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Variability in selected Properties of Crude Oil – Polluted Soils of Izombe, Northern Niger Delta, Nigeria

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Abstract: We investigated the variability in some soil properties influenced by crude oil-polluted soils of Izombe in Northern Niger Delta of Nigeria in 2013. A free survey technique was used in the field sampling with nine profile pits dug in the site. Routine soil analysis was conducted on some physico-chemical properties including heavy metals. Soil data were subjected to analysis of variance using proc mix-model of SAS software at $P \leq 0.05$. Results showed that soils were dark grayish brown to red in colour. Soils of the studied area were also deep (>100cm), well drained and having percent sands (>80%). Soils from crude oil-polluted site showed lower pH (<3.92) than the unpolluted soils with pH >4.00. Soil organic matter, C:N ratio, TEA and percent Al. Sat, were appreciably higher in soils affected by crude oil pollution. Unaffected soils by crude oil pollution exhibited higher TN, P, TEB and B.Sat. Heavy metal concentrations in the polluted sites were relatively higher than their unaffected counterparts and were significant ($p \leq 0.05$). Further studies should be conducted on some other properties and in owner-managed farm establishments.

Keywords: Variability, Crude Oil, Soil Quality, Tropical Soils

1. Introduction

Other than agricultural practices, oil exploration is a major economic activity in the Niger Delta areas of Nigeria. This has resulted in the pollution and contamination of agricultural lands for farming (terrestrial and aquatic environment). Soils and water polluted with crude oil poses a serious threat to living organisms within the environment. Crude oil contains heavy metals that may be phytotoxic to plants and injurious to animals [1]. It could also cause acidification of the soils [2]. Apart from factors such as previous farming practices, parent materials, topography, crude oil pollution results to variations in soil properties. However, variations of soil physical and chemical properties, nutrient levels and water content occur at field scale [3]. Crude oil reduces the fertility of the soil by making plant essential nutrients unavailable. [4] reported that sites polluted with crude oil contain metals such as Barium (Ba), Cadmium (Cd), Chromium (Cr), Lead (Pb), Nickel (Ni), Copper (Cu) and Zinc (Zn) and their mobility depends on the concentration and soil properties. Farmers are now amending and remediating soils affected by crude oil with the hope of optimizing agricultural outputs across fields. These attempts are made to regenerate soil fertility in the study area which has been lowered by the influence of crude oil spillage, using sewage sludge [5], water hyacinth residues [6]. Municipal solid wastes [7]), cassava peel, cattle dung and poultry droppings [8]. These efforts improved quality for increased productivity. Similarly study has been conducted in some other locations outside the study site. However, studies in this region have shown that most of the valuable lands in the studied site are either temporarily or permanently lost to oil exploration activities in form of flow-station, disposal pits for burying oil and land covered with spilled oil [9. Based on this, we investigated the influence of crude oil pollution on the variability of selected soil properties.

2. Materials and Methods

A field experiment was conducted at oil exploration sites during April, 2009 to March, 2010 at Izombe, Owerri –

Nigeria. The experimental site is located within Northern Niger Delta region of Nigeria (Latitudes $5^0\ 20^1$ and $5^0\ 41^1$ N and longitudes $6^0\ 37^1$ and $6^0\ 49^1$ E). Soils of the area are derived from coastal plain sands and are dominated by ultisols. The site belongs to the lowland area of Nigeria, with a humid tropical climate with mean annual rainfall of 2250mm and mean annual temperature range of 26 – 31^0C. The main socio-economic activity of the study site is arable farming, hunting and oil exploration activities. Land preparation includes slash and burn system with conventional tillage system.

2.1. Field Studies

A free survey technique was used to locate the study site. Nine (9) pedons of about 200cm depths were dug covering polluted sites (7) pedons and unpolluted sites (2) pedons. After horizon delineation soil samples were taken from the component horizons; air-dried and made to pass through a 2mm sieve prior to laboratory analysis.

2.2. Laboratory Analysis

Particle size *distribution* was estimated by hydrometer method [10].

Bulk density was determined by core procedure, [11]. The soil was transferred from the sample holders of core sampler to a container and placed in an oven at 105^0C and dried to a constant weight. The weight of soil was recorded and bulk density calculated by the formula of [12] as follows:

$$\text{Bulk density} = \frac{Ovendryweightsoil}{samplevolume}$$

Soil pH was determined electrometrically in a soil solution ratio of 1:2.5 [13].

Total nitrogen was estimated using the modified micro-kjeldahl digestion method [14] and sodium copper sulphate catalyst mixture [15].

Organic matter was measured as described by [16] Nelson and Somnars, (1982). Organic matter was calculated by multiplying organic carbon by [17], factor" of 1.724.

Available phosphorus was determined by using the molybdemum blue colour Bray II method [18].

