SOME PHYSICO-CHEMICAL CHARACTERISTICS OF ARABLE SOILS AROUND SELECTED OIL EXPLORATION SITES IN THE NIGER-DELTA REGION OF NIGERIA

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Abstract

This article evaluated the physico-chemical characteristics of soils around oil exploration sites in Niger delta. A free survey technique was used in the choice of sampling sites. A total of 6 pedons (greater than 180 cm deep) were dug with 4 sunk in polluted sites; and the remaining 2 pedons from unpolluted sites served as control profile pits. Pedons were described according to FAO procedure. Soil samples were collected from pedons based on horizon differentiation. These soil samples were air-dried and sieved using 2mm sieve in readiness for routine and special laboratory analyses. Soil data were subjected to statistical analysis using correlation, coefficient of determination and coefficient of variation. Results of the analysis showed that the soils were deep (0 -200 cm) and sandy (728 – 982 g kg^{-1}). The average value of moisture content varies from 15.61 g kg^{-1} to 33.28 g kg$^{-1.}$ The electrical conductivity in polluted pedons were lower (46.33 us/cm) than that of unpolluted pedons (55 um/cm). Heavy metals concentration was generally higher in polluted soils but their values were below critical levels for crop production. The values of Ni ranged from 0.18 -2.06 mg/kg (polluted) and 0.03 – 1.00 mg/kg (unpolluted). The physical parameters had high significant correlation association in unpolluted soils than in polluted soils.

Keywords: Characterization, Oil exploration, Soil properties, Arable soils, Niger Delta.

Introduction

Soil is an important natural resource for agricultural and industrial development of a nation. It has numerous functions some of which are provision of anchorage to growing plants, provision or supply of nutrients and water to crops. Optimum utilization of the soil for agricultural production is possible as long as the soil is stable and well supplied with nutrients, air and water. Unfortunately due to several anthropogenic and natural factors, the soil may become degraded and its productivity consequently lowered (Osuji and Onojake, 2006). Farmlands are lost to non-agricultural use and natural hazards annually at alarming rates. The evidence is all around us; slash and burn agriculture in the face of rising population growth is creating vicious cycle of soil degradation and impaired productivity. However rapid decline in crop yield associated with continuous cropping has been linked to deplorable level of soil fertility (Bationo and Mokwunye, 1991).

Other than the above factors, oil exploration gives rise to the degradation of arable soils in the Niger Delta region of Nigeria through spillage, drilling waste and dredge spoils which create negative impact on soil chemical, biological and physical properties (Phil-Eze and Okoro 2009). Reduction of soil fertility can be observed in the immediate vicinities of the flow stations where intense heat is generated by the burning of natural gas. This triggers off the volatilization of plant nutrients from the topsoil, evaporation of soil moisture and the disintegration of soil structure and texture (Amadi et al., 1993).

The goal of the study was to investigate some physico-chemical properties of arable soils around selected oil exploration sites in the Niger Delta region of Nigeria. Specific objectives of the study were to assess the heavy metals contents, total hydrocarbon content as well as micronutrients contents of the soils and to correlate the properties of affected sites with those of relatively unaffected sites using correlation coefficient (r) and coefficient of determination (r^2), with the aim of relating it to crop production.

Materials and Methods

Niger Delta region of Nigeria includes Anambra, Delta, Bayelsa, Rivers, Abia, Imo, Cross-River, Akwa Ibom, Edo and Ondo states. The soils are formed largely from coastal plain sands. The sampled locations namely Uzere and Egbema are in the Niger Delta region of Nigeria. Uzere site is found in Isoko South Local Government Area of Delta state which lies within latitudes 5^o 13' and 5^o 33' N and longitude 6^o 03' and 6^o 25' E. Egbema site is found in Ohaji/Egbema Local Government Area of Imo state and located within latitude 5^o 29' and 5^o 41' N and longitude 6^o 37' and 6^o 49' E. Isoko South has a mean annual rainfall greater than 2500 mm with a mean annual temperature range of 28 -30 ^{o}C (Ofune,1990). Similarly, Egbema has a mean annual rainfall of about 2500 mm with annual temperature ranging from 26 – 29 ^{o}C. The study sites have bimodal rainfall pattern. The elevation of the study sites at Isoko South was less than 55 m above sea level while Egbema is below 50 m (Ofomata,1975). Swamp vegetation predominated in Isoko South (Ofune, 1990) while it is a typical rainforest in Egbema site (Ofomata, 1975). Seasonal flooding characterized the two sites. Oil exploration and farming constituted the major socio-economic activities of the study sites.

Field Sampling

Free soil survey technique was adopted in field sampling. Profile pits greater than 180 cm deep were dug in study sites. The profile pits were described according to FAO (1990) soil description guidelines. Soils samples were collected based on horizonation. Soil samples were air-dried and sieved using a 2 mm sieve.

