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EFFECT OF PHYSICOCHEMICAL PROPERTIES ON CRUDE OIL POLLUTED SOILS REMEDIATED WITH ORGANIC MANURES AND INORGANIC FERTILIZER IN BAYELSA STATE

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Abstract: **Soil samples were analyzed to evaluate the effect of the application of organic and inorganic amendments on the soil physicochemical properties in the remediation of crude oil polluted soils of Bayelsa State. Two (2) crude oil spilled locations, Imiringi in Ogbia Local Government Area with latitudes 4. 8519 N and longitudes 6.3745 E and Koloama in Southern Ijaw Local Government Area with latitudes 4.582222 N and longitudes 6.064722 E respectively were selected for this research. Soil samples were collected at a depth of 0 – 30 cm, bulked for pot experiment in the screen house. Five (5) kilograms of soil were weighed into twenty-four (24) plastic buckets of seven (7) liters each for Imiringi and Koloama, making a total of forty-eight (48) plastic buckets used. The experimental design was a 2 x 8 factorial experiment laid out in a Complete Randomized Design (CRD) replicated three times. Results obtained were subjected to statistical analysis of variance using the Tukey's Test to separate means of significant difference at 5 % probability level. The amendment materials used were organic manures [cow dung (CD) and poultry dropping (PD)] inorganic fertilizer (NPK) and their combinations (CD + PD, PD + NPK, NPK + CD and CD + PD + NPK) on the soil physicochemical properties in the crude oil polluted soils. The study shows that Imiringi soils were significantly different from Koloama soils. Imiringi soils are sandy loam while that of Koloama soils are sandy clay loam. The high significant difference between the locations and among the treatments on the soil physicochemical properties in the study areas at 30 days, 60 days and 90 days respectively, indicates that the application of these amendment materials was effective.**

Keywords: **Crude Oil, Imiringi, Inorganic Fertilizer (NPK), Koloama, Organic manures, Physicochemical properties, Polluted Soils.**

1. INTRODUCTION

Crude oil is a complex mixture of diverse hydrocarbons including alkanes, aromatics, branched and non-branch hydrocarbons compounds. The pollution of soil by crude oil and its products has become a serious problem that presents a global concern for its potential consequences on the ecosystem and on human health (Onwurah *et al.*, 2007). These spills cause soil pollution which has become a major issue in Nigeria, especially in the Niger Delta states leading to huge environmental degradation (Nwilo and Badejo 2001). An increasing attention has been directed towards developing new strategies and environmental-friendly technologies for the remediation of soil polluted with petroleum hydrocarbons. Among these, bioremediation technology which involves the use of microorganisms to detoxify or remove pollutants through the mechanisms of biodegradation has been found to be an environmentally-friendly, non-invasive and relatively cost-effective option (April *et al.,* 2000).

When soils are polluted with crude oil, nutrients are rapidly consumed by microorganisms, leading to nutrient depletion (Rahman *et al.* 2002). To promote the bioremediation process, soil amendments are been used to replenish the nutrient reserves and improve the fertility of the soil. Organic nitrogen-rich nutrients, such as animal wastes (cow dung and poultry droppings) are effective in enhancing petroleum hydrocarbon degradation through bio-stimulation. These organic wastes are readily available and relatively inexpensive option for soil amendment. Danjuma *et al.,* (2012) attest to this, that animal organic waste like cow dung, pig dung, and goat dung mixed with petroleum hydrocarbons were found to show positive influence on petroleum hydrocarbon biodegradation in a polluted environment.

In regions like Bayelsa State in Nigeria, where oil exploration, spillage, and disposal of petroleum products have caused severe ecological problems (Teknikio *et al*., 2018), the use of bioremediation techniques becomes crucial. The pollution of the soil and aquatic environment with hydrocarbon compounds poses significant health risks due to their carcinogenic and mutagenic effects (Mishra *et al*., 2010). Biotic and abiotic factors, such as soil physicochemical properties (Barua *et al*., 2011), vegetation, and land use type, influence soil microbial activities and the success of bioremediation efforts.

