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Oil spills deposits effect on soil physicochemical properties in Port Harcourt metropolis: Implication for agricultural planning

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Abstract
Examined herein are the effects of oil spills on soil physicochemical characteristics in Port Harcourt, Rivers State. Experimental research design was adopted for the study. Soil samples were collected from oil imparted areas and compared with FEPA soil quality standards and control site. Using quadrat sampling technique five (5) oil impacted sites were selected for the experiment. The sites were picked purposively following the researchers' knowledge of oil spill issues in the area hitherto. Soil samples were collected at depths of 0-15cm and 15-30cm respectively and sent to the lab, to check for the physicochemical properties. Multiple regression and ANOVA statistics were used to test the hypotheses. Analysis of soil samples showed that soils of Port Harcourt metropolis were sandy-loamy and very acidic with pH that ranged between 2-3.5. Cation Exchange Capacity, magnesium, potassium, nitrogen, calcium, and organic carbon content were very low and could not support agriculture. The regression model showed that, oil spillage has significant effect on the physicochemical content of soils in Port Harcourt at $p<0.05$ (R-.870; r^2 .757). There was statistically significant difference in the spatiality of physicochemical characteristics of soils in the area. Prevention of further spills, phytoremediation and holistic agricultural planning are among the solutions advanced in the study.

Keywords: Agriculture; physicochemical; oil-spills; soil-pollution; planning

Introduction
Globally oil spill is a serious menace to soil, but more severe in the developing world (Sharma & Pandey, 2014). On one hand, attitudes of government and locals towards oil mining and syphoning and on the other, the poor technology available for oil exploitation (Adeola et al., 2022). Oil spills pollutes the soil, consequently resulting in less productive agricultural lands, since the microorganisms which are to interact with the soils are killed due to petroleum poisoning (Srivastava et al., 2019). In Nigeria, soil oil pollution, is as old as the period commercial exploitation of oil started (1958) (Ejiba et al., 2016). Nigeria produces a major part of world oil; thus, the pollution of the soil has also increased following this rise in amount of crude oil produced (Okoro, 2021). Osuagwu and Olaifa, (2018) averred that over 20,106 barrels of crude oil was spilled into the environment between 1976 and 1988, from 2000 oil spill cases.

Nigeria benefits from crude oil exploration as well as other countries that produce oil, however, the difference lies in the approach deployed when the negative (spills) sides appear (Adonteng-Kissi et al., 2021). Arising from the poor oil spill management approach, from all concerned with crude oil exploration and exploitation, in the Niger Delta Region (NDR), soils have continued to witness serious pollution, since there is relatively no remediation going on (Suthersan et al., 2016). When oil spills on to soil, aeration is distorted, since oil film shields soil surface, consequently acting as a blockade to the top soils and by implication the physicochemical and biological properties are either altered or destroyed (Chakraborty, 2021).

Frequent crude-oil spillage on agricultural soils, destroys the biological components of the soil, alters soil chemicals, and makes soil toxic and unproductive (Okon & Ekpo, 2022). Dimkpa et al., (2020) asserted that engine oil affects moisture content in plant; reduces soil fertility; with most of the essential nutrients depleted, of which plants suffer the because there are no nutrients for plant uptake. Spilled crude-oil which is denser than water reduces and restricts permeability: organic hydrocarbons which fill the soil pores expel water and air, thus depriving the plant roots the highly needed water and air (Kuch & Bavumiragira, 2019). Changes in soil properties due to contamination with petroleum derived substances can lead to water and oxygen deficit as well as shortage to available forms of nitrogen and phosphorus (Ahmed & Fakhruddin, 2018).

Oil spills have degraded most agricultural soil in Port Harcourt and have turned hitherto productive soil areas into wastelands. With increasing soil infertility and dwindling agricultural productivity, farmers have been forced to abandon their land, to seek non-existent alternative means of livelihood (Chijioke et al., 2018). It is discernible that farmers, whose farmlands are affected, have no alternative than to move to other areas during the cultivation season (Okon & Ogba, 2018). Overall, oil spillage affected crop yield and farm income, and by extension, the social and economic livelihoods of farming communities (Ejiba et al, 2016), there are some far reaching social implications for the farmers, not to be mentioned herein since it falls outside the scope of the study.

