PHYSICO-CHEMICAL PROPERTIES OF WETLAND SOILS AFFECTED BY CRUDE OIL SPILLAGE IN NIGER DELTA AREA, NIGERIA

Abstract:

Loss of soil fertility through loss of soil organic matter, leaching of nutrients, loss of the nutrient-laden topsoil, changes in soil-pH, reduction in cation exchange capacity, salinization, water logging and other forms of soil degradation are major problems associated with agricultural productivity in the oil producing areas of Nigeria. This analysis investigated some selected physico-chemical properties of wetland soils affected by crude oil spillage in Bodo city in the Niger Delta region of Nigeria. Field reconnaissance survey using a handheld Geographic Positioning system (GPS) and survey technique involving random sampling, was used in siting soil profile pits. The unpolluted samples were collected 50 meters away from the polluted site but in the same geographic region and was used as control site. Soil samples were collected based on degree of horizon differentiation and analyzed using routine and special analytical techniques. Soil data were subjected to analysis of variance using Genstat program. Result shows that soil physical properties of the polluted site: moisture content, soil bulk density, and soil texture were highly significant (p=0.01 and 0.05) when compared to the unpolluted site while some chemical soil properties analysed especially soil pH, organic matter, carbon-nitrogen ratio, available phosphorus were affected by crude oil spillage. Results from this study affirm that crude oil can have detrimental effect on soil physico-chemical properties, which implies low soil fertility and thereby affect crop production and increase food insecurity within the study site. Further studies involving more edaphic properties, biotoxic metals and their bioaccessibility in crops growing on waterside affected by crude oil spill will surely enhance knowledge and management of the these highly industrially influenced soils. Also, international and national oil and gas companies should carry out their activities with international best practice.

Keywords: Physico-chemical properties; wetland soils; crude oil spillage; Bodo City southern Nigeria

1.0 **Introduction**

Wetland soils are soils saturated with water sometimes in the year and in some cases throughout the year. (Udo *et al.*, 2009) The wetland soils are poorly drained in most part of the year and this is a key feature that tends to limit or hinder all year-round utilization of wetland soils for agricultural production. Wetlands are important aspects of the physical environment in Nigerian agriculture. Loss of soil fertility through loss of soil organic matter, leaching of nutrients, loss of the nutrient-laden topsoil, changes in soil-pH, reduction in cation exchange capacity, salinization, water logging and other forms of soil degradation are major problems associated with agricultural productivity in the oil producing areas of Nigeria. (Sanchez *et al.*, 1982) reported that "water logging has a positive attribute for growing of swamp rice, this is an indication that if the soils are well managed, characterized and classified they could also be used to produce paddy rice and other crops". Guthrie (1985) sees "wetland soils as having great potential for sustainable increase in food production because of their inherent high fertility status and their occurrence in the flat landscapes where soil erosion is not a major constraint to crop production". (Udo *et al.*, 2001) reported that the major constraints in wetland soils are low CEC, organic carbon, exchangeable cations, and available P which were observed to vary with the agro-ecological zone.

"The declining productivity from upland agriculture therefore poses a compelling need to expand arable cropping into the country's vast and hitherto little exploited wetland soil resources which can provide the much-needed sustainable production on account of their inherent soil fertility. However, the characteristics of wetlands soils vary widely in accordance with the multiplicity and diversity of ecologies with which the wetlands are associated. Wetland soils show high complexity in their chemical properties which are major determinants of nutrient status of soils" (Udo *et al.*, 2006). "In soils with low pH, many elements such as zinc, aluminium and manganese may be present in toxic levels while basic cations such as calcium and potassium are fixed in such conditions. Traction problem on wetland soil have been a major limitation to the adaptation of mechanization practice for cultivating the land" (Nwilo, 1998).

"Significant among the damages done to the environment by crude oil spills is pollution of soil which renders it less useful for agricultural activities and affects soil dependent organisms adversely" (Lundstedt, 2003). Pollution of agricultural soil has in turn significantly affected the growth performance of plants. Agbogidi (2011) reported that "contamination of soil with crude oil significantly reduced biomass accumulation in Jatropha curcas when compared to seedlings grown in uncontaminated subplots. He also observed a negative interaction between soil crude oil level and weight gain in the plants". "These petroleum hydrocarbons adversely affect the germination and growth of plants in soils" (Samina *et al.,* 2002).