Exchangeable Bases were determined from Ammonuim acetate (NH^4OAC) leachates of the soil [19].

Exchangeable Acidity was determined by leaching the soil with 1NKCl and titrates with 0.05 NaOH solutions [20]. Effective cation exchange capacity was estimated by the summation of the total exchangeable bases (TEB) and exchangeable acidity (TEA). It is expressed in Cmol/kg Soil [21].

Heavy metal concentrations were measured individually with atomic absorption spectrometer (AAS) after wet digestion with concentrated H_2SO_4 for Cr, mixture of HNO_3 and HCL for Hg, and Cd and HNO_3 for Ni, V and Pb respectively [22].

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using the Statistical Analysis System (SAS) version 2008 model.

3. Results and Discussion

The results of the morphological properties of the soil studied are summarized in Table 1.

Table 1. *Morphological properties of Studied Soils*

Horizon	Depth (cm)	Colour	Structure	Drainage	Boundary
Ap	0 – 23	2.5 YR $^4/_2$	W gr	ewd	Clear
AB	23 – 86	2.5 YR $^5/_2$	M gr	ed	Smooth
Bt_1	86 – 130	2.5 YR $^4/_9$	M sb	ed	Gradual
Bt_2	130 – 195	2.5 YR $^4/_8$	Si b	wd	Diffuse

W gr = Weak granular, m gr = Medium granular, m sb = Medium sub-angular block, Si b = Sub – irregular blocky, ewd = Excessively well drained, ed = Excessively drained, wd = well drained.

Table 2. *Some physical properties of the Studied Soils*

Location	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	BD(g/cm$^{3)}$	SCR
Polluted soils	0 – 23	80.23	7.80	8.17	1.42	0.95
	23 – 86	84.05	7.65	8.39	1.44	0.91
	86 – 130	81.20	8.90	9.99	1.47	0.89
	130 – 195	80.34	9.40	9.61	1.57	0.98
SED		2.94	1.21	0.85	0.03	0.33
P value		0.5433^{NS}	0.4292^{NS}	0.0973^{NS}	<0.0001	0.4808^{NS}
Unpolluted soils	0 – 23	83.17	6.17	10.67	1.37	0.58
	23 – 86	80.16	7.50	12.33	1.45	0.61
	86 – 130	77.67	7.83	14.50	1.49	0.54
	130 – 195	79.33	10.33	10.67	1.55	0.97
SED		5.56	4.11	3.16	0.08	0.74
P value		0.076^{NS}	0.8397^{NS}	0.6289^{NS}	0.2919^{NS}	0.3993^{NS}

Generally, the soils studied were deep (>100cm), well drained and with cleared horizons differentiation. The deep pedons with distinct horizonation is an indication that the soils have undergone pronounced weathering [23]. Results of soil physical properties are shown in Tab. 2. Results showed that soils in the studied site were sandy (>80%). No significant difference (P<0.05) was shown in the percentage sand between polluted and unpolluted soils. Soil texture is an inherent property and may not have been influenced significantly by crude oil pollution in the study area. The bulk density ranged from 1.37 – 1.57 $g/cm^3$with a mean of 1.48 g/cm^3 for polluted soils and 1.47 $g/cm^3$for unpolluted soils. There was no particular trend in bulk density distribution among the pedons but with higher values occurring in polluted soils. Crude oil is known to increase bulk density in soils perhaps due to aggregate disintegration. [24] reported that oil spillage increases bulk density due to aggregate disintegration. The chemical properties of the studied soils are presented in Table 3. The results showed that the soils of the area were acidic, with a mean pH value of 3.92 in polluted soils and 4.00 in unpolluted soils. The stronger soil reaction of the polluted soils could be attributed to the impact of crude oil pollution. Oil in soils tends to decrease the pH generally, making it unsuitable for crop production. This situation could be compounded by the high rainfall, leaching which results in washing away of basic cations from the soils and the acidic nature of the parent materials in the studied site. The resultant effect of these may be the preferential removal of basic cations through leaching resulting in the accumulation of exchangeable acidic cations (Al^+ and H^+) in the soil absorption complex of polluted soils [25]. Higher values of Organic matter (2.00%) and C/N ration (18.87) in crude oil polluted soils explained presence of carbon in the petroleum hydrocarbon discharged and deposited on the polluted soils during crude oil spillage. This finding is in line with earlier work done by [26] where low organic matter and C/N ratio in unpolluted land units confirmed high mineralization process in the organic matter and also due to high temperature and excessive high rainfall which characterize the study area [27]. Values of total nitrogen, phosphorus, ECEC and percent base saturation were consistently lower in polluted soils compared to the unpolluted counterparts, which revealed that crude oil pollution encouraged nutrient elements imbalance as well as phosphorus fixation among other elements [28]. Results of some heavy metals in the site are shown in Table 4.