In Port Harcourt, the closer an area is to oil fields and production sites, the more polluted their soils. Some examples are mechanic village, Eneka, abuluoma etc. Okon and Ogba, (2018) studied two oil spilled affected areas in Ogali and Agbonchia, and observed there was a significant decrease in the soil nutrients, as well as a significant increase in the sand fraction and Na content of the oil spilled affected soils when compared with control sites. Similarly, Iheriohanma, (2016), observed increase in toxins in soil of Port Harcourt. From these listed researches, farmlands in the NDR have been made infertile and unproductive due to frequent oil spills that are never cleaned up properly. Prior to the establishment of Port Harcourt Refinery and Petrochemical Company (PRPC) and Pipelines and Products Marketing Company (PPMC), the adjoining soils of Port Harcourt that was formally green and forested are near bare due to oil poisoning (Aroh, 2021). This environmental destruction has increased poverty level of locals (Elum et al., 2016; Dick, 2017). Although, physical clean-up is usually carried out by some companies, yet the lands are left bare, without adequate replanting to restore the environment to its natural or near-natural state. This study is initiated to evaluate the current state of crude oil pollution in Port Harcourt, with the thrust of determining the soil fertility potentials of the affected soils.

Materials and methods

Study area

Port Harcourt is found within the Niger Delta region of Nigeria and bounded to the North by Ikwere LGA, at the South section by Degema & Bonny, at the eastern section Tai/Ogo-Brila and to the West by Abua/odua cum Akuku-Toru LGAs. Port Harcourt metropolis is about 60km from the open sea and situates on longitude 6°56E & 7°03'E & latitude $4^{\circ}43'$ N & 4°54N of the equator.

Port Harcourt metropolis has expanded up to over 360km^2 in the past decades with elevations that range between 2m at the lowest points and to 18m above sea level at the highest (Warmate et al., 2011). This spontaneous growth results to an unplanned environment, thus affecting contingency planning at the local area level making it difficult for both planners and responders, identify protection strategies and response options to oil spilled sensitive environments (Afa, 2010).

The study is an experimental research involving the collection and analysis of soil samples of both oil impacted and non-oil impacted soils in Port Harcourt. The research design for this study follows that of Nwaichi et al., (2016). The type of data used for this study include soil data that were derived from primary sources. Primary data was used since the researchers wanted to determine the physical, chemical and fertility properties of soils using Doran and Parkin (1994) and Larson and Pierce (1994) assumptions. For the primary data, soil samples (5 samples for each location) from surface (depths=0-15cm) and sub-surface soil (depth=15-30cm) were collected from both oil impacted and non-oil impacted soils.

Systematic sampling technique was adopted for the study and five (5) oil impacted and one (1) non-oil impacted sites (detailed as control site) were selected for the experiment. The sites were picked, using the researchers' reconnaissance survey experience. Viz:

Site A: Tank Farm at Indorama Petrochemicals Company (a major tank farm).

Site B: Ikoku/Olu-Obasanjo road junction (a major centre for auto mechanics).

Site C: Mechanic Village, Diobu (a major centre for auto-mechanics).

Site D: Industrial Area (Tank Farm) around Eleme.

Site E: PPMC (Oil Company where products are loaded via tankers daily)

Site F: Rumuodata Forest (Control Site)

The area was divided into 15 grid plots, each measuring 4m by 4m, and about 25% of these plots (exactly 5) selected diagonally across the epicentre. From the epicentre grid plots (quadrat) three replicate soil samples were taken from two depths: top surface (0-15cm) and sub-surface (15-30cm). This was done by removing litter from the predetermined area inside each quadrat, using soil core samplers. The soil samples were taken from six replicate quadrats of the oil-impacted and control plots. Fifteen (15) soil samples were analysed from both oil-impacted and non-oil impacted sites. The samples from each sample site were collected and labelled (A1-A5, B1-B5, C1-C5, D1-D5, E1-E5 & F1-F5) using sterile polythene bags as in Kannahi and Sudha, (2013). The collected soil samples were used to investigate the soil pH, salinity, level of dissolved oxygen, hydrocarbon concentration levels, organic matter contents and Fertility Capabilities Classification (FCC) of the soils. The soils from the surface and 15cm depths were mixed together and used to study the physical and chemical properties of the soils. The soil FCC was based on the classification defined by Amare (2022).