"Oil spills affect plants by creating conditions which make essential nutrients like nitrogen and oxygen needed for plant growth unavailable to them" (Adam and others, 2002). "Oil spills have degraded most agricultural lands in the State and have turned hitherto productive areas into wastelands. With increasing soil infertility due to the destruction of soil micro-organisms, and dwindling agricultural productivity, farmers have been forced to abandon their land, to seek non-existent alternative means of livelihood" (Oyem and Oyem, 2013). Adam *et al. (*2002) reported that Aquatic lives have also been destroyed with the pollution of traditional fishing grounds, exacerbating hunger and poverty in fishing communities. The objective of this study was to delineate and evaluate the effects of crude oil spillage on some physico-chemical properties of the wetland soils of southern Nigeria. The results would serve as a management tool for sustainable wetland development and management of soils affected by crude oil spillage.

2.0 **Materials and Method**

2.1 **Description of the Study Area**

The study was conducted on wetland soils in Bodo city Ogoni kingdom, Gokana Local Government Area of Rivers State, Southern Nigeria. The study area is located between latitude $4^{0}36^{'}$ North and longitude $7^{0}15^{'}$ East. A handheld GPS (Global Positioning System) Receiver was used to georeference profile pits (Figure 1). The “Ogoni Sands” stretch over some 932.6 km^2 are in the central plain forming the north-eastern part of Rivers State in the Niger Delta in Nigeria Aroh (2003). They belong to the group of soils termed the “Acid Sands” in Southern Nigeria and belong to the Benin sands formation (Anderson, 1966) or “Coastal Plain Sands” Reyment (1965).

The geology of the area lies between 50-100 meters above sea level (Ofomata, 1975). The dominant vegetal type is the tropical rainforest, whose original biodiversity density of the area has been highly altered by anthropogenic activities. The socio-economic activities of the people in the area include arable farming, fishing, hunting, sand mining and crude oil prospecting at the mangrove and waterside and agriculture is practices at a subsistence level while the secondary plant cover characterized by variety of vegetation dominated by oil palm trees, coconut trees, banana and plantain trees, shrubs and crops such as cassava, cocoa yam, yam, maize and vegetables are produced in the area. The mean annual rainfall is about 3000 mm. The rainfall distribution is bimodal with the wet season beginning in March and ends in October while dry season begins in late October and ends in early March the next year. The average annual temperature is 29 □ with the highest and lowest is little above 30 □ but not more than 35□ and 24 □ in the month of February and September respectively. The soils are derived from marine deposits sands (Orajaka, 1975).

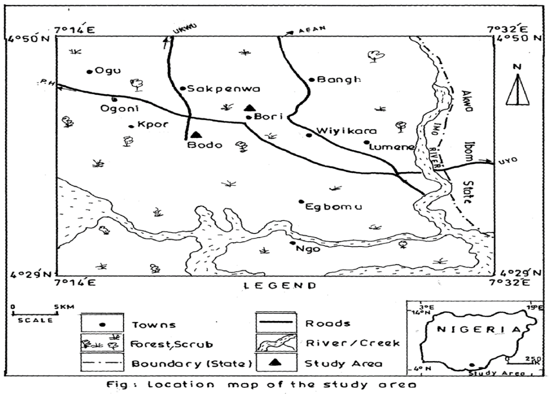

Figure 1: **Location map of the study area.**

2.2 **Field Studies**

A reconnaissance survey was conducted on the study site during which a base map was prepared using existing geologic, hydrologic, topographic and other relevant maps to facilitate field studies. The base map was used to locate the geomorphic sampling points in the study site. A handheld Global Positioning System (GPS) Receiver (Garm Ltd, Kansas) was used to georeference profile pits and random sampling technique was used in locating sampling points on identified geomorphic land units in the marine influenced soils. Four profile pits were sited on the selected geomorphic land units and were dug and described in the field using FAO (1990) guidelines. Soil sampling was done based on the degree of horizon differentiation and was labelled with masking tape, bagged with polythene bags and taken to the laboratory for analysis. In preparation for laboratory analysis, soil samples were weighed, air dried and passed through a 2-mm mesh sieve to obtain the fine earth fraction.

2.3 **Laboratory Analysis**

Particle size analysis was determined by hydrometer method as described by (Gee and Or, 2002). Textural classes were obtained using Soil Survey Staff (2003).