Bioremediation as a process that utilizes microorganisms and their metabolic activities to remove pollutants from soil. The presence of microorganisms with the appropriate metabolic capabilities is the most important requirement for oil spill bioremediation according to Venosa *et al.,* (2002). The microorganisms are adsorbed onto the soil particles by the mechanism of ionic exchange. In general, soil particles have negative charges, and the soil and bacteria are held together by an ionic bond involving polyvalent cations (Killham, 2006). When it comes to crude oil pollution, bioremediation offers an environmentally-friendly and cost-effective solution.

Consequently, the success of bioremediation depends on the bioavailability and biodegradability of the pollutants by the organisms (Semple *et al.,* 2001). This type of biological treatment is seen as a viable option because of the ability of these organisms to breakdown pollutants. The objective of this study is to assess the effectiveness of organic and inorganic manures on the physicochemical properties of the petroleum polluted soils in Imiringi and Koloama locations.

2. MATERIALS AND METHODS

Two (2) crude oil polluted locations were selected for this research namely; Imiringi with latitudes 4^o.52$'$ – 4^o.85$'$ N and longitudes 6^o.23$'$ – 6^o.37$'$ E in Ogbia Local Government Area and Koluama I with latitudes 4^o.58' - 52.8'N and longitudes 6^o.06' - 27.2$'$ E in Southern Ijaw Local Government Area both in Bayelsa State.

The soils were randomly collected at a depth of 0 – 30 cm from the oil spilled polluted sites for the experiment. A total of 48 samples comprising of the control, treatments and their combinations were analyzed in this experiment. The soils were bulked and 5kg of soil were measured into 48 plastic buckets of 7 liters each according to the controls, treatments and treatment combinations.

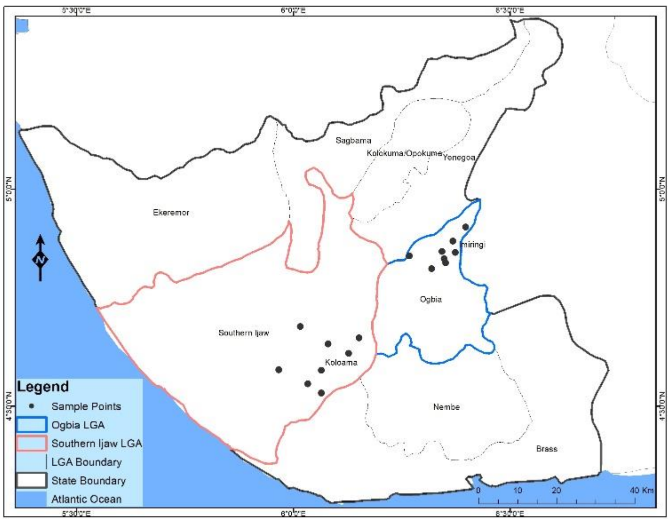

Fig. 1 Map of Bayelsa State showing the sampling points in the two study locations (Imiringi and Koloama) of the crude oil polluted soils

Soil Physiochemical Properties

Physical Analysis

Soil physical properties were analyzed. Soil moisture content by Smith (1998), bulk density was determined using the core method (Ibitoye, 2006), particle size using Bouyoucos hydrometer method as described by Gee and Or (2002).

Soil moisture content

Soil moisture determination is of major significance. Soil moisture influences crop growth not only by affecting nutrient availability, but also nutrient transformations and soil biological behaviour. All analyses in the laboratory are related air or oven-dry basis, and therefore, the actual soil moisture content (Smith, 1998) was considered.

The bulk wet soils were weighed and oven dried at 105ºC for 24 hours and re-weighed again after cooling the next day and then the moisture content was calculated using the formula;

$$\text{Soil Moisture Content } (\Theta) = \frac{\text{wet soil (g)} - \text{dry soil (g)}}{\text{dry soil (g)}}$$

Bulk density (Core method)

Bulk density is very important in estimating the weights of nutrients in the soil. So bulk density is the ratio of the mass of the soil to its volume and is express as g/cm^3. While the mass of the soil is easily determined, the volume of the soil is difficult so the core method is used in determining the soil bulk density. Bulk density was determined using the core method (Ibitoye, 2006).

