Effect of Oil Spillage on Selected Heavy Metals Concentration in the Soils of Ihugbogo in Ahoada East, Niger-Delta, Nigeria.

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Abstract

This study was carried out in Ihugbogo community, Ahoada East, Southern Nigeria- a community where Total E & P Nig. Ltd has carried out oil exploration and drilling dating back to over thirty years. This has led to a number of spillages on most arable soils in a community where peasant farming is a major occupation. Three locations were selected for the study, and designated as Location A, B and C which had experienced spillage in 1995, 2002 and 2007 respectively. Causes of spillage ranged from activity of vandals, leakage or explosion of the piping materials and or pressure from the crude oil products. This research however, sought to investigate the effects of the crude oil spillage on the selected heavy metals concentration of the soils as excess dosage of heavy metals on soils and invariably crops may lead to adverse health effect on man and animals which depend on crops for survival. The selected heavy metals studied were Chromium (Cr), Cadmium (Pb) and Lead (Pb). Results obtained indicated that Chromium and Lead were within the allowable limits (< 100 mg/kg) while Cd had value beyond the allowable limits (>3.0 mg/kg) according to World Health Organization. Physical and Chemical Properties of the studied soils indicated that the soils ranged from Sandy loam in locations A and B to Sandy in Location B. Available P was very low (<5.0 mg/kg) in locations A and B and moderate (5 – 15mg/kg) in location C while the exchangeable bases were very low as Ca was <2.0 cmol/kg, K and Na were <0.1 cmol/kg in locations A, B and C except Mg which was moderate (1.5 – 3 cmol/kg) in locations A and B and low (< 1.5 cmol/kg) in location C when the threshold limits were considered. There was a very strong and positive correlation between the heavy metals studied and soil organic carbon. For the studied soil to be very fit for agricultural productivity, liming will be necessary to reduce the soil acidity while organic and inorganic materials will be needed to enhance the nutrient element status of the soil.

Key words: oil spillage, heavy metals, soil nutrients, soil properties, ihugbogo community

Introduction

Anthropogenic activities have presented a growing environmental problem affecting food quality and human health in the Niger Delta Region of Nigeria. Nigeria as a major producer and exporter of crude petroleum oil continues to experience oil spills and this exposes the environment to hazards and its attendant effects on agricultural lands as well as plant growth and development (Agbogidi et al., 2005). Soil is the valuable natural resources of a nation whose quality determines its capability to function well for many intended uses (Onweremadu et al., 2007). Food is the most basic of human need for survival, health and productivity (Smith, 2006) but land degradation brought about by prolonged interface between human induced and natural factors exacerbated low food productivity (Di Falco et al., 2006) as well as its quality. One of the problems of land degradation is the accumulation of toxic heavy metals such as Mercury, Chromium, Lead, Copper, and Cadmium etc in agricultural soil (Isirimah et al., 2003).

Heavy metals concentrations in southern Nigeria soils include input from oil spillage (Roulet et al., 1999). Those from the commercial fertilizers, living materials sewage sludge, atmospheric deposition (Sensesi et al., 1999) and repeated application of organic manures, fungicides and pesticides (Li et al., 1997). Nevertheless, some of these heavy metals are naturally occurring and possibly from weathering of rocks but their concentration in the pedosphere increases due to anthropogenic inputs (Li et al., 1997). These heavy metals when present in the soil tend to decline the quality of the soil for many intended uses. As such incorporation of these heavy metals in the soil is one of the constraints to the use of waste as soil treatment (Warman et al., 1999). Pasture and crop plants act as vehicles for transferring these heavy metals and other toxic constituents into the soil and hence into the food chain (Onweremadu et al., 2006). However, the mobility of metals from solid to solution in the soil is mainly controlled by sorption – adsorption, chelating, precipitation, and oxidation – reduction process of the metal in soil (Basta et al., 2004). Some plants accumulate these heavy metals in their tissues where these constitute serious health hazards to man, grazing animals and the environment (Ellis et al., 2003).