Laboratory Analyses

Particle size distribution was determined by the hydrometer method as described by Gee and Bauder (1986). Bulk density was determined using the core method as described by Blake and Hartge (1986). Soil pH was determined in 0.1 mol/L KCl suspension using a soil ：liquid ratio of 1 ：2.5 and values were read off electrometrically using the pH meter. Exchangeable acidity was evaluated titrimetrically (Mclean, 1965) while cation exchange capacity was determined by the method described by Rhoades (1982). Exchangeable cations were extracted with ammonium acetate (NH_4OAC). While calcium (Ca) and magnesium (Mg) were evaluated by ethylene diamine tetra-acetic acid (EDTA) titration method, potassium (K) and sodium (Na) were determined by flame photometry (Jackson, 1962).

Total exchangeable bases (TEB) were obtained by summation and percentage base saturation （BSAT) or V- value was calculated thus :

BSAT =(TEB/ECEC)100

Where TEB = Total exchangeable bases (cmol/kg)

ECEC=Effective cation exchange capacity (cmol/kg)

Soil organic carbon (soc) was analysed by Walkley and Black method as described by Nelson and Sommers (1982). Soil organic matter was derived by multiplying the value of soil organic carbon by a Bemmelen's factor of 1.724. Percent total nitrogen was measured by micro - kjeldahl digestion method (Bremner and Muilvaney, 1982). Available phosphorus was determined using Bray (II) method （Olsen and Sommers, 1982). Micronutrients was determined by a method described by Bruce and Whiteside (1984). Heavy metals was determined by a method described by Bruce and Whiteside (1984). Total hydrocarbon was determined by using an infrared spectrophotometer method adopted from the Shell Thorton Research Laboratory (STRL).

Data analysis

Soil data were subjected to mean, correlation coefficient, coefficient of determination and coefficient of variation.

Results and Discussion

Morphological and physical properties of soils in polluted and unpolluted pedons.

Morphologically, soils from Uzere ranged from dark brown to light reddish brown in colour, while those from Egbema ranged from dark brown to light olive brown (Table 1). The dark brown to light color of the soils is attributed to the same parent material and drainage condition of these soils, in addition to organic matter content especially at epipedons.

Table 1 : Some morphological properties of soils around selected oil exploration sites in the Niger Delta region of Nigeria.

Location	Depth (cm)	Colour	Structure	Drainage	Slope(%)
Uzere	0 - 16	2.5R5/2	medium granular	well drained	0-1
(Affected)	16 – 52	7.5YR3/2	sub-angular blocky		
	52 - 95	7.5YR5/8	sub-angular blocky		
	95 - 200	7.5YR7/8	angular to sub-angular blocky		
Uzere	0 -20	7.5YR4/4	weak granular	well drained	0-1
(Affected)	20 – 45	7.5YR5/8	sub-angular blocky		
	45 – 115	7.5 YR5/8	sub-angular blocky		
	115 – 20	7.5YR5/4	medium granular		
Uzere	0 – 20	2.5YR3/2	medium granular	well drained	0 -1
(Unaffected)	20 – 45	2.5YR3/4	medium granular		
	45 -115	5YR6/3	medium sub-angular blocky		
	115 - 200	5YR7/1	medium sub-angular blocky		
Egbema	0 – 16	10YR4/3	medium granular	well drained	0-1
(Affected)	16 – 46	10YR5/6	granular		
	46 – 83	10YR6/4	angular to sub-angular blocky		
	83 – 12	2.5YR5/6	sub-angular blocky		
	125 – 200	10YR5/4	sub-angular blocky		
Egbema	0 – 18	5YR6/3	granular	well drained	0-1
(Affected)	18 – 3	5YR5/4	medium granular		
	38 – 8	2.5YR3/6	sub-angular blocky		
	86 – 135	2.5YR5/6	angular to sub-angular blocky		
	135 – 200	10YR5/8	sub-angular blocky		
Egbema	0 – 16	7.5YR6/2	medium granular	well drained	0-1
(Unaffected)	16 –32	7.5YR5/2	granular		
	32 – 92	10YR3/2	medium sub-angular blocky		
	92 – 200	10YR6/2	sub-angular blocky		

Table 2: Selected physical properties of soils around selected oil exploration sites in the Niger Delta region of Nigeria.