Total organic carbon (TOC), total nitrogen, pH, available phosphorus, exchangeable cations and total organic matter which is determined by multiplying the total organic carbon by 1.724. Thus, in determining the physicochemical properties of the soils, soil pH, Nitrate, Potassium, and Phosphate parameters were tested (See Devatha et al., (2019). The chosen metals result from their susceptibility to oil spill impacts (Doris et al., 2016).

The soil samples were oven dried at $105^{o}C$, and passed through a 2mm sieve and were analysed for; particle size composition using hydrometric technique (Callesen et al., 2018); organic carbon by chromic acid digestion method of Schulte and Hoskins, (1995); total nitrogen by regular micro-kjedhl digestion method (Atuma & Ojeh, 2013); available phosphorus by Brays PI solution and determined in accordance with procedure; soil pH determined potentiometrically in distilled water using soil to water ratio of 1:1; cation exchange capacity value was determined by using ammonium acetate (NH_4OAC) leachate method; and consecration of metals – lead, cadmium, nickel and chromium in the soil were determined by Atomic Absorption (AAS).

Tables and statistical diagrams were deployed to present data. Analyses of data was achieved using multiple regression statistics. The data on physicochemical properties (Soil pH, Nitrate, Potassium, Phosphorus, and Cation Exchange Capacity) were analysed using the multiple regression analysis. Therefore, the hypothesis 'there is no significant relationships between crude oil pollution and physicochemical characteristics of the soils in Port Harcourt' was tested. On the other hand, the variation in the physicochemical properties were analysed using Analysis of Variance (ANOVA). ANOVA thus, tested the hypothesis 'there is no significant spatial variation in the physicochemical properties of soils in Port Harcourt metropolis'. All analyses were done in the environment of Statistical Package for Social Sciences (SPSS) version 26.

Results

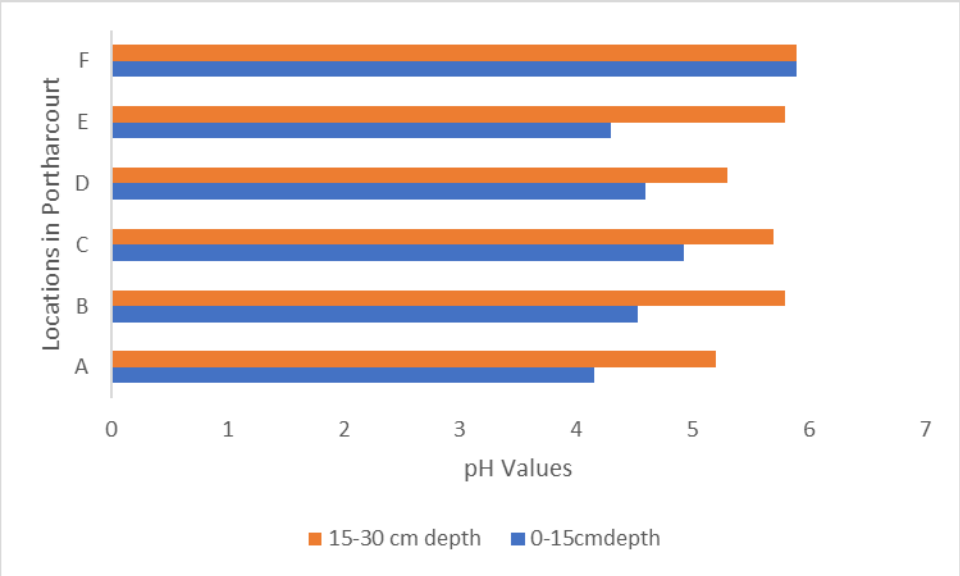
Table 1 shows the particle sizes of the soil samples collected at different depths in the study area. At the Tan farm area, soil samples collected at the 0-15cm depth showed that there was a higher amount of sand (48.9%) then clay (45.5%) and silt is 4.2%. Soil samples collected at the 15-30cm depth showed that there was a higher amount of sand (73.5%) then clay (21.7%) and silt is 4.2%. At Ikoku/Olu area, soil samples collected at the 0-15cm depth showed that there was a higher amount of clay (54.9%) then sand (42.3%) and silt is 1.5%. Soil samples collected at the 15-30cm depth showed that there was a higher amount of clay (51.9%) then (48.4%) and silt is 0.8%. This same kind of soil alteration mechanics is witnessed other locations, whether mechanic village, Eleme industrial area, PPMC (E) or Rumuodara forest. Under normal circumstances, the composition of soil is supposed to be 20% clay, 40% silt and 40% sand. Sadly, what is witnessed in the study area is a clear sign of pollution from oil and interferences with the normal compositions of soil. The composition witnessed herein, cannot sustain soil nutrients due to large pore spaces and peculations rates which is made high (Adeola et al., 2022).