The chronic problems associated with long term heavy metals exposure, include serious hematological and brain damage, anemia and kidney malfunctioning (Sonayi et al., 2009). Heavy metals such as Pb and Cd are lethal even in very small dose. Lead has a negative influence on the somatic development, decreases the visual acuity and acidities thresholds (Simeonov et al., 2010). Acute exposure to lead causes brain damage, neurotically symptoms, brain damage and could lead to death (Simeonov et al., 2010). Cd exposure on the other hand, causes renal dysfunction, calcium metabolism disorders and also increased incidence of some forms of cancer possibly due to the inhibition by Cd of DNA mismatch remediation (Kumar, 2009). Malignant Neoplasia and skin ulcers have been reported due to various occupations with exposure to chromium compounds. Chromium VI inhalation is responsible for bronchial asthma (Sarkar, 2005). In Ihugbogo Community, farming is the major occupation of the people within a farm land where Total E&P Nig. Ltd pipe line pass across. Therefore, the accumulation of heavy metals in soils of Ihugbogo Community is gotten from crude oil spillage. The objective of this research was to investigate the effect of oil spillage on heavy metals concentration of Ihugbogo soils in Ahoada East, Southern Nigeria.

Materials and Methods

Study Area - Location

Ahoada is located on the Latitude 5° 07’01” and 5° 4’26”N and Longitude 6° 39’12”and 6°65’01”E. Elevation is below 100m above the sea level. The rainfall distribution is seasonal, rain occurs, on the average, every month of the year, but with varying duration. It is characterized by high rainfall, which decreases from south to north. Total annual rainfall ranges from 2,700mm to 3,500mm in the region. The maximum monthly temperature ranges from 28°C to 33°C, while the mean minimum monthly temperatures are in the range of 17°C to 24°C. The hottest months are February to April. The difference between the dry season and the wet season temperature is only about 2°C. Relative humidity is high (91 – 94%) throughout the year and decreases slightly in the dry season.

Table 1. *Location Coordinates of Study area*

Location	Long.	Lat.	Elevation (m)
ILA	6° 65″	5° 19″	60
ILB	6° 54″	5° 23″	60
ILC	6° 60″	5° 11″	61

ILA, B and C: Ihugbogo locations A, B and C

Socio-economic Activities

About 50 percent of the active labour force engages in one form of agricultural activity or another in which about 30 percent are women. The predominant food crops in the area are yam, cassava, plantain, maize, cocoyam, and vegetable. The dominant trees are mahogany (Angio spp), Obeche (*Protobullas spp*) and Iroko (*Cassia spp*).

Field Work

A reconnaissance study was carried out and the study location identified in Ihugbogo community along an oil pipeline track that cuts across major farmlands in the area. The three major locations investigated, designated as Location A, B and C had experienced spillage in 1995, 2002 and 2007 respectively. The spillage had been caused by TOTAL E&P Nig. Ltd pipeline. About five samples were collected in each of the locations and subjected to laboratory analysis to determine the effect of oil spillage on the selected heavy metals such as; Lead (Pb), Chromium (Cr) and Cadmium (Cd) concentration of the soils as well as soil physical and chemical properties.

Laboratory Analysis

The following soil properties were determined by standard routine laboratory methods as follows: The particle size distribution was determined by hydrometer method according to the procedures of (Gee and Or, 2002), Bulk density was measured by core method (Gross man and Reinsch, 2002). Porosity was computed from bulk density and particle density. Soil pH was determined potentiometrically in 1:25 soil liquid ratio (Hendershot et al., 1993). Organic carbon was determined using method described by (Nelson and Sommers, 1982) and the result of organic carbon was multiplied by 1.724 to determine the organic matter content. Total available phosphorus was determined using Bray II method (Olsen and Sommers, 1982). Total Nitrogen was determined using Kjeidal Digestion and Technicon/Auto analyzer method. Exchangeable base was determined by extraction of ammonia acetate (NH_4O_{AC}) at pH 7.0 known as extractant in determining calcium, magnesium while sodium and potassium was determined using flame photometer. The exchangeable acidity was determined using extraction of exchangeable H^+ and $Al^{3+}$with KCl and titrated as outlined by (Mclaren et al., 1994). The effective cation capacity was estimated by the summation of all the exchangeable base and acidity.

Statistical Analysis

Coefficient of variation (C.V) ranked as follows: low variation ≤ 15%, moderate variation > 15≤36%. High variation >35% was used to estimate the degree of variability of soil properties (Wilding et al., 1994).

