 when compared with the unpolluted control. ‘b’ is significant at *p*<0.05 when compared with the polluted control. ‘*’ is significant at *p*<0.05 when compared with the corresponding baseline values.
Note: MAT= Months after Treatment; % R =Percentage Reduction, NA=Not Applicable, P100gPKSP = Polluted + 100g Palm Kernel Shell Powder; P200gPKSP = Polluted + 200g Palm Kernel Shell Powder; P400gPKSP = Polluted + 400g Palm Kernel Shell Powder; P100gPM= Polluted + 100g Poultry Manure; P200gPM= Polluted + 200g Poultry Manure; P400gPM = Polluted + 400g Poultry Manure

Table 4: Manganese levels (mg/kg) of palm kernel shell powder and poultry manure treated soils

GROUP	BASELINE	MONTH 3	% R 3 MAT
Unpolluted Control	453.95±29.92	68.60±2.45*	N/A
Polluted Control	706.53±29.04^{a}	721.53±12.14^{a}	N/A
P100gPKSP	568.47±39.30^{a,b}	202.64±5.89^{a,b,*}	64.35
P200gPKSP	556.45±32.12^{a,b}	227.64±15.68^{a,b,*}	59.09
P400gPKSP	466.34±22.98^{b}	305.39±17.24^{a,b,*}	34.51
P100gPM	535.36±20.36^{a,b}	294.42±17.37^{a,b,*}	45.00
P200gPM	415.35±8.48^{b}	154.38±11.67^{a,b,*}	62.83
P400gPM	450.14±28.90^{b}	242.34±24.13^{a,b,*}	46.16

Values are mean ± standard error of triplicate determination. ‘a’ is significant at *p*<0.05 when compared with the unpolluted control. ‘b’ is significant at *p*<0.05 when compared with the polluted control. ‘*’ is significant at *p*<0.05 when compared with the corresponding baseline values.
Note: MAT= Months after Treatment; % R =Percentage Reduction, NA=Not Applicable, P100gPKSP = Polluted + 100g Palm Kernel Shell Powder; P200gPKSP = Polluted + 200g Palm Kernel Shell Powder; P400gPKSP = Polluted + 400g Palm Kernel Shell Powder; P100gPM= Polluted + 100g Poultry Manure; P200gPM= Polluted + 200g Poultry Manure; P400gPM = Polluted + 400g Poultry Manure

The soil organic matter and pH is presented in Figure 1-2. The observed significantly higher baseline organic matter level in the polluted soil when compared with the baseline unpolluted soil as seen in figure 1 may have occurred as a result of the contamination arising from the crude oil polluted soil. Some researchers (Obasi et al., 2013; Egobueze, et al., 2019) have linked an increase in organic matter content of polluted soil to the presence of crude oil. Furthermore, the carbon substrates present in the crude oil could have resulted to the observed increase in the organic matter of both the polluted control and amended soils when compared with the unpolluted soils (Oyedele et al., 2016) Addition of animal manure increases soil organic matter (SOM), soil aggregate, stability, water holding capacity, water infiltration and hydraulic condition. (Adeyemo et al., 2019). The significant increase observed in organic matter of the polluted soils amended with organic amendment in this study could have culminated to an influence in the soil property such as water holding capacity and mobilization of soil nutrients thereby contributing to the overall physical and chemical property of the soil. (Obasi et al., 2013; Egobueze, et al., 2019) The significantly higher (p <0.05) organic matter level of groups amended with poultry manure in comparison to the polluted control is linked to the fact that poultry manure is a good source of organic substrate which consists of nitrogen, phosphorus and potassium. It also enhances the activities of microorganisms resulting to the gradual release of nutrients within the soil. This is in line with the works of (Okafor et al. 2016) who pointed to the fact that poultry manure is enriched with organic matter thus allowing for a reasonable number of microorganisms. Also, higher organic matter value is linked to a large microbial biomass thereby enhancing proliferation of microorganisms (Evbuomwan et al, 2019), The reduction in organic matter content in the amended groups P100gPKSP, P400gPKSP, P100gPM and P400gPM when compared with the polluted control 3 MAT indicates the presence of increased microbial activities occurring from a large number of microbial populations in the soil which in turn utilize the organic carbon as a source of energy thereby releasing CO_2 amidst degrading the petroleum hydrocarbons. This is in accordance with the findings of (Benson et al., 2016) who reported that a decrease in total organic matter (TOM) and total organic carbon (TOC) in amended treatments is due to carbon utilization by soil micro-organisms as energy source for the oil degradation due to favourable pH level. This is also in line with the work of (Lee et al., 1995) who reported that organic manures have stimulatory effects on crude oil degradation by broadening the total heterotrophic microbial growth and activity.