Then the core samples were taken to the laboratory for analysis. The soil samples were weighed and then oven dried at 105ºC to a constant weight then the bulk density was calculated using the formula;

$$\text{Bulk Density (Bd)} = \frac{X_2 - X_1}{\text{Volume of soil (cm}^3)}$$

where, X_1 = weight of empty cylinder (g)

X_2 = weight of oven-dry soil + cylinder (g)

$V = \pi r^2 h$

Soil Porosity

The porosity of a soil is the amount of the pore spaces that is influenced by the physicochemical properties of the soil such as the percolation, infiltration aeration and redox reaction of the soil. The porosity of the soil is obtained from the bulk density and particle density measurement.

$$\text{Porosity (\%)} = \frac{Pd - Bd}{Pd} \times 100$$

Where;

Pd = Particle density or specific gravity and Bd = Bulk density.

Particle size distribution of soil

The soil particles were analyzed using Bouyoucos hydrometer method as described by Gee and Or (2002) and the soil texture read with the textural triangle.

Formula;

% Silt = (% Silt + Clay %) - % Clay

% Sand = 100 – (% Silt + Clay %).

Soil texture was determined using the textural triangle.

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Chemical Analysis

Soil pH as described by Mclean (1982), soil organic carbon/matter as described by Nelson and Sommers (1996), total nitrogen was determined by the Kjeldahl method, as described by (Bremner *et al.*, 1996), available phosphorus Bray-1 method by and CEC by both summation method (Ca and Mg) and flame method (K).

Soil pH is a fundamental chemical property as the life of the soil depends on it. Soil pH was determined in water by electrometric method as described by Mclean (1982) in a ratio of 1: 2.

10 g of 2-mm sieved air-dried soil is placed in a 50 ml pH cups, and 20 ml of water was added to the soil and then the suspension was stirred and allowed to stand for 30 minutes undisturbed, and the pH was determined after calibrating the pH meter with buffer 4, 7 and 9, then the glass electrode was carefully immersed in the suspension making sure the electrode does not touch the bottom of the cup and the readings were taken and recorded for water.

Electrical Conductivity of the soil was determined using the Lovibond conductivity meter-bridge (dS/m) type at 25ºC. The soil suspension used for pH determination was used for the conductivity measurement and readings taken accordingly.

The organic matter and carbon content were determined by Walkley-Black method 1934 as described by Nelson and Sommers (1996).

$$\text{Oxidizable Organic carbon (\%)} = \frac{(\text{Vblank} - \text{Vsample}) \times 0.003 \times 0.5}{\text{Wt (soil)}}$$

Total Organic carbon (%) = 1.334 x Oxidizable Organic Carbon (%)

Organic Matter (%) = 1.724 x Total Organic Carbon (%).

Total Nitrogen was determined by digesting the soil sample using Kjeldahl method, as described by (Bremner *et al.*, 1996) and later distilled and titrated with 0.1 N of H_2SO_4 and the values recorded accordingly.

Available Phosphorus was determine using dilute acid-fluoride method of Bray-1, and the filtrate was determined for (A P) using Spectrophotometer at 712 nm wavelength.

Where;

$$\text{P (mg/kg)} = \frac{\text{X(mg)} \times \text{vol. of solution}}{\text{aliquot sample} \times \text{sample wt (g)}}$$

The cation exchange capacity of soils was analyzed for the following; Magnesium (Mg^{2+}) and Calcium (Ca^{2+}) was carried out by summation method using EDTA, while Potassium (K^{+}) was carried out by flame photometer.

EXPERIMENT/ MATERIALS USED

The experiment was carried out in the screen house, using plastic buckets. A total of 48 plastic buckets of 7 liters each were filled with soils collected from the two (2) polluted locations at a fixed weight of 5 kg for each bucket, 24 plastic buckets per location. A fixed rate of 0.5 kg of the amendments (cow dung, poultry dropping, NPK 20 -10 -10 and their combinations) were applied to the polluted soils 3 weeks after collection from the field and were observed to ascertain the effect of the amendment materials on the physicochemical properties during the remediation period.