Table 1: Soil Particle Size Composition (%)

Sites	Depth (cm)	**Clay**	**Sand**	**Silt**
	0-15	45.5	48.9	4.2
Tank Farm (A)	15-30	21.7	73.5	2.4
Ikoku/Olu-Obasanjo road junction	0-15	54.9	42.3	1.5
(B)	15-30	51.9	48.4	0.8
	0-15	62.2	37.3	0.6
Mechanic Village, Diobu (C)	15-30	70.2	25.5	4.3
	0-15	23.9	73.5	2.2
Eleme Industrial area (D)	15-30	55.7	35.9	7.4
	0-15	78.6	17.1	3.55
PPMC (E)	15-30	56.6	42.1	0.4
	0-15	67.3	32.3	0.8
Rumuodata Forest (F)	15-30	52.6	49.4	0.4

Source: Field work (2021)

A=Tank Farm at Indorama Petrochemicals Company; B=Ikoku/Olu-Obasanjo road junction; C=Mechanic Village, Diobu; D=Eleme Industrial Area; E=PPMC (Oil Company); F=Rumuodata Forest (Control Site)



Source: Field work (2021)

Figure 1: pH values for soils in the study area

A=Tank Farm at Indorama Petrochemicals Company; B=Ikoku/ Olu-Obasanjo road junction; C= Mechanic Village, Diobu; D=Eleme Industrial Area; E=PPMC (Oil Company); F=Rumuodata Forest (Control Site).

Figure 1 shows the acidity level of the soil in both the oil impacted soils at the different depths in the study area site. The soil pH determines rates of soil acidity or alkalinity in a solution. It also determines to what extent the health of a soil is and possible sources of pollutions. An acidic soil is most likely to have been polluted by petroleum. Thus, the soils at depth of 0-15cm are slightly acidic as compared with that of 15-30cm depth. There was a slight variation in the pH values of the soils, which ranged from 4.1 to 5.6. The observed pH values herein are a clear sign of pollution from oil as suggested by the findings of Osuagwu and Olaifa, (2018).

Table 2 shows the cation exchange capacity (CEC) amounts for soil samples collected in the study area. The values collected are then compared with that of the control sites values. The values ranged between CEC/Meq/100g of 1 to 4. This is far from the expected of within 5-10 Meq/100g. Showing the level of oil impartation on the soils in the study area. This also supports the level of acidity identified in figure 1. Thereby, this finding justifies that the soil in the area is highly oil polluted.

Table 2: Soil cation exchange capacity (CEC) in Port Harcourt metropolis

		Meq/100g	
Locations	**Depths**	**Impacted soil**	**Control**
	0-15	1	5-10 (fine sandy-Loam)
A	15-30	3	5-10 (fine sandy-Loam)
	0-15	1	5-10 (fine sandy-Loam)
B	15-30	4	5-10 (fine sandy-Loam)
	0-15	2	5-10 (fine sandy-Loam)
C	15-30	2.5	5-10 (fine sandy-Loam)
	0-15	1	5-10 (fine sandy-Loam)
D	15-30	3.6	5-10 (fine sandy-Loam)
	0-15	1	5-10 (fine sandy-Loam)
E	15-30	3.3	5-10 (fine sandy-Loam)
	0-15	1	5-10 (fine sandy-Loam)
F	15-30	1.5	5-10 (fine sandy-Loam)

A=Tank Farm at Indorama Petrochemicals Company; B=Ikoku/Olu-Obasanjo road junction; C=Mechanic Village, Diobu; D=Eleme Industrial Area; E=PPMC (Oil Company); F=Rumuodata Forest (Control Site).