Table 3. *Some Chemical Properties of the Studied Soils*

Location	Depth (cm)	pH (1NKCl)	OM (%)	TN (%)	C/N (%)	Av.P (mg/kg)	Ca (Cmol/100g)
Polluted soils	0-23	4.08	3.75	0.1	20.61	11.79	0.9
	23-86	3.95	1.72	0.06	16.94	7.09	0.74
	86-130	3.89	1.51	0.05	18.53	5.02	0.93
	130-195	3.73	1.01	0.05	19.42	5.13	0.88
	SED	0.1	0.94	0.019	3.73	0.9	0.192
	P Value	0.0114	0.0329	<0.001	0.7952	<0.001	0.123
Unpolluted soils	0-23	4.05	2.79	0.17	24.57	1.15	1.18
	23-86	4.25	1.66	0.14	19.28	9.1	1.13
	86-130	4.11	1.39	0.13	16.96	7.87	1.74
	130-195	3.6	1.21	0.12	22.69	7.57	0.83
	SED	0.39	0.59	0.02	0.1446	0.873	1.01
	P value	0.5568	0.1375	0.1666	0.9528	0.9703	0.8599

Table 3. *continued*

Location	Mg (Cmol/100g)	K (Cmol/100g)	Na (Cmol/100g)	H^+ (Cmol/100g)	Al^{3+}	ECEC	Al.sat	B.sat
Polluted soils	0.57	0.07	0.64	1.23	0.89	4.11	24.24	50.81
	0.63	0.057	0.46	1.32	0.96	4.07	24.41	46.86
	0.87	0.107	0.46	1.36	0.76	4.13	23.17	45.35
	0.9	0.071	0.51	1.19	0.7	4.13	22.26	50.45
	0.2147	0.036	0.16	0.316	0.07	0.33	0.406	3.87
	0.09	0.5451	0.6235	0.9336	0.0024	0.9971	0.9517	0.4284
Unpolluted soils	1.09	0.18	0.64	0.57	0.62	5.96	11.04	65.54
	1.05	0.15	0.46	0.88	0.69	5.98	12.78	43.99
	0.93	0.18	0.46	0.51	0.55	5.13	15.32	62.4
	0.67	0.23	0.51	0.48	0.45	4.76	11.92	66.03
	0.087	0.16	0.16	0.08	0.09	0.59	3	2.27
	0.0208	0.97	0.674	0.001	0.18	0.245	0.566	0.002

OM = Organic matter, TN = Total nitrogen, C/N = Carbon-nitrogen ratio, Av.P = Available phosphorus, Ca = Calcium, Mg = Magnesium, K = Potassium, Na = Sodium, H = Hydrogen, Al = Aluminum, ECEC = Effective Cation Exchange Capacity, Al.sat= Aluminium saturation, B.sat= Base saturation.

***Table 4.** Some heavy metals concentration in the Studies Site*

Location	Depth (cm)	Hg (mg/kg)	Cd (mg/kg)	V (mg/kg)	Cr (mg/kg)	Pb (mg/kg)
Polluted soils	0 - 23	0.04	7.52	0.09	7.25	5.35
	23 – 86	0.04	6.74	0.94	7.41	4.66
	86 – 130	0.02	5.84	0.61	6.99	4.55
	130 – 195	0.02	5.65	0.59	6.95	4.50
SED		0.003	1.03	0.22	1.12	0.45
P value		<0.003	0.2665	0.0066	0.9741	0.2173
Unpolluted soils	0 - 23	0.02	0.63	0.39	3.48	4.68
	23 – 86	0.01	3.20	0.29	3.81	4.67
	86 – 130	0.02	2.38	0.13	3.10	1.70
	130 – 195	0.01	2.97	0.10	3.48	1.29
SED		0.005	0.06	0.05	0.08	0.29
P value		0.4850	<0.001	0.0027	0.005	0.001

Hg = Mecury, Cd = Cadmium, V = Vanaduim, Cr = Chromium, Pb = Lead

Higher values of heavy metals (Hg, Cd, V, Cr, and Pb) were observed in polluted soils compared to the unpolluted soils. [29] reported that crude oil contains heavy metals and possibly added to the soil during oil spillage but below their critical levels for crop production [30].

4. Conclusion

The study revealed that the study soils were deep and well drained with high proportion of percent sand. Oil exploration activities had a meager effect on particle sizes, influences soil properties by increasing the values of Om, C/N ratio, % H and Al saturation. Soil pH, N, P, % B. sat are decreased as influenced by crude oil pollution. Concentration of heavy metals in the polluted soils were compounded by crude oil pollution and showed a significant difference ($P<0.05$). The study indicated that crude oil exhibited a negative influence on soil productivity in the Niger Delta region of Nigeria, hence required improved agronomic practices and crude oil remediation for optimum agricultural production.

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