EXPERIMENTAL DESIGN AND DATA COLLECTION

Experimental design was a 2 x 8 factorial experiment in a complete randomized design (CRD) where locations and treatments are factors replicated three (3) times. Soil samples were collected at (30 days, 60 days and 90 days) for analysis during the research period.

STATISTICAL ANALYSIS

The data collected were subjected to statistical analysis of variance (ANOVA) and data analysis of General Linear Model (GLM) were used to evaluate the effects of treatments on the crude oil polluted soils. The Tukey test was used to separate all the means. All analyses were performed using Minitab Statistical Software Release 17.1, and significance reported at 5% probability level.

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3. RESULTS

KEY:

IMI = Imiringi

KLM = Koloama

Control = (Polluted Soil Not Treated)

CD = Polluted Soil Treated with Cow Dung Manure

PD = Polluted Soil Treated with Poultry Dropping Manure

NPK = Polluted Soil Treated with Nitrogen Phosphorous Potassium Fertilizer (Inorganic Manure)

CD + PD = Polluted Soil Treated with Cow Dung Manure + Poultry Dropping Manure

PD + NPK = Polluted Soil Treated with Poultry Dropping Manure + Nitrogen Phosphorous Potassium Fertilizer (Inorganic Manure)

CD + NPK = Polluted Soil Treated with Cow Dung Manure + Nitrogen Phosphorous Potassium Fertilizer (Inorganic Manure)

CD + PD + NPK = Polluted Soil Treated with Cow Dung Manure + Poultry Dropping Manure + Nitrogen Phosphorous Potassium Fertilizer (Inorganic Manure)

Main and interaction effects of locations and treatments on the soil physical properties at intervals of 30 days, 60 days and 90 days during the remediation period

Table 1a. Main and interaction effects of locations and treatments on the soil physical properties

Factors	% MC			BD (g/cm^3)			% P		
Locations	30 Days	60 Days	90 Days	30 Days	60 Days	90 Days	30 Days	60 Days	90 Days
IMI	27.04a	22.17b	17.92b	1.18c	1.28b	1.39a	55.89a	52.48a	47.70a
KLM	26.54a	25.79a	25.17a	1.28b	1.33a	1.37a	51.53b	49.98b	48.28a
Treatments									
CONTROL	22.44a	18.78b	15.00c	1.37b	1.40b	1.43ab	48.62c	47.08b	46.04e
CD	27.33a	24.89a	23.00a	1.14e	1.23c	1.31cd	56.86a	54.66a	50.43ab
PD	28.67a	23.22ab	17.78bc	1.13e	1.21c	1.28d	57.63a	54.46a	51.83a
NPK	20.56a	20.00ab	20.44ab	1.49a	1.51a	1.52a	43.74d	43.00c	42.81e
CD + PD	28.33a	24.33a	20.77ab	1.15de	1.22c	1.30cd	57.27a	54.62a	51.17a
PD + NPK	22.67a	21.89ab	19.55ab	1.31bc	1.36b	1.40bc	50.72bc	48.74b	47.37bc
CD + NPK	25.89a	22.89ab	22.11a	1.32bc	1.37b	1.41ab	50.32bc	49.17b	46.64cd
CD + PD + NPK	25.22a	22.78ab	20.56ab	1.25cd	1.32b	1.37bc	52.73b	50.71b	48.37ab
P value									
Locations	NS	*	*	*	*	NS	*	*	NS
Treatments	NS	*	*	*	*	*	*	*	
Locs. x Trts	NS	*	*	*	*	*	*	*	*
CV (%)	19.90	12.01	13.40	4.32	3.26	4.52	3.91	4.05	5.01
R^2 (%)	48.58	67.08	82.98	86.09	84.14	68.95	86.65	82.77	69.27

The means with same letters in the columns separated using Tukey's Test are not significantly different at $p \leq 0.05$ level test. Same letters, NS = Not Significantly different and different letters, * = Significantly different.