Results and Discussion

Soils physical properties of the investigated soils were as shown in table 2 where soil texture were dominated by sand and loamy sand in all investigated soils as highest sand occurred at location C (85.36%), followed by location A (76.36%) while Location B indicated lowest content (59.76%). The means of silt and clay contents were 17.08, 30.88, 10.80 and 6.56, 7.36, 6.56% for silt and clay contents in locations A, B and C respectively. Bulk densities were high in locations C (1.66 g/cm^3) and A (1.64 g/cm^3) while location B (1.57 g/cm^3) indicated the lowest bull density. The high bulk densities distributions in the investigated soils may have resulted due to high preponderance of sand especially as seen in locations C and A respectively. Bulk density values were less than the acceptable limits of 1.85 g/cm^3 as suggested by Akamigbo 1999.

Table 2. *Mean of Selected Soil Physical Properties in the three Locations*

	SAND (%)	SILT (%)	CLAY (%)	Bulk Density (g/cm^3)	TC
Location A	76.36	17.08	6.56	1.64	LS
CV (%)	9.7	36.4	27.2	2.3	
Location B	59.76	30.88	7.36	1.57	LS
CV (%)	9.6	15.5	53.2	2.7	
Location C	85.36	10.8	6.56	1.66	S
CV (%)	3.1	62.1	46.2	2.3	
Lsd (0.05%)	NS	NS	NS	NS	

Coefficient of variation of physical properties indicated that sand varied lowly in all the investigated locations; CV<15% scoring 9.7, 9.6 and 3.1 % in Locations A, B and C respectively. Silt had moderate variability in location B (15.5%) and high variability in Locations A and B where they scored 36.4 and 62.1% respectively. Clay however varied moderately (CV >15≤35%) in location A and highly (CV>35%) in locations B and C. Bulk density varied lowly (CV<15%) in all investigated locations.

Table 3. *Means of Soil Chemical Properties in the three Locations*

SAMPLE	pH	pH	OC	TN	Av. P	Ca	Mg	K	Na	Al^{3+}	H^{+}	TEA	TEB	ECEC	%BS
Location A	(H_2O)	(KCl)	(%)	(%)	(mg/kg)	← Cmol/kg →									
MEAN	5.484	4.866	1.68	0.286	3.942	0.784	1.744	0.004	0.005	0.48	0.334	0.84	2.639	3.5004	67.542
CV (%)	6.8	2.9	9.7	95.3	21.9	94.1	91.4	18.2	24.6	21.6	54.9	16.0	73.0	64.9	34.1
Location B															
MEAN	5.334	4.836	1.7434	0.163	3.763	0.856	1.078	0.003	0.005	0.536	0.332	0.87	1.939	2.813	62.873
CV (%)	2.8	4.0	7.4	15.1	36.9	91.4	76.6	37.8	82.6	13.8	26.5	13.9	65.2	43.9	29.6
Location C															
MEAN	5.528	4.65	0.85	0.204	5.138	1.072	0.614	0.002	0.009	0.482	0.376	0.818	0.896	2.18	54.551
CV (%)	5.2	5.1	25.5	157.3	26.3	51.5	72.9	18.7	3.1	19.4	26.2	14.0	58.2	33.6	35.5
Lsd (0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

OC= Organic Carbon, Av.P= Available Phosphorus, TEA= Total exchangeable acidity, TEB= Total exchangeable bases, ECEC= effective cation exchange capacity, %BS=percentage base saturation

Soils pH was both measured in water and in KCl as pH in KCl would release internally held reserved acidity of soils (Table 3). It is however noticed that pH in KCl was lower than the pH measured in water. The pH in the various locations as measured in KCl were 4.866, 4.836 and 4.65 in locations A, B and C respectively. This pH is highly acidic as it falls below the acceptable pH range of 5.5 -6.5 in arable soils (Tabi et al 2012). The high acidic content may not have resulted entirely due to oil spill as most soils in the southern Nigeria have been known to be highly acidic, fragile and leached (Iheka et al., 2015).