Table 3 reveals potassium contents in soil samples in both oil impacted and control soils. The values of potassium ranged between 0.03 - 0.23 mg/kg in oil impacted soils and control soils, potassium in soils is 80 mg/kg. In all the sites it is clear that the extent of potassium present cannot support crop yield nor meaningful agriculture, as corroborated by Okon and Ekpo, (2022)

Table 3: Soil Potassium in the soils of the study area

		Mg/kg	
Locations	**Depths**	**Impacted soil**	**Control**
	0-15	0.03	80 fine sandy-Loam
A	15-30	0.14	80 fine sandy-Loam
	0-15	0.05	80 fine sandy-Loam
B	15-30	0.03	80 fine sandy-Loam
	0-15	0.09	80 fine sandy-Loam
C	15-30	0.04	80 fine sandy-Loam
	0-15	0.23	80 fine sandy-Loam
D	15-30	0.08	80 fine sandy-Loam
	0-15	0.15	80 fine sandy-Loam
E	15-30	0.08	80 fine sandy-Loam
	0-15	0.16	80 fine sandy-Loam
F	15-30	0.14	80 fine sandy-Loam

Source: Field work (2021)

A=Tank Farm at Indorama Petrochemicals Company; B=Ikoku/Olu-Obasanjo road junction; C=Mechanic Village, Diobu; D=Eleme Industrial Area; E=PPMC (Oil Company); F=Rumuodata Forest (Control Site).

In Table 4, the values of magnesium ranged from 0.02-0.34 for oil impacted soils and 0.05-0.5 in control soils. This is strange, nevertheless, plants don't need much of it to do well. The only danger associated with magnesium for plants is that when very high in content, it can affect the up-take of potassium by plants (Chijioke et al., 2018).

Table 4: Soil Magnesium content in sampled soil and control

Locations	Depths	% Impacted soils	Control
	0-15	0.23	0.05-0.5
A	15-30	0.22	0.05-0.5
	0-15	0.14	0.05-0.5
B	15-30	0.22	0.05-0.5
	0-15	0.35	0.05-0.5
C	15-30	0.26	0.05-0.5
	0-15	0.27	0.05-0.5
D	15-30	0.34	0.05-0.5
	0-15	0.14	0.05-0.5
E	15-30	0.06	0.05-0.5
	0-15	0.10	0.05-0.5
F	15-30	0.09	0.05-0.5

Source: Field work (2021)

A=Tank Farm at Indorama Petrochemicals Company; B=Ikoku/Olu-Obasanjo road junction; C=Mechanic Village, Diobu; D=Eleme Industrial Area; E=PPMC (Oil Company); F=Rumuodata Forest (Control Site).

In Table 5, are the values of nitrogen which ranged from 0.01 to 0.37% in oil affected soils and for control soils 1-5% soil? This shows that the soil falls short of nitrogen required for agriculture and hence the yields. This is attributable to changes in the microbial characteristics of soil. This finding is in tandem with that of Ejiba et al, (2016)

Table 5: Soil Nitrogen in soil in the study area

Locations	Depths	% Impacted	Control
	0-15	0.29	1-5
A	15-30	0.31	1-5
	0-15	0.2	1-5
B	15-30	0.13	1-5
	0-15	0.31	1-5
C	15-30	0.22	1-5
	0-15	0.31	1-5
D	15-30	0.01	1-5
	0-15	0.24	1-5
E	15-30	0.37	1-5
	0-15	0.32	1-5
F	15-30	0.34	1-5

Source: Field work (2021)

A=Tank Farm at Indorama Petrochemicals Company; B=Ikoku/Olu-Obasanjo road junction; C=Mechanic Village, Diobu; D=Eleme Industrial Area; E=PPMC (Oil Company); F=Rumuodata Forest (Control Site).

Table 6 shows the soil calcium content of both oil and non-oil impacted soil, the values of calcium ranged from 11 – 47% in oil impacted soils and for control soils ranges between 70-80%. The values were lower in oil affected soils than the control soils. This shows that oil spillage decreased the calcium content of the soils in the study area and thus needs to be looked into. The finding has been corroborated by Dimkpa et al., (2020).

Table 6: Soil Calcium in soils in the study area

Locations	Depths	% Impacted	Control
	0-15	11	70-80%
A	15-30	16	70-80%
	0-15	23	70-80%
B	15-30	27	70-80%
	0-15	21	70-80%
C	15-30	29	70-80%
	0-15	22	70-80%
D	15-30	44	70-80%
	0-15	21	70-80%
E	15-30	33	70-80%
	0-15	41	70-80%
F	15-30	47	70-80%

Source: Field work (2021)

A=Tank Farm at Indorama Petrochemicals Company; B=Ikoku/Olu-Obasanjo road junction; C=Mechanic Village, Diobu; D=Eleme Industrial Area; E=PPMC (Oil Company); F=Rumuodata Forest (Control Site).