Location	Horizon	Depth (cm)	Total sand g kg^{-1}	Total silt g kg^{-1}	Total clay g kg^{-1}	Textural class	MC g kg^{-1}	BD mg m^{-3}
Uzere	Ap	0 – 16	931.0	37.0	32.0	sand	189.4	1.59
(Affected)	A	16 – 52	916.0	47.0	37.0	sand	351.4	1.26
	Bt_1	52 -95	908.0	66.0	26.0	sand	275.2	1.42
	Bt_2	95 -200	846.0	132.0	22.0	LS	230.1	1.60
Uzere	A	0 – 20	965.0	12.0	23.0	sand	101.6	1.36
(Affected)	AB	20 – 45	947.0	22.0	31.0	sand	119.0	1.38
	Bt_1	45 -115	937.0	17.0	46.0	sand	135.6	1.46
	Bt_2	115 – 200	907.0	32.0	61.0	sand	182.0	1.34
Uzere	Ap	0 – 20	916.0	57.0	27.0	sand	284.2	1.38
(Unaffected)	AB	20 – 45	831.0	137.0	32.0	LS	215.6	1.65
	Bt_1	45 –115	728.0	112.0	160.0	LS	230.9	1.54
	Bt_2	115 – 200	748.	92.0	160.0	LS	264.2	1.61
Egbema	Ap	0 – 16	963.0	07.0	31.0	sand	106. 0	1.21
(Affected)	AB	16 – 46	942.0	37.0	21.0	sand	120.8	1.48
	Bt_1	46 – 83	884.0	98.0	18.0	sand	128. 8	1.47
	Bt_2	83 – 125	846.0	130.0	24.0	LS	170.3	1.55
	Bt_3	125 – 200	838.0	91.0	71.0	LS	205.2	1.66
Egbema	Ap	0 – 18	982.0	12.0	06.0	sand	74.6	1.37
(Affected)	A	18 – 36	966.0	22.0	12.0	sand	66.5	1.65
	Bt_1	38 – 86	928.0	51.0	21.0	sand	102.8	1.67
	Bt_2	86 – 135	829.0	128.0	33.0	LS	126.1	1.56
	Bt_3	135 – 20	844.0	102.0	54.0	LS	123.9	1.75
Egbema	Ap	0 – 16	930.0	22.0	08.0	sand	495.6	1.31
(Unaffected)	AB	16 – 32	946.0	32.0	22.0	sand	456.2	1.34
	Bt_1	32 – 92	950.0	28.0	22.0	sand	347.6	1.37
	Bt_2	92 – 200	841.0	98.0	62.0	LS	367.8	1.57

Ls = loamy sand

Results of some physico-chemical properties are shown in Tables 2 and 3. Soils were sandy, there were no sharp differences in textures of unaffected and affected soils. The values of sand decreased with depth in all pedons except pedons 3 (unpolluted) and 5 (polluted) which showed initial decrease followed by an increase. However, pedons 3 (unpolluted) and 5 (polluted) recorded the lowest (748 g kg^{-1}) and highest (982 g kg^{-1}) values of total sand respectively. Percent clay was generally low in all the pedons. Percent clay increased gradually with depth. Equally silt content was low, like clay content percent silt generally increased gradually with depth. In term of textural classification soils varied from sand to loamy sand in both polluted and unpolluted pedons. The sandy nature of the soils could be attributed to the nature of coastal plain sands from which they were derived. Low clay content characterized soils of the study site showing the possibility of high rainfall status of the area including leaching of clay particles away from top soils horizons.

Akamigbo (1984) reported that climatic factors like rainfall and temperature cause changes that engender low clay content in southern Nigeria. Similar low values were found of silt which is indicative of the degree of weathering and leaching of the pedon (Akamigbo, 1984). Although, soil textures for unpolluted and polluted pedons tends to be similar, slight differences in the particle size distribution could be attributed to intra-pedal properties such as infiltration rates, moisture content and drainage of the soil (FAO,1986).

The pedons were deep showing that the soils have undergone advanced pedogenic processes. Drainage was classified as "well drained" which could be explained by the sandiness of the soils and the associated macro porosity. There were no sharp distinctions between polluted and unpolluted pedons in terms of depth and drainage. The bulk density ranged from 1.21 – 1.75 mg m^{-3}. Generally the affected pedons had higher bulk densities in comparison with the unaffected pedons. There was no particular trend in bulk density distribution among the pedons. Values of bulk density were lower than values reported by Oti (2002). However, Oti (2002) studied eroded soils which are associated with increased bulk density resulting from direct compacting effect of heavy raindrops on unprotected soils with diminished organic matter. Results of bulk density influenced moisture content. The value of moisture content were generally low ranging from 66.5 – 495.6 g kg^{-1}. Results indicated that moisture content was lower in pedons affected by oil pollution compared to unaffected pedons.

Chemical properties of soils in polluted and unpolluted pedons

Soils affected by oil pollution showed lower pH values than the affected ones. This is contrary to earlier observation by Osuji and Onojake (2006) who reported high pH in the oil- affected site. Higher pH values occurred in the surface horizons of the pedons studied. Polluted soils were more acidic than unaffected soils 3.00 - 4.95 (polluted) and 3.78 - 5.00 (unpolluted) in 0.1 mol/L KCl. This is worsened by high rainfall, leaching and acidic nature of parent materials. Aroh (2003) reported pH range of 3.8 - 4.0 (1 mol/L KCl) for most soils of Niger Delta which Foth (1984) observed was not good for crop production as most essential nutrients become available at pH 5.5 -7.3.

The values of total nitrogen in the studied soils were low ranging from 0.1 –2.4 g kg^{-1}. Percent total nitrogen decrease with depth with higher values occurring in the surface horizons in all pedons. Generally, higher values of total nitrogen were recorded in the polluted soils than the unaffected ones of Uzere, but this was the reverse in soils of Egbema. Total nitrogen was slightly higher in unpolluted soils. The low nitrogen content of the soils is as a result of leaching losses after rains (Opukiri et al., 1991). However, total nitrogen was slightly higher in unpolluted soils due to the fact that crude oil pollution leads to loss of nitrogen among other elements. Also oil spills result in an imbalance in the carbon-nitrogen ratio at the spill site, because crude oil is essentially a mixture of carbon and hydrogen. This causes a nitrogen deficiency in an oil soaked soil, which retards the growth of bacteria and the utilization of carbon

source(s) (Ayotamuno et al., 2006).