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Table 1b. Main and interaction effects of locations and treatments on the soil physical properties

Factors	Particle Size Distribution								
	% Sand			% Silt			% Clay		
Locations	30 Days	60 Days	90 Days	30 Days	60 Days	90 Days	30 Days	60 Days	90 Days
IMI	71.63b	72.84b	74.26a	16.90a	15.69a	14.43a	11.47c	11.47c	11.34b
KLM	62.13c	58.13c	54.13b	16.07a	15.36a	14.85a	21.80a	26.51a	25.53a
Treatments									
CONTROL	70.80a	68.36a	65.91a	12.42a	14.76a	16.96a	16.78cd	16.89ab	17.14a
CD	74.36a	70.91a	67.40a	12.73a	12.18a	11.62ab	12.91d	15.91b	16.02a
PD	71.91a	69.91a	67.91a	13.02a	15.80a	18.51a	15.07ab	17.18ab	15.80a
NPK	69.02a	70.13a	71.24a	12.51a	10.31a	7.91c	18.47a	16.89ab	16.68a
CD + PD	73.14a	69.69a	67.69a	12.84a	13.62a	15.07ab	14.02bc	17.36ab	16.47a
PD + NPK	70.47a	69.91a	69.58a	12.62a	12.29a	13.17ab	16.91ab	18.02a	16.46a
CD + NPK	71.69a	70.47a	69.36a	12.51a	10.84a	9.73bc	15.80cd	17.02ab	16.85a
CD + PD + NPK	71.80a	70.24a	68.91a	12.29a	12.51a	12.40ab	15.91ab	17.24ab	16.80a
P value									
Locations	*	*	*	NS	NS	NS	*	*	*
Treatments	NS	NS	NS	NS	NS	*	*	*	NS
Locs. x Trts	*	*	*	*	*	*	*	*	*
CV (%)	8.34	4.16	6.95	29.67	26.80	28.80	5.74	6.16	9.13
R^2 (%)	80.56	89.55	87.04	71.84	66.42	62.37	98.89	97.63	94.13

The means with same letters in the columns separated using Tukey's Test are not significantly different at $p \leq 0.05$ level test. Same letters, NS = Not Significantly different and different letters, * = Significantly different.

Main and interaction effects of locations and treatments on the soil chemical properties at intervals of 30 days, 60 days and 90 days during the remediation period

Table 2a. Main and interaction effects of locations and treatments on the soil chemical properties

Factors	pH (H_2O)			EC (dS/cm)			% OC			% OM		
Locations	30 Days	60 Days	90 Days	30 Days	60 Days	90 Days	30 Days	60 Days	90 Days	30 Days	60 Days	90 Days
IMI	6.81c	6.91b	6.91a	809.38c	717.63c	732.76c	0.92b	1.04b	1.20b	1.60b	1.80b	2.07b
KLM	6.94b	6.77c	6.80c	815.62b	789.74b	781.52a	0.89c	0.97c	1.18c	1.53c	1.67c	2.03c
Treatments												
CONTROL	6.81f	6.79f	6.76h	661.09h	633.85f	596.71h	1.24a	1.43a	1.60a	2.15a	2.46a	2.77a
CD	6.92c	6.96c	6.93e	954.32a	908.82a	874.07a	0.87f	1.01d	1.29d	1.50f	1.74d	2.22d
PD	6.86e	6.87e	6.82g	766.94g	675.57e	667.19g	1.18b	1.17b	1.36b	2.04b	2.02b	2.34b
NPK	7.00a	7.12a	7.29a	823.32e	807.40c	818.36c	0.80h	0.78g	1.03g	1.40h	1.35g	1.78h
CD + PD	6.89d	6.92de	6.88f	860.65c	792.19c	770.63e	1.03c	1.09c	1.32c	1.77c	1.88c	2.28c
PD + NPK	6.93c	7.00c	7.06c	795.15f	741.48d	742.72f	0.99d	0.98e	1.20e	1.72d	1.69e	2.06f
CD + NPK	6.97b	7.07b	7.13b	888.86b	858.11b	846.17b	0.84g	0.89f	1.16f	1.46g	1.54f	2.00g
CD + PD + NPK	6.93c	6.99c	7.02d	848.19d	807.05c	786.51d	0.95e	0.98e	1.22e	1.64e	1.70e	2.11e
P value												
Locations	*	*	*	*	*	*	*	*	*	*	*	*
Treatments	*	*	*	*	*	*	*	*	*	*	*	*
Locs. x Trts	*	*	*	*	*	*	*	*	*	*	*	*
CV (%)	0.24	0.25	0.27	0.04	0.47	0.02	1.51	0.81	1.62	1.86	0.77	1.29
R^2 (%)	99.48	99.28	99.65	100.00	99.50	100.00	99.76	99.88	99.54	99.70	99.86	99.73