Moisture content was determined by gravimetric method (Cater, 1983).

$$Ms = \frac{\text{Wt of wet soil-Wt of dry soil}}{\text{Wt of dry soil}} \times \frac{100}{1}$$

Where ms = gravimetric moisture content (saturated) (%)

Bulk density was determined by core sampling method (Grossman and Reinsch, 2002). Soil pH was measured electrometrically in both distilled water and 0.1 NKCl suspensions using soil-liquid ratio of 1:2.5, that is, 20 g of air dried and sieved soil to 25 ml of the liquid suspension distilled water and 0.1NKCl. Soil organic carbon was analyzed by Walkley and Black wet digestion method (Nelson and Sommers, 1982). Thereafter, organic matter was derived by multiplying the value of organic carbon by a factor of 1.724 (Ven Bermelen's factor). Total Nitrogen was determined by Kjeldehl digestion method (Bremner and Mulvaney, 1982). Exchangeable bases (Ca, Mg, K, and Na) were extracted with neutral ammonium acetate buffered at pH 7.0 (Thomas, 1982). Exchangeable Ca and Mg were determined by EDTA complex metric titration while exchangeable K and Na were determined by flame photometry (Jackson, 1962). Carbon: Nitrogen ratio (C: N) was calculated by dividing percentage organic carbon by percentage total nitrogen. Available phosphorus was determined using Bray II method (Olson and Sommers, 1982). Base saturation was calculated by dividing total exchangeable base (TEB) by corresponding cation exchangeable capacity valve multiplied by 100. Exchangeable sodium to be calculated using.

$$ESP = \frac{\text{Exchangeable Na + (Meq/100g)}}{\text{CEC (Meq/1000g)}} \times 100$$

2.4 **Statistical Analysis**

“Analysis of variance (ANOVA) and mean separation using LSD at 5% probability were conducted on the samples using Genstat statistical package” (Buysse *et al.*, 2004). Also, coefficient of variation to establish the variation among soils.

3.0 **Results and Discussion**

Physical characteristics of soils for polluted and unpolluted sites of the study area are presented in Table 1 and Figure 1.

3.1 **Physical Properties of Soils of the study area**

The results of the physical analysis in Table 1 showed that the textural class for the unpolluted site registered mean values of 86.53, 3.37 and 10.09 % respectively, for sand, silt and clay with sand having the highest value and dominating the profile downward. While the polluted site registered a mean value of 94.61, 1.42 and 4.47 % respectively, for sand, silt and clay and sand dominating the entire profile. However, when comparing the unpolluted and polluted profiles it deferred significantly (0.6) between the unpolluted and polluted sites and interacted significantly (LSD = 0.05), suggesting that crude oil pollution did not alter sand percentage, which is like the findings of Marinescu *et al. (*2011), who reported no significant result in crude oil pollution on granulometric fraction of the soil.

The silt content deferred significantly (0.02) and interacted significantly between the unpolluted and the polluted site (LSD = 0.05). Crude oil in the soil did not affect silt content of the soil when compared with the unpolluted site (Table 1). A similar result was obtained by Marinescu *et al.* (2011) who observed in a crude oil polluted area that granulometric fraction of the soil was not influenced by the presence of crude oil. The percent clay in the unpolluted site varied slightly within the profile with AP horizon recording the highest value of 16.11 % and polluted sites had a consistent trend in distribution within the profile with average of 4.47 %. However, the percent clay deferred significantly (0.02) with the unpolluted and polluted sites and interacted significantly (LSD = 0.05). This shows that crude oil pollution had no significant influence on the clay size particles which agree with the findings of Ewetola (2013), who reported that crude oil pollution did not significantly influence clay size particles.

Table 1: **Selected physical properties of soils affected by crude oil spillage**