The values of available phosphorus in all the pedons were low, ranging from 0.06 – 15.50 mg/kg. Phosphorus distribution did not show a particular trend down the profile. Results showed that soils from Egbema gave highest values of available phosphorus. Higher values were recorded in unaffected pedons than in affected ones. Higher available phosphorus in unpolluted soils than polluted soils could be attributed to higher acidity of polluted soils which causes the fixation of available phosphorus (Nnaji et al., 2002). However, the content of available phosphorus in the study sites was below the critical level (10 -17mg/kg) for agricultural production (Odu et al., 1983).

Table 3:Selected chemical properties of soils around oil exploration sites in the Niger Delta region of Nigeria.

Location	Horizon	Depth	pH(1:2.5)		OC	TN	Exch.	Acidity	Avail	Exch. Cations						
		(cm)	H20	KCl	g/kg	g/kg	H+	AL3+	P	Na	K	Ca	Mg	ECEC	BS	EC
							(cmol/kg)		(mg/kg)		(cmol/kg)			cmol/kg	g/kg	(us/cm)
Uzere	Ap	0 -16	.20	.20	0.2	2.1	.60	1.80	2.72	.18	.06	.38	. 40	3.42	98.2	68
(Affected)	AB	16-52	.40	.40	1.2	1. 0	.40	1.40	2.91	.14	.04	.33	.16	2.47	71.3	58
	Bt1	52-95	.50	.60	0.3	0.4	.80	1.60	2.04	.13	.01	.19	.13	2.86	60.8	43
	Bt2	95-200	.10	.20	.6	0.2	.10	1.30	2.62	.04	.03	.14	.17	2.78	36.7	22
Uzere	Ap	0-200	.60	.80	1.6	1.7	.80	1.80	3.04	. 20	.07	.33	.46	3.66	89.6	69
(Affected)	AB	20-45	.70	.70	.4	0.8	.70	2.30	2.62	.12	.01	.29	.39	3.81	12.6	25
	Bt1	45-115	.50	.60	.4	0.3	.40	1.30	3.20	.41	.03	.29	.18	2.61	48.7	32
	Bt2	115-200	.20	.00	.8	0.1	.20	1.10	2.91	.64	.05	.11	.24	2.34	44.4	48
Uzere	Ap	0 -20	.50	.30	2.5	1.8	.40	0.92	10.63	.63	.33	.69	.61	6.63	03.3	47
(Unaffected)	AB	20-45	.10	.10	.2	1.7	.34	0.83	6.14	.47	.04	.46	.24	5.38	63.8	45
	Bt1	45-115	.00	.90	.2	1.3	.29	0.60	10.27	.89	. 60	.18	.01	4.57	89. 0	36
	Bt2	115-200	.10	.80	.3	0.8	.17	0.54	8.71	.72	. 60	.05	.62	4.25	08.1	28
Egbema	Ap	0 - 16	.08	.98	. 0	0.6	.30	1.40	2.68	. 80	.02	.72	.08	4.32	06.5	53
(Affected)	AB	16- 46	.05	.95	.5	0.5	.40	1.40	1.82	.71	.08	. 50	.02	4.16	67.3	40
	Bt1	46- 83	.00	.93	.6	0.1	.10	1.40	0.81	.71	.03	.48	.93	3.65	89. 0	75
	Bt2	83 -125	.96	.98	.9	0.2	.20	1.20	1.72	.74	.03	.12	.74	4.03	57.6	54
	Bt3	125-200	.22	.36	3.4	1.3	.10	0.50	2.51	.75	.02	. 60	.62	3.59	32.9	27
Egbema	Ap	0 - 18	.29	.31	.9	0.2	.40	0.70	2.83	.38	. 10	. 40	.14	4.12	33. 0	64
(Affected)	AB	18 -38	.50	.49	.5	0.4	.60	1.40	0.06	.73	.04	. 20	. 40	5.09	07.1	43
	Bt1	38 -86	.29	.90	.6	0.3	.50	0.70	1.15	.84	.04	.56	.56	3. 20	75. 0	51
	Bt2	86-135	.15	.11	.3	0.1	.70	0.70	1.47	.77	.05	.96	.96	4.14	61.8	30
	Bt3	135-200	.26	.06	.6	0.1	.40	1.70	2.95	.84	.04	.56	.88	3.92	91.8	32
Egbema	Ap	0 -16	.15	.02	. 0	2.4	.30	0.80	8.03	.88	.04	. 60	. 70	5.38	95.5	96
(Unaffected)	AB	16 -32	.03	.98	4.7	1.5	.30	1.10	13.68	.89	.11	.36	.32	5.08	24.4	78
	Bt1	32 -92	.96	.89	.6	1. 0	.40	0.80	15. 50	. 00	.07	.64	.84	3.75	80. 0	64
	Bt2	92 -200	.91	.78	.4	0.7	.40	0.80	12.22	. 70	.06	.44	.52	3.92	93.9	46

OC : Organic carbon, TN : Total nitrogen, ECEC : Effective cation exchange capacity, BS : Base saturation

Table 4 : Simple correlation coefficient (r) among soil properties (n= 26)

Soil properties	Oil polluted soils	Unpolluted soils
BD and EC	0.66**	0.85**
MC and BD	0.20	0.78**
MC and BD	0.60**	0.99**
Cd and TEA	0.88**	0.58**
Cu and TEB	-0.42	0.99**
Mn and TEB	-0.14	0.94**
Cl and TEB	-0.60**	0.99**
Zn and TEB	0.08	0.74**
Cd and TEB	-0.11	0.84**

BD : Bulk density, EC : Electrical conductivity, MC : Moisture content, TEA : Total exchangeable acidity, TEB: Total exchangeable bases.