The means with same letters in the columns separated using Tukey's Test are not significantly different at $p \leq 0.05$ level test. Same letters, NS = Not Significantly different and different letters, * = Significantly different.

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Table 2b. Main and interaction effects of locations and treatments on the soil chemical properties

Factors							Cation Exchange Capacity (CEC)								
	% TN			AP (mg/kg)			K (cmol/ kg)			Ca (cmol/ kg)			Mg (cmol/ kg)		
Locations	30 Days	60 Days	90 Days	30 Days	60 Days	90 Days	30 Days	60 Days	90 Days	30 Days	60 Days	90 Days	30 Days	60 Days	90 Days
IMI	1.66c	2.59b	2.93b	0.96c	1.10c	1.28b	1.69a	1.99a	2.31a	0.19a	0.15b	0.20a	0.13a	0.13a	0.15a
KLM	2.52a	2.86a	3.04a	1.14b	1.17b	1.26c	1.66a	1.98a	2.10c	0.14c	0.16a	0.19b	0.09c	0.11b	0.12c
Treatments															
CONTROL	2.01h	2.17f	2.33f	0.18h	0.31h	0.53f	1.00c	1.29g	1.64d	0.13d	0.13e	0.15e	0.13a	0.16a	0.19a
CD	1.71h	1.95g	2.27g	0.60g	0.64g	0.87e	0.84c	1.15h	1.40e	0.13d	0.14d	0.16d	0.08g	0.08g	0.10f
PD	2.59a	2.75c	2.95d	1.77a	1.84a	2.03a	2.24a	2.45a	2.63a	0.12e	0.13e	0.15e	0.10e	0.10e	0.11e
NPK	2.39c	3.37a	3.67a	1.31c	1.37c	1.47c	2.10a	2.37c	2.75a	0.24a	0.21a	0.25a	0.13a	0.14b	0.16b
CD + PD	2.15e	2.35e	2.61e	1.19e	1.24e	1.45c	1.54b	1.80e	2.01c	0.13d	0.14d	0.15de	0.09f	0.09f	0.11e
PD + NPK	2.49b	3.05b	3.32b	1.54b	1.61b	1.75b	2.17a	2.41b	2.69a	0.19b	0.18b	0.20c	0.12b	0.12c	0.14c
CD + NPK	2.05f	2.61d	2.97c	0.96f	1.01f	1.17d	1.63b	1.77f	2.08c	0.19b	0.18b	0.20c	0.11c	0.12c	0.13d
CD + PD + NPK	2.23d	2.69cd	2.96cd	1.23d	1.28d	1.46c	1.76b	1.99d	2.37b	0.17c	0.16c	0.22b	0.10d	0.11d	0.13d
P value															
Locations	*	*	*	*	*	*	NS	NS	*	*	*	*	*	*	*
Treatments	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Locs. x Trts	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
CV (%)	1.25	1.13	0.31	1.47	1.51	1. 65	2.01	1.05	1.84	0.41	0.88	1.27	0.00	1.46	1.05
R^2 (%)	99.90	99.20	99.97	99.95	99.95	99.98	92.56	99.89	96.42	99.93	99.56	99.17	99.48	99.24	99.03

The means with same letters in the columns separated using Tukey's Test are not significantly different at $p \leq 0.05$ level test. Same letters, NS = Not Significantly different and different letters, * = Significantly different.