Land unit	**Depth**	**Sand** →	**Silt %**	**Clay** ←	**TC**	**MC** →	**SCR %**	**P** ←	**BD g/Cm3**
				Unpolluted	**Site**				
AP	**0-21**	78.35	5.55	16.11	LS	3.06	0.34	30.93	1.88
AB	**21-42**	88.08	2.83	9.08	S	4.3	0.32	30.55	1.92
BG1	**42-63**	84.07	4.83	11.09	LS	2.31	0.44	43.02	1.54
BG2	**63-83**	91.08	1.83	7.08	S	8.16	0.26	33.57	1.93
BC	**83-107**	91.08	1.82	7.08	S	1.34	0.26	30.57	1.85
Mean		**86.53**	**3.37**	**10.09**		**3.83**	**0.32**	**33.37**	**1.82**
				Polluted Site					
AP	**0-16**	93.36	2.54	4.07	S	6.29	0.63	10.94	2.95
AB	**16-38**	91.63	2.27	6.06	S	15.77	0.37	23.76	3.95
BG1	**38-52**	95.04	0.83	4.08	S	78.02	0.22	43.41	1.5
BG2	**52-68**	97.36	1.42	4.07	S	8.66	0.36	2.26	2.29
BC	**68-94**	95.64	0.29	4.08	S	7.83	0.04	20.37	2.12
Mean		**94.61**	**1.47**	**4.47**		**23.31**	**0.32**	**20.15**	**2.49**
LSD: $_{0.05}$	factor A:	0.6	0.02	0.02		0.02	0.01	0.01	0.01
	factor B:	0.67	0.02	0.02		0.02	0.01	0.01	0.01
factor A:	factor B:	1.35	0.04	0.04		0.03	0.03	0.02	0.02
	CV:	0.9	0.8	0.3		0.01	4.4	0.1	0.7

MC= Moisture Content, SCR = Silt Clay ratio, P= Porosity, BD = Bulk Density, TC = Textural class, LS = Loamy sand, S =Sand. CV = Coefficient of Variation, LSD = 5 %.

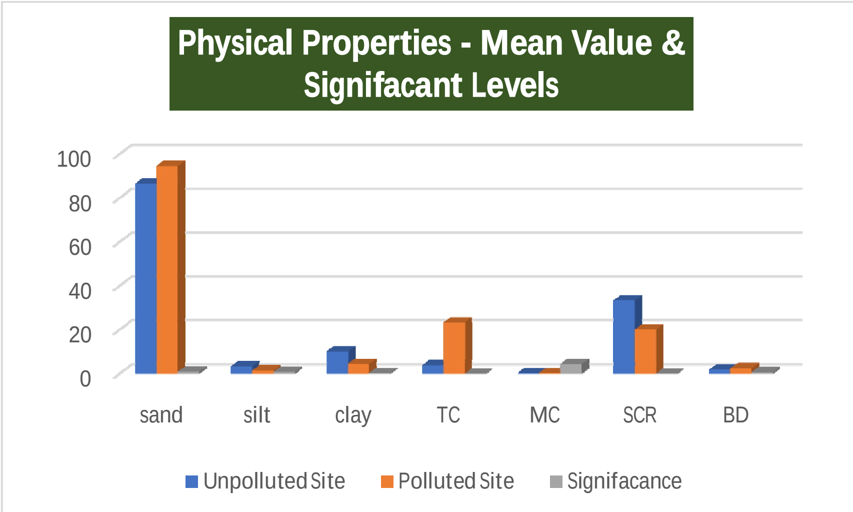

Figure 2: **Comparing some selected physical properties of the polluted and unpolluted site**

The low clay content of the soil maybe also attributed to the coarse texture of the soils. This agrees with the finding of (Ime *et al.*, 2008), who observed low clay content in wetland soils of Eket. The coefficient of variation was 0.3 percent indicating very low variability between the different sites.

The moisture content of the unpolluted site registered a mean value of 3.83 % and polluted site registered a mean value of 23.31 %. However, the moisture content was irregular in their distribution pattern within the profiles. The moisture content deferred significantly (0.02) between the unpolluted and polluted sites and interacted significantly (LSD = 0.05). The low moisture content observed is the unpolluted site agrees with the finding of Hanselman (2003). The low moisture content may be a result of low organic matter content in the wetland soils and low moisture content retards microbial growth and survival. Whereas the high moisture content in the polluted site was a result of the inherent nature of the wetland soils and blockage of the air pores on the surface and subsurface of the soil causing inadequate aeration and reduced evaporation of water which agrees with the finding of Osuji and Nwoye (2007), that higher moisture content in oiled surface and subsurface soils can be attributed to insufficient aeration of the soil that have arisen from the displacement of air in the soils; this probably encouraged water logging and reduced rate of evaporation. Partial coating of soil surfaces by the hydrophobic hydrocarbons might reduce the water holding capacity of the soil due to some significant reduction in the binding property of clay.