Table 7 shows the soil available phosphorus, the values ranged from 0.01-0.1 Meq/100g in oil impacted soils, while the control soil is 0.25 Meq/100g. The values were lower in oil affected soils and near non-available, thus making the soils not fit for agricultural purposes.

Table 7: Soil available Phosphorus in the study area

Locations	Depths	Meq/100g Impacted	Control
	0-15	0.01	0.25
A	15-30	0.04	0.25
	0-15	0.01	0.25
B	15-30	0.05	0.25
	0-15	0.06	0.25
C	15-30	0.10	0.25
	0-15	0.04	0.25
D	15-30	0.1	0.25
	0-15	0.13	0.25
E	15-30	0.01	0.25
	0-15	0.03	0.25
F	15-30	0.07	0.25

Source: Field work (2021)

A=Tank Farm at Indorama Petrochemicals Company; B=Ikoku/Olu-Obasanjo road junction; C=Mechanic Village, Diobu; D=Eleme Industrial Area; E=PPMC (Oil Company); F=Rumuodata Forest (Control Site).

Table 8 shows the organic carbon content of soil in both the oil impacted and control soils. The normal organic carbon in soils had a range of 0.5-3%. However, the impacted soils posted values that ranged between 29 and 18% respectively. These values indicate that there are more organic carbon contents are high in the soils of the study area. Albeit, these concentrations of carbon may not have come from healthy sources and as such cannot guarantee plant growth.

Table 8: Soil Organic Carbon in the study area

Locations	**Depths**	**% Impacted**	**Control**
	0-15	25	0.5-3.0
A	15-30	21	0.5-3.0
	0-15	23	0.5-3.0
B	15-30	18	0.5-3.0
	0-15	24	0.5-3.0
C	15-30	17	0.5-3.0
	0-15	24	0.5-3.0
D	15-30	19	0.5-3.0
	0-15	22	0.5-3.0
E	15-30	19	0.5-3.0
	0-15	29	0.5-3.0
F	15-30	18	0.5-3.0

Source: Field work (2021)

A=Tank Farm at Indorama Petrochemicals Company; B=Ikoku/Olu-Obasanjo road junction; C=Mechanic Village, Diobu; D=Eleme Industrial Area; E=PPMC (Oil Company); F=Rumuodata Forest (Control Site).

Table 9 shows the model summary result of the regression checking the relationships between oil pollution and physicochemical characteristics of the soils in Port Harcourt. Result indicate that there is a strong positive correlation between oil spillage and physicochemical properties of soils in Port Harcourt metropolis (R;0.870) and the model could explain 75.7% of the characteristics of soil physicochemical properties in Port Harcourt metropolis. Also, the model is significant at $P<0.05$, thus, the physicochemical characteristics of the soils in Port Harcourt are significantly affected by the oil spill.

Table 9 Regression summary of the relationships between oil spills and soil physicochemical properties in the study area

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change
1	.870[a]	.757	.729	1.2134	.757	10.234	3	32	.001

a. Predictors: (Constant), Potassuim, pH, CEC, Nitrogen, Magnessuim, Calcuim
b. Predictand Crude pollution (as an index)

Table 10 shows calculated ANOVA statistics (F) for the soil physicochemical characteristics in the study area. To obtain data for the model computation data collected from the top and sub-soil were averaged and the averages were compared across the region. In all there were 6 areas from which soil samples were collected and in each place 5 quadrat making total sample 30. Albeit, the model showed significant difference in physicochemical properties of the soil measured. The ones not captured had no significant difference in the means for all areas. The F calculated for the properties are: calcium F=2.980; $p<0.05$; soil pH F=1.789; $p<0.05$; Cation Exchange Capacity (CEC) F=4.465; $p<0.05$; Soil Potassium F=3; $P<0.05$; Soil Magnesium content F=2.336; $P<0.05$; Soil Nitrogen F=8.986; $P<0.05$. This is a clear indication that there is a significant spatial variation on the soil oil pollution across the study area.