4. DISCUSSION

Crude oil pollution has negative effects on the physicochemical properties of soils, including increased acidity, reduced nutrient content, altered soil structure, and decreased water holding capacity. It also increases toxic compounds like polycyclic aromatic hydrocarbons (PAHs), which persists in the soil and impact negatively on soil fertility and microbial activity. Organic manures, such as cow dung and poultry droppings, and inorganic fertilizers have been used as remediation approaches in this study. They enhanced the degradation of crude oil pollutants and also influenced the physicochemical properties of the soil as observed in this study.

From this study, the addition of organic manures improved soil structure, increased nutrient availability, and enhanced the degradation of crude oil. These manures are rich in organic matter and microbial populations, that promoted the biodegradation process (Meena *et al.*, 2014). They also increased soil moisture retention and reduced hydrocarbon toxicity to the microorganisms as time went by as observed in Table 1a. The addition of organic manures improved soil structure as seen in Table 1b and enhanced nutrient availability, thus facilitating the degradation of crude oil in the soils of the locations (Imiringi and Koloama). Inorganic fertilizers, especially nitrogen and phosphorus, in particular, are essential nutrients for microbial metabolism and promote the activity of hydrocarbons degrading bacteria (Meena *et al.*, 2014). By supplying these nutrients to the soil, inorganic fertilizers enhanced microbial degradation of crude oil pollutants and indirectly stimulate the growth of oil-degrading microorganisms resulting in microbial degradation of crude oil pollutants.

The effectiveness of crude oil remediation with organic manures and inorganic fertilizers is influenced by soil texture, pH, organic matter content, and nutrient status as observed in this study. Sandy soils exhibit faster degradation rates as compared to clayey soils due to differences in microbial activity and nutrient availability as shown in the result in Table 1b. Thus, soils with higher organic matter content have higher microbial biomass and activity (Khan *et al.*, 2018), leading to enhanced biodegradation. Optimal moisture content levels and pH also plays a role in microbial activity and hydrocarbon degradation processes (Meena *et al.*, 2014).

Therefore, the pH of the soil affects the activity and diversity of microbial communities involved in biodegradation processes as shown in Table 2a. The study found that the addition of organic manures and inorganic fertilizers significantly improved the soil properties by increasing organic matter content and nutrient availability. These enhancements ultimately led to increased crude oil degradation in the treated soils. Crude oil pollution disrupts the availability of essential nutrients such as nitrogen, phosphorus, and potassium and other nutrients as calcium and magnesium which are crucial for plant growth.

This study has shown that the addition of organic manures and inorganic fertilizers significantly improves soil properties in the two locations (Imiringi and Koloama) by increasing the organic matter content and nutrient availability, which ultimately enhanced crude oil degradation. These remediation approaches replenish essential nutrients compensating for nutrient deficiencies caused by crude oil pollution and aiding in the recovery of soil health.

5. CONCLUSION

The remediation of crude oil-polluted soils in Bayelsa State (Imiringi and Koloama) with organic manures and inorganic fertilizers and their combinations had a positive impact on the soil characteristics in improving the soil physicochemical properties and promoting the degradation of crude oil pollutants as seen in the results above. These amendments enhanced soil physicochemical properties promoting microbial activities and accelerated the degradation of petroleum hydrocarbons. However, further research is needed to optimize the application rates and assess the long-term effects of these remediation strategies in order to develop sustainable approaches in the restoration of crude oil-polluted soils.

REFERENCES

[1] Meena, V. S.; Maurya, B. R.; Verma, J. P. (2014) Does a rhizospheric microorganism enhance K^+ availability in agricultural soils? Microbiol Res 169:337–347

[2] Khan, M. A. I.; Biswas, B.; Smith, E.; Naidu, R.; Megharaj, M. (2018). Toxicity assessment of fresh and weathered petroleum hydrocarbons in polluted soil – a review. Chemosphere 212, 755 – 767.

[3] April, T. M.; Foght, J. M.; Currah, R. S. (2000). Hydrocarbon-degrading filamentous fungi isolated from flare pit soils in northern and western Canada. *Canadian Journal of Microbiology*, vol. 46, no. 1, pp. 38–49.