Table 5 : Coefficient of Determination (r^2) among soil properties

Soil properties	Oil polluted soils	Unpolluted soils
Cu and TEB	0.002	0.99
Cd and TEA	0.77	0.49
Mn and TEB	0.02	0.88
Cl and TEB	0.36	0.97
Zn and TEB	0.01	0.58
BD and EC	0.43	0.72
MC and EC	0.04	0.61
MC and BD	0.36	0.98
Cd and TEB	0.01	0.70

Organic carbon content was low, the value ranged from 0.5 – 25 g kg^{-1}. Organic carbon values decreased with depth with higher values occurring in the surface horizons of pedons. Distribution of organic carbon varied with locations. Soils from Uzere that were affected by oil pollution showed higher values of organic carbon and organic matter than the unaffected ones. However, soils affected by pollution in Egbema showed lower values of organic carbon and organic matter than their unaffected counterparts in the same location .This could be attributed to longer time of pollution as the amount of carbon reduce with time. The higher values of organic matter in crude oil polluted soils than in unaffected soils could be attributed to the effect of crude oil in filling the pore spaces denying the microbes of oxygen hence they die as most are aerobic. Consequently, the organic matter decomposition slows down, thereby increasing organic matter content of polluted pedons. This is in line with the findings of Jobson et al. (1974) who revealed that oil spillage plugs the pores and kills soil microbes. Meanwhile, Sims (1990) contended that low organic matter in the tropics is due to high temperature which hastens mineralization process in organic matter.

The electrical conductivity of the soils was low (22 – 96 us/cm). Values of electrical conductivity in polluted soils were slightly lower than that in unaffected soils. This is contrary to observation by Osuji and Onojake (2006) who reported high conductivity in the oil-affected site. Electrical conductivity was low since the values were below the critical level (9400 us/cm) considered harmful to plants (Odu et al., 1985). As sandiness confers macroporosity, soils tend to have low EC values. Similar findings have been reported by Mbagwu et al. (1983)

There was better association between BD and EC in unpolluted soils (r =0.85; r^2 = 0.78) than in polluted soils (r =0.66 ; r^2 = 0.43) at probability levels of 5 %. The same trend was followed by MC and EC, and MC and BD (Tables 4 and 5). Higher bulk densities in affected soils could be attributed to the impact of exploration activities. This is in line with Foth (1984) who reported that oil spillage increased the bulk density due to aggregate disintegration. Moisture content was low in polluted soils which could be due to clogging of pores by oil droplet as well as high rate of evaporation as a result of heat generated by burning natural gas. Idike (1998) reported similar trend but added that the disintegration of soil structure on spillage is instrumental to low moisture content of polluted soils.

The exchangeable bases were generally low in all the pedons. Generally there were greater variation in affected soils than the unaffected ones. Moderate variation in calcium (CV =29.23 %) was recorded in unaffected pedon at Egbema while it was 43.39 % in affected ones. This trend was not observed on Mg with unaffected pedon having (CV = 42.44 %) while affected ones had CV = 20.82 % (Table 6).

Table 6 : Coefficient of Variation among soil properties

Soil properties	Uzere affected (%)	Uzere unaffected(%)	Egbema affected(%)	Egbema unaffected(%)
MC	29.65	39.73	24.55	14.66
BD	2.80	17.13	8.55	14.95
EC	3.23	19.31	33.59	25.86
OC	21.11	25.00	70.81	47.80
Na	47.83	33.61	15.77	12.27
K	0.00	62.I6	48.67	36.42
Ca	0.00	18.52	43.39	29.23
Mg	18.52	32.14	20.82	42.44
H	15.87	30.00	48.43	14.29
Al	3.16	22.22	30.79	14.77
ECEC	4.00	21.30	11.48	15.63
BS	19.79	12.91	21.66	6.16
THC	44.55	0.00	43.78	0.00
Cl	1.03	56.14	30.68	9.47
Zn	11.27	51.70	65.89	11.60
Cu	0.10	96.43	33.65	26.96
Fe	10.15	50.22	17.36	20.21
Mn	1.26	66.99	50.22	29.33
Ni	11.11	72.00	72.86	99.25

MC: Moisture content; BD : Bulk density; EC: Electrical conductivity; OC: Organic carbon; ECEC: Effective cation exchange capacity; BS : Base saturation; THC: Total hydrocarbon.

Micronutrients and total hydrocarbon concentration of soils in polluted and unpolluted pedons.