The porosity of the unpolluted and polluted sites was generally low and decreased with depth. However, the percent porosity had no significant difference and did not interact significantly within the unpolluted and polluted sites and had a low coefficient of variation of 0.1 percent among the study sites indicating low variability. However, the mean values for the unpolluted and polluted sites were 33.37 % and 20.15 % respectively when compared. The low values show no significance but indicates that crude oil pollution has effect on the polluted site by reducing the macro spaces of the soil there by increasing water holding capacity within the wetland which agrees with the finding of Ewetola (2013), who reported that macro porosity of the soil decreased with the presence of pollutant. This is evidence of clogging of the pore spaces with crude oil. This may serve as impediment for air and water flow within the soil and in similar wetland soils of Zarama (Onweremadu *et al.*, 2007).

The soil bulk density in the unpolluted and polluted sites increased within the geomorphic units with mean values ranges from 1.82 g/cm3 = terrace and 2.49 g/cm3 = marsh land unit, However, the bulk density deferred significantly among the unpolluted and polluted sites and interacted significantly (LSD = 0.05). Also the coefficient of variation was 0.7 percent indicating low variability among the two sites. The high bulk density in the polluted site when compare with unpolluted site may be due to the resultant effects of crude oil spillage which blocked micro spore, increased percolation, reduced aeration increased water table.

Ewetola (2013) reported that "it is worthy of note that crude oil pollution increased bulk density and reduced total porosity. This also may result as blockage of pore spaces with the pollutant". Kayode and Olowoyo (2010) also reported a decrease in bulk density of soil polluted with spent lubricating oil when compared to a control. Oyem and Oyem (2013) reported that "the viscous crude oil settled into the pores to increase both the soils wet weight and the liquid content, this in turn cause increase in bulk density as compared to Arunton soil samples (control)". This is also in line with the finding of (Onweremadu *et al.,* 2007) who reported similar case that poor drainage may have influenced wetland soils of Zarama.

3.2 **Chemical properties of Soils of the study area**

The Chemical characteristic of the unpolluted site and polluted site are shown in Table 2 and Figure 3.

The pH in H_2O shows an average value of 6.52 in the unpolluted site as mean value indicating that the soils are acidic in all the horizon of the profile which may be attributed to high degree of weathering, leaching and rainfall which is in agreement with the finding of (Amiefionkmkpong *et al.,*2003) who reported that wetland soils are acidic with low pH a value which can be as a result of the salty nature of the rivers around the wetland soils. (Chukwu *et al.,* 2009) observed that wetland soils of southern Nigeria are acidic with pH values less than 5, also low pH value (<5) may be due to Al saturation in the soil's solution. However, the polluted site recorded acidic soils as well within the horizon with a mean value of 6.43 indicating that crude oil spillage has great effect on soil pH due to the heavy metal content in crude oil which was observed by Adams & Ellis (1961), that high concentration of heavy metals in polluted soils could be attributed to the presence of metallic ions and trace elements in the crude oil. Ekundayo *et al.* (2000), reported that the contamination of soil with crude oil resulted in an increase in pH which affects plant growth primarily through its effects on nutrient availability. High or low pH cause deficiencies in essential nutrients that plants need to grow.

According to the Marjar and Bob (2012), acidic soils frequently experience deficiencies in calcium, phosphorus and magnesium. Alkaline soils demonstrate deficiencies in phosphorus and many micronutrients Oyem and Oyem (2013). However, the pH in H_2O deferred significantly (0.03 and 0.04) between the unpolluted and polluted site respectively (LSD = 0.05), while the coefficient of variation is 0.8 indicating low variability among the sites.

The organic carbon increased down the horizon with a mean value of 0.93 % on the unpolluted site (Fig.3) may be attributed to continuous farming, cultivation and plant uptake of area.

Table 2: **Selected chemical properties affected by crude oil spillage**

Land units	Depth	pH H_2O	OC %	TN %	C:N Ratio	P Ppm	K Cmol/Kg	EC	Salinity %
Unpolluted Site									
AP	0-18	6.05	0.7	0.02	39.33	14.55	0.01	0.17	6.35
AB	18-35	6.21	0.49	0.02	33.29	15.04	0.02	0.53	6.4
Bg1	35-70	6.16	1.3	0.02	51.87	16.1	0.01	0.39	6.81
Bg2	70-98	7.63	1.55	0.03	44.46	17.51	0	0.55	6.91
BC	98-136	6.55	0.63	0.02	47.5	14.01	0.01	0.45	6.91
Mean		6.52	0.93	0.02	43.29	15.44	0.01	0.42	6.68
Polluted Site									
AP	0-15	5.66	0.6	0.02	7.5	17.62	0.02	5.22	5.59
AB	15-30	6.39	0.16	0.02	14.53	18.2	0.03	5.05	5.39
Bg1	30-55	7.13	0.86	0.02	42.9	14.01	0.01	1.78	5.3
Bg2	55-65	6.37	0.53	0.02	18	0	0.02	0.01	5.21
BC	65-73	6.6	0.09	0.03	3.5	0	0.02	0	4.86
Mean		6.43	0.45	0.02	17.28	9.97	0.02	2.41	4.23