Table 10: ANOVA on the Spatial Variation of Soil Physicochemical characteristics

Physicochemical	Groupings	SS	Df	MS	F	Sig.
CA	Between Groups	27.644	5	6.529	2.980	.000
	Within Groups	2.729	24	2.191		
pH	Between Groups	4.187	5	3.837	7.767	.002
	Within Groups	14.833	24	0.494		
CEC	Between Groups	163.289	5	32.658	4.465	.004
	Within Groups	219.418	24	7.314		
K	Between Groups	.020	5	12.004	3.000	.005
	Within Groups	.050	24	4.002		
Mg	Between Groups	.536	5	14.117	2.336	.051
	Within Groups	1.320	24	6.044		
N	Between Groups	.220	5	18.044	8.986	.001
	Within Groups	.233	24	2.008		
P	Between Groups	621.806	5	124.361	12.843	.000
	Within Groups	290.500	24	9.683		
pH	Between Groups	1.440	5	14.321	1.789	0.041
	Within Groups	.230	24	8.004		

Discussion

Generally, the particle sizes of the soil samples collected at different depths (0-15cm and 15-30cm) in the study area revealed different percentages in clay, silt and sand. Within the Tank farm area, soil samples collected at the 0-15cm depth showed that there was a higher amount of sand (48.9%) clay (45.5%) and then silt (4.2%). At the 15-30cm there was a higher amount of sand (73.5%) then clay (21.7%) and silt is 4.2%. At Ikoku/Olu area, soil samples collected at the 0-15cm depth showed that there was a higher amount of clay (54.9%) then sand (42.3%) and silt is 1.5%. Soil samples collected at the 15-30cm depth showed that there was a higher amount of clay (51.9%) then (48.4%) and silt was 0.8%. This same kind of soil alteration mechanics is witnessed in the other locations, whether mechanic village, Eleme industrial area, PPMC (E) or Rumuodara forest. Under normal circumstances, the composition of soil is supposed to be 20%clay, 40% silt and 40% sand. Sadly, what is witnessed in the study area is a clear sign of pollution from oil and interferences with the normal compositions of soil. The composition witnessed herein, cannot sustain soil nutrients due to large pore spaces and peculations rates which is made high (Ahmed & Fakhruddin, 2018; Kuch & Bavumiragira, 2019). Also, the presence of the crude pollutants affects the normal recycling of materials and so the development of materials that binds the soils is limited. Also, organic materials are limited to create organic manure for the soils. The poisoning of the soils therefore continues unabated and hence the creation of imbalances in the soil properties (Okon & Ogba, 2018; Aroh, 2021).

A quick look at the physicochemical properties of the soil showed that there was serious alteration on the physicochemical properties resulting from the crude oil impartation. The soil pH determines rates of soil acidity or alkalinity in a solution. It also determines to what extent the health of a soil is and possible sources of pollutions. An acidic soil is most likely to have been polluted by petroleum. Thus, the soils pH observed as compared with that of control was seriously acidic. There was a slight variation in the pH values of the soils, which ranged from 4.1 to 5.6. The observed pH values observed were a clear sign of pollution from oil as suggested by the findings of Okon and Ogba, (2018); Aroh, (2021). Normal soil pH ought to be range from 6.5-7.5 considering the amount of rainfall in the study area the amount of foliage which ought to be available to the soil (Aroh, 2021).

The cation exchange capacity (CEC) amounts for soil samples collected in the study area compared with that of the control sites ranged between CEC/Meq/100g of 1 to 4. This is far cry from what ought to be ie 5-10 Meq/100g. This implicates the level of oil impartation on the soils in the study area. This finding corroborates the finding of Elum et al., (2016) Potassium contents in soil samples showed a difference compared to control soil. The values of potassium ranged between 0.03 - 0.23 mg/kg in oil impacted soils and control soil potassium was 80 mg/kg. In all the sites it is was clear that the extent of potassium present cannot support crop yield nor meaningful agriculture. As corroborated by Osuagwu and Olaifa, (2018) that the absence of potassium in soil means that plants will not do well. Same could be said of magnesium (0.02-0.34 compared to control soils of 0.05-0.5) which was strange, nevertheless, plants do not need much of it to do well. The only danger associated with magnesium for plants is that when very high in content, it can affect the up-take of potassium by plants (Ejiba et al., 2016). The values of nitrogen which ranged from 0.01 to 0.37% in oil affected soils and for control soils 1-5% soil. This shows that the soil falls short of nitrogen required for agriculture and hence the yields. This is attributable to changes in the microbial characteristics of soil. This finding is in tandem with that of Adonteng-Kissi et al., (2021). Calcium content of both oil and non-oil impacted soil values ranged from 11 – 47% in oil impacted soils and for control soils ranges between 70-80%. The values were lower in oil affected soils than the control soils. This shows that oil spillage decreased the calcium content of the soils in the study area and thus needs to be looked into. The finding has been corroborated by Suthersan et al., (2016). Available phosphorus values ranged from 0.01- 0.1 Meq/100g in oil impacted soils, while the control soil is 0.25 Meq/100g. The values were lower in oil affected soils and near non-available, thus making the soils not fit for agricultural purposes. Similarly, the organic carbon content of soil in both the oil impacted and control soils showed a deviation from the normal. Normal organic carbon in soils had a range of 0.5-3%. However, the impacted soils posted values that ranged between 29 and 18% respectively. These values indicate that there are more organic carbon contents are high in the soils of the study area. Albeit, these concentrations of carbon may not have come from healthy sources and as such cannot guarantee plant growth.