[4] Barua, D.; Buragohain, J.; Sarma, S. K. (2011). Certain physiochemical changes in the soil brought about by contamination of crude oil in two oil fields of Assam, NE India. *Euro. Journal. Exp. Bio.* **1**: pp 154-161.

[5] Bremner, J. M. and Mulvaney, C. S. (1996). Total nitrogen determination in Methods of Soil Analysis, Page, A. L.; Miller, R. H.; Keeney, D. R. Eds., p. 595, American Society of Agronomy, Madison, Wis, USA.

[6] Danjuma, B. Y.; Abdulsalam, S.; Sulaiman, A. D. I. (2012). Kinetic investigation of Escravos crude oil contaminated soil using natural stimulants of plant sources. *International Journal of Emerging Trends in Engineering and Development*, 2(5), pp 478–486.

[7] Gee, G. W. and Or, D. (2002). Particle Size Analysis. In Dane, J. H. and Topp, G. C., Eds., Methods of Soil Soil Analysis. Part 4, Physical Methods, SSSA, Incorporated, adison, 255 – 294.

[8] Ibitoye, A. A. (2006) *Laboratory Manual on Basic Soil Analysis*. 2nd Edition, Foladave Nigeria Ltd., Akure, Nigeria, pp 70.

[9] Killham, K. Soil Ecology (fourth ed.) (2006) Cambridge University Press, Cambridge, UK, p. 242.

[10] McLean, E. O. (1982). Soil pH and lime requirement. Black C A (ed.): Methods in soil analysis: chemical and microbiological properties. Part II-American Society of Agronomy, Madison, Wisconsin, USA.

[11] Mishra, U.; Lal, R.; Liu, D.; Van Meirvenne, M. (2010). Predicting the spatial variation of soil organic carbon pool at a regional scale, Soil Sci. Soc. Am. J., 74, pp 906–914.

[12] Nelson, D. W. and Somners, L. E (1996). Total Carbon, Organic Carbon and Organic Matter. In:

[13] Sparks, D. L. et al., Eds., Methods of Soil Analysis part 3. SSSA Book Series Madison, pp. 961 - 1010.

[14] Nwilo, P. C. and Badejo, O. T. (2001). Impact of Oil spills along the Nigerian coast. Proceedings of the Association for Environmental Health and Sciences. 10(5): pp 20-24.

[15] Onwurah, I. N. E.; Ogugua, V. N.; Onyike, N. B.; Ochonogor, A. E.; Otitoju, O. F. (2007) Crude oil spills in the environment, effects and some innovative clean-up biotechnologies, *Int. J. Environ. Res*., 1: pp 307–320.

[16] Rahman, K. S.; Banat, I. M.; Thahira, J.; Thayumanavan, T.; Lakshmanaperumalsamy, P. (2002). Bioremediation of gasoline contaminated soil by a bacterial consortium amended with poultry litter, coir pith and rhamnolipid biosurfactant. Bioresour. Technol. 81: pp 25-32.

[17] Semple, K. T.; Reid, B. J.; Fermor, T. R. (2001). Impact of composting strategies on the treatment of soils contaminated with organic pollutants. Environmental Pollution 112: pp 269-283.

[18] Smith, G. N. (1998). Elements of Soil Mechanics, Blackwell Science, Oxford, UK, 7th edition.

[19] Teknikio, J. B.; Ojeniyi, S.O.; Adeyemo, A. J.; Tate, J. O. (2018). Isolation and Identification of Bacteria in Petroleum Hydrocarbons Polluted Soils in North-West, Bayelsa State. Covenant Journal of Physical and Life Sciences (CJPL) Special Edition Vol. 1 (2); pp 1 – 13.

[20] Venosa, A. D; Lee, K.; Suidan, M. T; Garcia-Blanco, S.; Cobanli, S. (2002). Bioremediation and bio-restoration of a crude oil contaminated freshwater wetland on the St. Lawrence River. Bioremediation journal 6: pp 261-281.

[21] Walkey, A and Black, A. I. (1934). An examination of Degtjareff methods for determining soil organic matter and proposed modifications of the chromic acid titration method. Soil Science 37: pp 29-38.