LSD: $_{0.05}$	Factor A	0.03	0.01	0.06NS	0.02	0.01	0.01 NS	0.01	0.1
	Factor B	0.04	0.01	0.0NS	0.02	0.01	0.01 NS	0.01	0.1
	Factor A.B	0.07	0.03	0.0 NS	0.03	0.02	0.01NS	0.02	0.2
	CV	0.8	0.02	36	0.1	0.1	49	0.6	0.5

OC = Organic Carbon, C/N = Carbon Nitrogen Ratio, P = Phosphorus, EC = Electrical Conductivity, S = Sulphur Content, K = Potassium, Total Nitrogen = N, CV = Coefficient of variation, NS = Not Significant

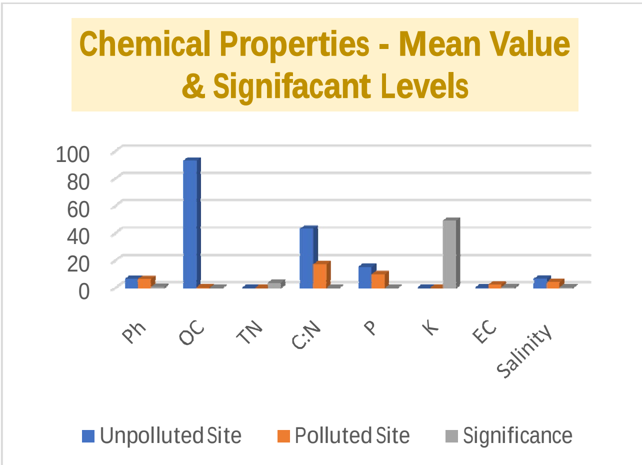

Figure 3: **Comparing some chemical properties of the polluted and unpolluted sites of the study area**

While the polluted site showed a mean value of 0.45 % which indicates crude oil spillage affects the soil organic materials from decomposing and inhibits exchangeable cations from mobile nature which is in line with the findings of Marinescu *et al*. (2011), that crude oil has a significant influence on this parameter of organic carbon. However, the percent organic carbon content in the unpolluted and polluted sites deferred significantly (0.01) and interacted (0.03) significantly (LSD = 0.05).

The total nitrogen shows consistent values on the horizon with a mean value of 0.02 % in the unpolluted site. The low values observed in the unpolluted site may be attributed to continuous land cultivation and bush burning in preparation of the next farming season due to limited farmland for proper farm rotation a result of crude oil spillage within the farmland area. This is in line with the report of Lal (1979), that low total nitrogen is attributed to continues cultivation of the farmland and harvesting of crops as well as land preparation through bush/residue burning as well as forest fires by hunters during the dry season this hasten volatilization of available nitrogen. The polluted site also showed consistent value within the profile and recorded a mean value of 0.2 % indicating low nitrogen in the polluted site which may be attributed to the bare nature of the site and the presence of crude oil spill which has displaced the nitrogen within the soil. Asuquo *et al*. (2001) observed increases in organic carbon in crude oil contaminated soil following an initial scarcity. This causes nitrogen deficiency in an oil-soaked soil, which retards the growth of bacteria and the utilization of carbon source(s), as well as deficiency in certain nutrients like phosphorus which may be growth-rate limiting (Atlas and Bartha, 2005). However, the percent total nitrogen showed a non-significant difference (0.06) between the unpolluted and the polluted sites and the interaction not significant (0.0).

The carbon/nitrogen ration showed an increasing trend down the horizon of the unpolluted site with a mean value of 43.29 indicating a good soil fertility status which could be related to the amount of organic matter content within the soil. On the other hand, the polluted site showed a decreasing trend down the horizon with a mean value of 17.28 indicating that the pollutant settled at the top of the horizon due to its sticky nature inhibiting the availability of the carbon/nitrogen uptake in the polluted site. However, the Carbon/Nitrogen (C/N) ratio deferred significantly (0.02) and interacted significantly (0.03) between the unpolluted and polluted sites (LSD = 0.05).