Result of the regression checking the relationships between oil pollution and physicochemical characteristics of the soils in Port Harcourt indicated that there is a strong positive correlation between oil spillage and physicochemical properties of soils in Port Harcourt metropolis (R;0.870) and the model could explain 75.7% of the characteristics of soil physicochemical properties in Port Harcourt metropolis. Also, the model is significant at $P<0.05$, thus, the physicochemical characteristics of the soils in Port Harcourt are significantly affected by the oil spill.

Furthermore, calculated ANOVA statistics (F) for the soil physicochemical characteristics in the study area showed significant difference in physicochemical properties of the soil measured. The F calculated for the properties are: calcium F=2.980; $p<0.05$; soil pH F=1.789; $p<0.05$; Cation Exchange Capacity (CEC) F=4.465; $p<0.05$; Soil Potassium F=3; $P<0.05$; Soil Magnesium content F=2.336; $P<0.05$; Soil Nitrogen F=8.986; $P<0.05$; and available Phosphorus F=12.843; $P<0.05$. This is a clear indication that there is a significant spatial variation on the soil oil pollution across the study area.

Implication of soil-oil pollution for agricultural practices in Port Harcourt

Evidently, agriculture is not only important as a source of labour creation, it is also a serious source of food creation for the populace to feed from. What have been found from data shows that the soil of the study area is seriously impacted with crude oil. The properties of the soil have also been altered thus making the soil not useful for agriculture. This is because, such soil cannot guarantee proportionate yields for farmers (if investment is to be put into account). This means there is urgent need for action that will not only remediate the environment but guarantee food security for locals in Port Harcourt. Sadly, the government as of now is not doing anything about agricultural planning. It is greatly baffling that such a critical industry would be disregarded in the state. Albeit, the following are advanced as a plan to ameliorate the current situation and guarantee some improvement in the agro status quo in the area:

There is great need to designate the land-uses meant for agriculture. This should be followed by remediation. Biological or phytoremediation is greatly recommended at this point following the already polluted environment from crude oil (Okoro, 2021). It therefore implies that there shall be no agricultural practices carried out at the period of remediation as recommended by post impact assessment which must be carried out as a follow-up to this study. After remediation, rotational agriculture should be the practice since the available lands are few and scarce (following the spate of urbanization). Future oil pollution must be discouraged and hence there will be no more new sources of pollution (Okon & Ogba, 2018). Thankfully, the government of the state already lunched a state-wide clamp down of crude oil bunkering and theft this year (2022). We hope that these planning techniques advanced will help improve soils and by extension the agriculture.

Conclusion

This study examined the effects of oil spills on soil physicochemical properties in Port Harcourt. The study revealed that soils of Port Harcourt metropolis are fine sandy-Loam and acidic in content. Albeit, oil imparted soils had more acid while, CEC, magnesium, potassium, nitrogen, calcium, and organic carbon content were low compared with the control soil. Similarly, the pollution rates were found to be spatially varied, while a strong relationship existed between crude oil pollution and the physicochemical properties of soil. This by extension implicates the fact that the soil ought to be better in form and properties than it was at the time of examination. A conclusion of this study is that a holistic post impact assessment should be carried out to determine the extent of impact of pollution. While planning to remediate the area should follow.

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