Organic carbon content was moderate in locations A (1.68%) and B (1.743%) while it is low in location C (0.85%). Total Nitrogen also follows the same trend; 0.286, 0.163 and 0.204% in locations A, B and C respectively. It is worthy to note that organic carbon and total nitrogen are a function of organic matter content of soils (Obasi et al., 2015). Although the results obtained on organic carbon were moderate and low, in the investigated soils, oil spill tend to increase the organic carbon content of soils (Marinescu et al., 2010). However, the duration of this spillage having taken a long while (1995, 2002 and 2007 in locations A, B and C respectively) may have contributed to the recuperation of the studied soils. This recuperation is enhanced through the activities of microbial organisms in the decomposition of litter and mineralization or organic compounds leading to phyto-remediation.

Available P contents of these soils were very low on the scale of critical limits of available P in the tropical soils. Mean available P content of the studied locations were 3.942, 3.763 and 5.138 mg/kg in locations A, B and C respectively. The expected moderate available P ranges from 5 – 15 mg/kg. Therefore, location C tends to have a relatively acceptable available P content.

Calcium, Potassium and Sodium were very low in the investigated soil. Ca had 0.784, 0.856 and 1.072 cmol/kg, K had 0.004, 0.003 and 0.002 cmol/kg Na had; 0.005, 0.005 nd 0.009 cmol/kg while Mg had 1.744, 1.078 and 0.614 cmol/kg all in locations A, B and C respectively. Only Mg in location A had the moderate Mg requirement of >1.5 cmol/kg according to Tabi et al 2012 who gave the moderate Mg requirement as 1.5 – 3.0 cmol/kg. Total exchangeable bases (TEB) scored 2.639, 1.939 and 0.896 cmol/kg in locations A, B and C respectively. Effective cation exchange capacity (ECEC) also recorded 3.5004, 2.813 and

2.18 cmol/kg in locations A, B and C. The base saturations were 67.542, 62.873 and 54.551% in locations A, B and C.

The implication of the low contents of exchangeable bases follows the fact that the studied soils will likely struggle to provide the nutrient elements needed for plants growth and development. Exchangeable bases are nutrient elements adsorbed in the clay complex of soils and made available to the roots nodules of crops. The effects of oil spillage on these soils may have included fixation of these nutrients as well as reduction of soil aeration leading to the choking of soil fauna. This situation will ultimately reduce the mineralization activities taking place in the soil thereby immobilizing the few available nutrient elements.

The pH in water and KCl all had low variability (CV<15%) in all investigated locations. Organic carbon and Total Nitrogen had low variability (CV<15%) in locations A and B and moderate (CV>15≤35%) in location C. Total exchangeable bases varied highly (CV>35%) in all locations while ECEC varied highly in locations A and B and moderately (CV>15≤35%) in location C while Base saturation varied moderately (CV>15≤35%) in locations A and B and highly (CV>35%) in location C. There was however no significant difference in all investigated soil properties at the three locations of the studied area.

Table 4. *Heavy Metals in Crude Oil Spilled Site in Ihugbogo under TEPN Pipeline*

Parameter		Location A (mg/kg)				Mean
	ILA 1	ILA 2	ILA 3	ILA 4	ILA 5	
Cr	3.776	3.168	3.789	3.512	3.513	3.551
Pb	6.2	6.48	6.512	6.10	6.211	6.286
Cd	3.04	2.944	2.961	2.10	2.20	2.649
		Location B				
	ILB 1	ILB 2	ILB 3	ILB 4	ILB 5	
Cr	3.888	3.16	3.221	3.711	3.598	3.515
Pb	6.688	6.768	6.910	6.661	2.752	5.954
Cd	3.20	3.168	3.442	3.510	3.11	3.286
		Location C				
	ILC 1	ILC 2	ILC 3	ILC 4	ILC 5	
Cr	2.294	2.08	2.981	2.611	2.501	2.493
Pb	2.752	2.312	2.910	2.512	2.322	2.561
Cd	1.344	1.504	1.982	1.332	1.291	1.490