Micronutrients showed decreasing trend with depth in most of the pedons, with higher values occurring on the surface horizons. However, Cu, Fe, Mn values were higher in affected pedons. Values of Cl and Zn were highest in affected soils of Egbema than soils of Uzere. Generally, the result revealed that micronutrients concentration was consistently higher in affected pedons in comparison with unaffected pedons (Table 7).There was significantly good relationship between micronutrients and total exchangeable bases in unpolluted soils (r^2 = 0.99, 0.88, 0.97 and 0.58) for Cu, Mn, Cl and Zn respectively (Table 5) at 5 % level of probability. But poor association existed between Fe and total exchangeable bases in unpolluted soils (r^2 =0.01) while very good relationship was found between the same parameters in polluted pedons (p =0.05) (Table 5). Micronutrients concentration was slightly higher in polluted soils than in unpolluted soils. This is in line with Akamigbo and Jidere (2002) which reported that spilled petroleum led to the availability of essential micronutrients.

There were higher values of total hydrocarbon (THC) in polluted soils (0.06 – 5.60 mg/kg) than in unpolluted soils (0.01 – 0.14 mg/kg). Generally, THC decreased with depth in all the affected pedons with the exception of one polluted pedon at Uzere where THC decreased at upper horizon but increased at a depth of 115 – 200 cm. Similarly, THC decreased with depth in all the unaffected pedons (Table 7). However, there were moderate variations in affected soils (CV = 43.78 – 44.55 %) while unaffected soils did not vary (CV = 0 %) (Table 6). Higher values of total hydrocarbon recorded in polluted soils could be attributed to the possession of non volatile and poly-cyclic hydrocarbons which alters the chemical properties of soils and also due to the existence of anaerobic condition which resulted into insufficient oxygen supply and hence anaerobic decomposition ensued resulting in organic materials（methane and carbon dioxide, the former – a hydrocarbon）being produced and hence the increase in the THC. Ayotamuno,et al., 2006 made a similar observation. This implies that nutrient elements imbalance will be encouraged in polluted soils (Udo, 1975). However, the values of THC did not exceed critical level of 6.1 – 7.3 mg/kg (FAO, 1986).

Table 7: Some micronutrients and total hydrocarbon concentration of soils around selected oil exploration sites in Niger Delta of Nigeria

Location	Depth (cm)	Cu	Mn	Fe	Zn	Cl (ppm)	THC (ppm)
		……….mg/kg	………	………	………		
Uzere (Affected)	0 – 16	4.20	4.50	66.5	3.99	28.81	5.60
	16 – 52	2.15	2.30	9.98	1.41	25.23	3.50
	52 – 95	1.80	1.50	11.12	1.35	35.14	2.10
	95 – 200	1.37	1.11	13.70	0.31	32.66	1.50
Uzere (Affected)	0 – 20	5.30	4.88	6.88	4.11	27.30	1.20
	20 – 45	1.90	3.10	7.88	2.41	23.01	0.65
	45 – 115	1.15	1.12	10.09	1.56	35.73	0.65
	115 – 200	1.08	0.49	11.64	1.34	33.23	1.60
Uzere (Unaffected)	0 – 20	2.10	2.00	1.05	1.23	35.88	0.14
	20 – 45	1.00	1.00	2.36	1.20	26.40	0.04
	45 – 115	0.20	0.80	4.01	1.14	13.15	0.04
	115 – 200	0.05	0.20	1.02	1.08	11.22	0.02
Egbema (Affected)	0 – 16	0.75	2.30	1.98	1.92	27.56	1.82
	16 – 46	1.02	1.40	1.66	0.48	20.80	1.64
	46 – 83	0.94	0.60	1.49	1.11	39.00	1.09
	83 – 125	1.13	0.20	1.46	1.12	27.54	0.75
	125 – 200	1.76	0.49	1.16	0.97	13.77	0.50
Egbema (Affected)	0 – 18	1.10	3.05	1.98	0.59	32.64	2.30
	18 – 38	1.26	3.05	1.98	0.59	32.64	2.30
	38 – 86	0.85	3.11	1.90	1.11	26.01	1.08
	86 – 135	0.60	4.14	1.67	1.67	15.30	1.06
	135 – 200	0.42	2.04	1.55	14.71	16.32	0.06
Egbema (Unaffected)	0 – 16	1.04	1.24	1.93	1.3	28.96	0.12
	16 – 32	1.55	1.05	1.56	1.55	27.96	0.07
	32 – 92	0.90	0.80	1.76	1.34	23.28	0.02
	92 – 200	0.80	0.53	1.08	1.14	23.92	0.01

THC : Total hydrocarbon

Heavy metals concentration

Generally, heavy metals values were higher in soils affected by pollution than in unaffected ones. The heavy metals decreased with depth of soil profile, so corroborating Osuji and Onojake（2006）. The higher concentrations of these metals at the surface depth may be attributed to the fact that metal profiles in polluted soils penetrate a little below the 10 cm region even after many years (Smith et al., 1999). However, the affected soils of Uzere recorded highest values of heavy metals than affected soils of Egbema (Table 8). Higher values of heavy metals in polluted soils could be attributed to the fact that crude oil contains Hg, Pb, V, and Cr (Ahalya et al., 2003), and these were possibly added to the soil during spillage. But the values of these heavy metals did not exceed their critical levels for crop production (Isirimah et al., 2003

Table 8: Some heavy metals concentration of soils around selected oil exploration sites in Niger Delta of Nigeria.