The available Phosphorus in the unpolluted site showed an increasing trend in the horizon with a mean value of 15.44 ppm while when compared to the polluted site which showed a decreasing trend on the horizon with a mean value of 9.97 ppm which indicate low organic matter in the polluted site as well as high pH content due to the presence of pollutants. Marinescu *et al.* (2011) reported that the content of available Phosphorus decreased with depth in polluted soils of Perisoru, Braila. Available phosphorus (P- ppm) showed a significant difference between the unpolluted and polluted sites (LSD =0.05) while the coefficient of variation is 0.1 percent indicating low variability among the sites.

The Potassium content showed a consistent value of 0.01 cmol/kg within the horizon as well as the mean value of 0.01 cmol/kg on the unpolluted site. The polluted site equally showed similar trend of consistence in value as 0.02 as well as the mean value indicating low values generally on both sites, which indicates leaching down the profile for the unpolluted site and clogging by the crude oil spill on the polluted site making the mobile phosphorus unavailable. However, mobile K deferred significantly (0.01) among the unpolluted and polluted sites (LSD = 0.05) and not significant.

The electric conductivity (EC) for the unpolluted and polluted sites deferred significantly (LSD = 0.05). It had a mean value of 0.42 and showed high values downward the horizon of the unpolluted site indicating strongly acidic soils which were inversely proportional to the pH content of the soil as recorded in this research, which is in line with the findings of Mohsen *and* Rashidi (2008). The polluted site showed a strong EC value at the first three horizon and decrease at the last two horizon indicating acidity of the soil at top of the horizon as a result of the degree of the crude oil spill at that level and the characteristics of the crude oil which may block aeration and spore spaces, which also may be responsible for the low values recorded at the last two horizon and the presence of trace metals in the crude oil. This is in line with the findings of Onyem and Onyem (2013) who reported that the significantly higher electrical conductivity values obtained from soils of Orgonoko and Kana could be a result of the high concentration of charged ions (cations and anions) in the oil impacted sites. Anions, metallic ions and carbonic acids contribute to electrical conductivity of tropical soils. However, the polluted site recorded a mean value of 2.41 indicating very strong acidity. The coefficient of variation 0.6 percent indicating low variability between the sites.

The salinity of the soils of the unpolluted site showed a very low salt value within the horizon with a mean value of 6.68 % which tends towards neutral, indicating high level of leaching due to heavy rainfalls of the region, which is in line with Ekundayo (1997). While the polluted site showed a mean value of 4.23 % indicating moderately salty which may be due to presence of crude oil spill, which is in line with the Onye and Onyem (2013) that the crude oil spillage increases the soil salinity of the impacted locations.

4.0 **Conclusion**

The study showed that there was not much variation, influence or significant difference in the physical properties analysed in the polluted site when compared to the unpolluted which revealed that in sand, silt and clay content (P= 0.01), while moisture content, silt/clay ratio and porosity showed great influence by crude oil spill (P = 0.01) as well as bulk density. The study further revealed strong significance on the soils' chemical properties of the polluted site when compared to the unpolluted site. Soil pH, organic carbon, total nitrogen was all influenced by the crude oil spill significantly (P= 0.01). More so, the presence of the oil spill affected the electrical conductivity increasing the salty nature of the soil, available P was significant (P = 0.01) while mobile potassium was not significant (P = 0.05). The study has revealed that crude oil has significant effect on wetland soils and its soil fertility and this has adverse effect on food productivity in the area. The study recommends prevention of occurrence of oil spillage as the best alternative towards achieving sustainable environment in the region. The government of Nigeria should muster the political will to exact stricter respect for environmental laws and regulations by oil companies and a penalty plan established. Multinational and indigenous oil companies should ensure regular and constant inspection and maintenance of oil facilities to avoid accidental discharge or spillage of crude oil and other petroleum products. Effective and adequate clean-up exercise is needed in the polluted areas via bioremediation and compensation made to the affected communities.

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Appendix 1

Figure 3. Profile pit of polluted site

Figure 4: Profile pit of unpolluted site

Figure 5: Soil samples of the study area, collected for feel test

Figure 6: Collection of samples in the study area.