ILA = Ihugbogo location A, ILB = Ihugbogo location B, ILC = Ihugbogo location C

The three heavy metals considered in the studied sites were Chromium (Cr), Lead (Pb) and Cadmium (Cd) as shown in Table 4. Chromium had means of 3.551, 3.515 and 2.493 mg/kg in locations A, B and C respectively. Lead had means of 6.286, 5.954 and 2.561 mg/kg in locations A, B and C respectively. Cadmium however recorded 2.649, 3.286 and 1.490mg/kg in locations A, B and C respectively. When the minimum allowable limits were considered according to World Health Organization (WHO), Cr and Pb were within the acceptable limits in the studied soils while Cd was higher than the allowable limits of 3.0 mg/kg (Atieno et al., 2011). Also when the minimum allowable limits of countries like Poland, United Kingdom, United States of America and Australia were considered (Mantaz and Chowdhary 2006); Cr and Pb were within the allowable range while Cd falls beyond the allowable limits of Poland, United Kingdom and United States of America, whereas it falls within the allowable limits of the country of Australia.

Table 5. *Correlation of some soils properties with Heavy metals*

	%BS	Av. P	Al^3Sat	Ca	Cd	Cr	ECEC	OC	Pb	TEB	pHKCl
%BS	1										
Av. P	-0.407	1									
Al^3Sat	-0.325	0.0662	1								
Ca	0.6204	-0.2646	-0.6112	1							
Cd	0.3773	-0.5501	0.1326	0.0979	1						
Cr	0.4580	-0.5701	-0.1724	0.3654	0.8019	1					
ECEC	0.9194	-0.2568	-0.4050	0.7426	0.2469	0.3731	1				
Mg	0.7796	-0.0341	-0.1620	0.3591	0.1618	0.2321	0.8341				
OC	0.5480	-0.3005	0.0399	0.3170	0.6671	0.7008	0.5313	1			
Pb	0.3038	-0.3359	0.1755	-0.0254	0.7835	0.7483	0.1744	0.7364	1		
TEB	0.9085	-0.2368	-0.4643	0.7445	0.2415	0.3638	0.9953	0.5146	0.1689	1	
pH_KCl	0.2507	-0.1118	-0.6594	0.3315	-0.2200	-0.052	0.3312	0.2484	-0.393	0.369	1

Table 6. *Mean and Range of Current Study in Comparison with WHO (2006) Maximum Allowed Limits*

Parameters	Mean ± SE (Range of present study in mg/kg)	WHO values (mg/kg)
Cr	3.551 – 2.493	100.00
Pb	5.954 – 2.561	100.00
Cd	3.286 – 1.490	3.00

WHO Values Source**:** Mantaz and Chowdhary (2006); Atieno *et al.,* (2011)

Table 7. *Shows the MAL for different Countries in Comparison to the levels Obtained in the Study*

Element	Poland	UK	USA	Australia	Mean obtained in Current study mg/kg
Cr	100.000	50.000	100.000	100.000	3.515
Pb	100.000	100.000	200.000	100.000	5.954
Cd	3.000	3.000	0.7.000	5.000	3.286

Source: Mantaz and Chowdhary (2006)

The correlation of studied heavy metals with some selected soil properties were as shown in Table 5. Cadmium correlated highly and negatively with available P, it correlated highly and positively with Cr, Organic Carbon and Pb. Chromium correlated highly and negatively with available P, highly and positively with Cd, Organic C and Pb. Lead correlated highly and positively with Cd, Cr and Organic C. the studied heavy metals however had low correlation with all other studied soil properties. This study agrees with that of Onweremadu and Duruigbo (2007) and Nkwopara et al (2012) that heavy metal such as Cadmium have strong and positive correlation with soil organic carbon.

Conclusion

The investigated soils were very acidic, very low in exchangeable cations as well as low available P. The effects of oil spillage on these soils may have included fixation of these nutrients as well as reduction of soil aeration leading to the choking of soil fauna. This situation will ultimately reduce the mineralization activities taking place in the soil thereby immobilizing the few available nutrient elements. The studied heavy metals all had strong and positive correlation with organic carbon. Cadmium correlated highly and negatively with available P, it correlated highly and positively with Cr, Organic Carbon and Pb. Chromium correlated highly and negatively with available P, highly and positively with Cd, Organic C and Pb. Lead correlated highly and positively with Cd, Cr and Organic C. the studied heavy metals however had low correlation with all other studied soil properties. These soils need inputs that would neutralize the high acidity such as liming as well as use of fertilizer and organic materials to enhance the nutrients need of the studied soils.

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