Location	Depth (cm)	Hg	Cd	V	Cr	Pb	Ni
		…………	…………	………….mg/kg	…………	…………	…………
Uzere	0 – 16	0.03	1.32	1.36	1.16	2.16	1.80
(Affected)	16 – 52	0.02	1.24	0.94	0.94	1.80	1.20
	52 – 95	0.01	0.32	0.44	0.44	1.45	0.70
	95 – 200	0.01	0.08	0.28	0.25	1.14	0.29
Uzere	0 – 20	0.04	1.60	1.20	1.12	2.40	2.06
(Affected)	20 -45	0.03	0.56	4.68	0.28	1.36	1.01
	45 – 115	0.02	0.03	1.48	0.48	1.02	0.08
	115 – 200	0.02	0.07	1.32	0.13	0.06	0.04
Uzere	0 – 20	0.02	0.03	0.44	0.21	1.20	1.00
(Unaffected)	20 – 45	0.02	0.28	0.36	0.14	0.86	0.70
	45 – 115	0.01	0.12	0.28	0.04	0.47	0.20
	115 – 200	0.01	0.03	0.21	0.02	0.33	0.11
Egbema	0 – 16	0.04	1.07	0.14	1.12	2.70	1.57
(Affected)	16 – 46	0.03	0.60	0.12	0.87	1.92	0.66
	46 – 83	0.04	1.02	0.17	0.18	1.78	0.64
	83 – 125	0.01	0.70	0.14	0.21	1.83	0.56
	125 – 200	0.01	0.30	0.16	0.05	1.85	0.37
Egbema	0 – 18	0.04	1.16	2.00	0.07	1.45	1.61
(Affected)	18 – 38	0.02	1.04	1.72	0.08	1.57	0.36
	38 – 86	0.02	0.18	1.49	0.01	1.16	0.23
	86 – 135	0.01	0.36	1.28	0.06	1.88	0.34
	135 -200	0.01	0.44	1.21	0.08	1.64	0.18
Egbema	0 – 16	0.02	0.45	0.48	0.35	1.02	0.26
(Unaffected)	16 – 32	0.01	0.31	0.43	0.30	1.21	0.67
	32 – 92	0.03	0.02	0.18	0.02	0.30	0.04
	92 – 200	0.01	0.04	0.14	0.02	0.14	0.03

Conclusion

There were more variation in polluted soils in terms of the distribution of exchangeable bases. Heavy metals concentration and THC were higher in polluted soils than the unpolluted soils. However, the values of heavy metals and THC below critical level for crop production indicate uncontamination. There was significantly positive correlation between exchangeable acidity and all heavy metals ($p = 0.05$). With the exception of Fe and Cl, micronutrients also exhibited high positive correlation with exchangeable acidity. The implication of this relationship is that as heavy metals, micronutrients increase, exchangeable acidity increases. The R^2 values of these parameters predicted good association hence one aptly concludes that crude oil pollution does not favour agricultural production.

Acknowledgements

The authors gratefully acknowledge the assistance of Shell Petroleum Development Company (SPDC) and Shell Global Environmental Consultant Limited, Warri in carrying out the field work and soil analysis.

References

Ahalya, A. Ramachandra T.V and Kamamadi R.D (2003). Biosorption of heavy metals. Resear. J. Chem. Environ., v. 7, No. 4, pp 71 -79.

Akamigbo, F.O.R (1984). The accuracy of field textures in a humid tropical environment. Soil survey and land evaluation 493: pp 63-70

Akamigbo, F.O.R and Jidere C.M (2002). Carbon-Nitrogen dynamics in organic wastes amended- crude oil polluted wetland soil. J. trop. Agric., Food, Environ. Exten. v. 3, No1, pp 20-26.

Amadi, A. Dickso, A and Maate, G. O (1993). Remediation of oil polluted soils: 1. Effect of organic and inorganic nutrient supplements on the performance of maize (Zea may L.). Water and Air Soil Pollut. 66: pp59-76.

Aroh, J.E.K (2003, December). Classification of the " OGONI SANDS" in the Niger Delta in Nigeria:(Paper presented at the 28th Annual Conference of the Soil Science Society of Nigeria

Ayotamuno, M.J, Kogbara R.B, Ogaji S.O.T and Probert S.D (2006). Bioremediation of a crude- oil polluted agricultural-soil at Port Harcourt, Nigeria. Applied Energy 83: pp 1249-1257.

Batiano, A. and Mokwunye, A.U (1991) Role of manure and crop residues in alleviating soil fertility constraints to crop production. Fert. Resear. v. 29, No.1, pp117-125.

Blake, C.A and Hartge, C (1986). Methods of soil analysis. Agronomy no. 9 part 2. American Society of Agronomy, Madison. Wisconsin.

Bremner, J.M and Mulvaney, C.S (1982). Total Nitrogen. (In A.L Page, R.H Miller, and D.R Keeney (Eds.), Methods of soil analysis. Part 2 (Pp 149 -158) Madison, W.I. Ame. Soc. Agron.)