Soil pH is a significant soil parameter that indicates changes in the pH values of all soil samples over a period of time. The observed increase in pH value for soils amended with P100gPM, P200gPM and P400gPM when compared with the unpolluted control may have occurred as a result of an upsurge in metabolic activities of microorganisms and the degradation of hydrocarbons in the soil that may have resulted to the synthesis of intermediary metabolites. It is also pertinent to note that the pH of the poultry manure group was within the proper range (6-8) which favoured the growth of microorganisms during the remediation period. Soil pH is vital because most microbial species can survive only within a certain pH range. Majority of soil microbes thrive and survive in neutral pH (6-7) as a result of the high availability of most nutrients within this pH range. Furthermore, the result of this research confirms the findings of earlier researcher (Ijah and Antai., 2003) that organic manures such as poultry manure is capable of having a buffering effect on crude oil polluted soil. Several reports show that higher biodegradation is achieved at increased pH. This can be supported with works of Obasi., et al., (2013); Tanee and Kinako., (2008) who stated that an increase in pH range (6-9) provides a conducive environment for the mineralization of hydrocarbons because numerous bacteria capable of metabolizing and degrading hydrocarbons develop best at neutral pH. The significant increase ($p<0.05$) recorded in pH levels of all the amended soils 3 MAT can be attributed to the nutrient supplement supplied by the poultry manure and palm kernel shell powder which enhanced the microbial mineralization of the amended soils. This is in line with the work of (Oyedele and Amoo, 2014). Soil pH influences the availability and absorption of nutrients to plants. Also, the increase in pH of the amended soils may have favoured the degradation of petroleum hydrocarbon as observed in other studies (Tanee & Kinako, 2008; Atlas & Bartha, 1992; Manuel et al. 1993). This is also in line with the work of (Gadhvi, 2019) who also reported that the addition of organic nutrients such as poultry manure either alone or in combination is used to improve the physiochemical properties such as pH of crude oil contaminated soils thereby improving crude oil biodegradation rates. Hamoudi-Belarbi, et al., (2018) also reported that the pH of soils amended with carrot peel wastes increased at the end of their study. The decrease in pH value of the polluted control soil may be due to increased degradation of the crude oil by the soil microorganisms resulting to the accumulation of acidic metabolites. Ejileugha, er al, (2015); Osazee & Yerima, (2014); Ataikuru, et al., (2017) also reported that soils polluted with crude oil results to a decrease in pH. The application of amendment material in all the amended cells, resulted to an increase in the pH 3 MAT to an alkaline/neutral state thereby enhancing microbial growth and biosynthesis of vital enzymes necessary for the biodegradation of petroleum hydrocarbon (Obasi et al 2013; Evbuomwan et al, 2019). The observed increase in pH in the unpolluted soil could be as a result of external interference occurring from the presence of base forming cations occurring in natural soils. This is in line with the work of (Neina, 2019) who reported that soil pH is controlled by the leaching of basic cations such as Ca, Mg, K and Na far beyond their release from weathered minerals, leaving H^{+} and Al^{3+} ions to dominant exchangeable cations

IV. CONCLUSION

This study has proven that amending crude oil polluted soils with organic wastes enhanced soil physical qualities. The organic amendments (palm kernel shell powder and poultry manure) have shown considerable promise in the restoration of crude oil polluted agricultural lands. Furthermore, because the long-term goal of bioremediation is to develop a cost-effective and environmentally friendly approach, cheap fertilizers like poultry manure and palm kernel shell powder which are readily available and effective in supplying limiting nutrients required for bioremediation of crude oil polluted agricultural soils, can be harnessed into preserved forms that can be used as a remedy for the deleterious effects of crude oil contaminants in soils.

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