Bruce, A.M and Whiteside P.J (1984). Introduction to atomic absorption spectrophotometer. (3rd ed.). (England: Pye unicam limited)

FAO (Food and Agricultural Organization) (1990) Guideline on profile description, Food and Agricultural Organization Rome. Pp 66.

FAO (Food and Agricultural Organization) (1986) Report on the agro-ecological zones project. Results from south-west Asia. World soils resources report. 481 v. 2. FAO Rome.

Foth, H.D (1984) Fundamental of soil science (2nd ed.). (New. York: John Wiley and sons)

Gee, G and Bauder, J.W (1986) Particle size analysis. In: A Klute and Madison, W.I. Eds). Methods of soil analysis part 1.(pp 91 -100) Ame. Soc. Agron.

Idike, H (1998, November) The effects of waste gas flare on the surrounding farmland vegetation. Paper presented at a Seminar on Petroleum Industry and the Environment of Niger Delta. Warri).

Isirimah, B.T, Archimota, A.D and Igwe, C (2003) Introduction to soil chemistry and biology for agriculture and biotechnology.(Nigeria: Osia Int'l. Publishers Ltd.). ,

Jackson, M.L (1958) Soil chemical analysis. (New Jersey: Prentice- Hall Inc. Englewood cliff)

Jobson, A. Mclauglin, M. Cook, F.D and Westlake, D.W.S (1974). Effects of amendments on the microbial utilization of oil applied to soil. Appl. Microbiol v 27, No.1, pp 66-77

Mbagwu, J.S.C, Lal R and Scott T.W (1983). Physical properties of three soils in Southern Nigeria. Soil Sci. 136 : pp 48- 55.

Mclean, E.O (1965). Aluminium, In : Black, C.A, include all authors (eds.). Methods of soil analysis, part 2.(pp986 -994.). Amer. Soc. of Agron.).

Nelson, D.W and Sommers, L.E (1982) Total carbon, organic carbon and organic matter.(In A.L. Page, R.H. Miller, and D.R. Keeney. (Eds.), Methods of soil analysis, Part 2. (Pp 539 -579). Amer. Soc. Agron., Madison, W.I.

Nnaji, G.U, Asadu, C.L.A and Mbagwu J.S.C (2002). Evaluation of physico-chemical properties of soils under selected agricultural land utilization types. J. Trop. Agric., Food, Environ. Exten.v. 3, No. 1 pp. 27 -33

Odu, C.T, Nwoboshi L.C and Ogunwale J.A (1983). Environmental study of Shell operated areas (soils and fresh water vegetation). Shell Lagos.

Odu, C.T, Esuruoso, O, Nwoboshi L.C and Ogunwale J.A (1985). Environmental study of the Nigeria Agip oil company operational areas . In: Proceedings of the soils and fresh water vegetation conference, Milan (Italy) ;1985.

Ofomata, G.E.K (1975) Nigeria in maps Eastern state. (Benin city: Ethiope Publishing house Midwest mass communication corporation).

Ofune, J.A (1990) Regional geograghy of Nigeria. West Africa and the rest of Africa., (Nigeria: Umeh press, Benin city)

Olsen, S.R and Sommers, L.E (1982). Phosphorus.(In A.L. Page, R.H. Miller, and D.R Keeney (Eds.).Methods of soil analysis, part 2.(Pp 1572.). Madison, W.I. Amer. Soc. Agron.

Opukiri, S.B. Zuofa K and Douglas D.C (1991). The influence of urea fertilizer on yield of upland rice (Oryza sativa) on acid soil in Rivers state. Nig. J. Crop, Soil Forestry.v.1, pp 42-43.

Osuji, L.C and Onojake C.M (2006). Field reconnaissance and estimation of petroleum hydrocarbon and heavy metal contents of soils affected by the Ebocha-8 oil spillage in Niger Delta, Nigeria. J. Environ. management 79: pp133- 139.

Oti, N.N (2002) Discriminant functions for classifying erosion degraded lands at Otamiri, South eastern Nigeria. Agro. Sci. v.3 No.1 pp34-40.

Phil-Eze, P.O and Okoro I.C (2009) Suitable biodiversity conservation in the Niger Delta : A practical approach to conservation site selection. J. Biodivers. Conserv. v. 18 No.5 pp1247-1259

Rhoades, J (1982) Cation exchange capacity. (In A.L .Page, R.H .Miller, and D.R Keeney(Eds.). Methods of soil analysis, part 2.(Pp 149 -158.). Madison, W.I. Amer. Soc. Agron.

Sim, G..K (1990) Biological degradation of soil. In R. Lal, and B.A .Steward (Eds.). Advances in soil sci. 11 : 150 -187.

Smith, I.C, Ferguson T.L and Carson B.L (1999) Metals in New and Used Petroleum Products and By-Products: Quantities and Consequences.(New York: Elsevier).

Udo, E.S. (1975). The effects of soil pollution on germination growth and nutrient uptake of corn. Journal of Environmental quality. 4: 537-840.

Vogel, C (1978) Quantitative inorganic analysis. (4th eds.) (London:Longman group Ltd.).