JOURNAL of SUSTAINABLE TROPICAL AGRICULTURAL RESEARCH

VOLUME 15

An international and interdisciplinary academic journal for the publication of critical reviews, analytical expositions, theoretical and empirical research reports in all areas of tropical agriculture and related disciplines:

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Prof. Lawrence Etim *(Ph.D., B.Sc.)*
Editor-in-Chief/Executive Editor

2005 *Treasure Publishers, Nigeria* *ISSN 1596-079X*

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THE CONCENTRATIONS OF SOME TOXIC METAL IONS IN A TROPICAL ULTISOL FROM THE COASTAL PLAIN AREA OF AKWA IBOM STATE, NIGERIA.

UDOSEN, E. D • AWAKA-AMA, J. J.
Department of Chemistry, University Uyo, Nigeria.
e- mail:essienandong@yahoo.com. Tel: +234-8036706060

ABSTRACT

The variations in the concentrations and mobility of ten (10) toxic metal ions (Pb, Cd, Ni, As, Se, Hg, Cr, Fe and Zn) in a tropical ultisol from the coastal plain area of Akwa Ibom State, Nigeria was investigated using soil samples obtained from ten (10) different locations at four (4) soil depths of 10 cm, 15 cm, 20 cm and 25 cm. A general decreasing trend in metal concentration with soil depth was established. The mean concentration (μgg^{-1}) of the metal in the soil at a profile of 10cm were Pb(40:05); Cd(0.00); Ni(0.09); Se(0.45); Hg(0.04); Cr(0.06); Cu(126.25); Fe(6375.00) and Zn(254.50). From the overall results, four distinctive trends were discernable viz. Hg>Cu at a depth of 10 cm, Cd>Hg at 15 cm, Ni = Cd at 20 cm and Cd>Ni at the depth of 25 cm. The concentration of Cu, Fe and Zn were hign (P= 0.001) indicating a significant heavy metal pollution of the soil based on set standards. The relative migration of the heavy metals decreased in the order Fe>Zn>Cu>Pb=Cr=Se=Ni=Hg=Cd=As in the soil depths. The possible effects of the acidic characteristics of the ultisol (with mean pH of 4.90) and other physicochemical parameters of the soil, in relation to the mobility of the metals ions and its implications to the environment have been discussed.

Key words: Toxic metals, ultisol, coastal plain, mobility, Ibeno, Akwa Ibom, Nigeria

CITATION

Udosen, E. D and Awaka-Ama, J. J 2005.Concentration s of some toxic metal ions in a tropical ultisol from the coastal plain area of Akwa Ibom State, Nigeria. **Journal of Sustainable Tropical Agricultural Research 15** : 86 - 92

INTRODUCTION

Recently, environmental scientists have raised concern on the increasing ecological and toxicological problems arising from the pollution of the environment. Heavy metals represent an important source of pollutant. While many heavy metals are essential elements at low levels, they can exert toxic effects at concentrations higher than those permitted in the environment (Dean-Ross and Mills, 1989). Soil receives heavy metals coming from different sources and at the same time acts as a buffer that controls the movement of these heavy metals to other natural components.

The soils of the coastal plain areas of Akwa Ibom State and the Niger Delta region in Nigeria are generally acid soils with pH ranging from 3.0 to 6.0 (Dublin-Green et. al., 2003). The potential of heavy metals to migrate in soil is primarily controlled by pH, redox potential, total metal concentration, complexation and ion exchange (EPA, 1987; Udosen et al; 2001). However, little attention has been given to their transport dynamics in the soil of the Niger Delta environment. The objectives of this study are to determine the concentration and mobility of these metals in the soil at different depths in order to ascertain the quality of the ultisol of the Niger Delta.

METHODS

The study was carried out in Mkpanak, Ibeno in Akwa Ibom State. The region is located within the coastal (Niger Delta) region of Nigeria (Fig.1).

The region is characterised by bi-modal rainfall pattern and acidic sandy loam soils classified as Ferralitic sandy-loam ultisols (Udo et al, 1981; Essien and Udosen 2000). Ibeno is located in a typical climatic zone with distinct dry and wet seasons. The dry season begins in November to February while the rainy season begins in March to October, with peak periods of heavy rain in July and a period of two weeks of 'August break' within the peak of the rainy season.

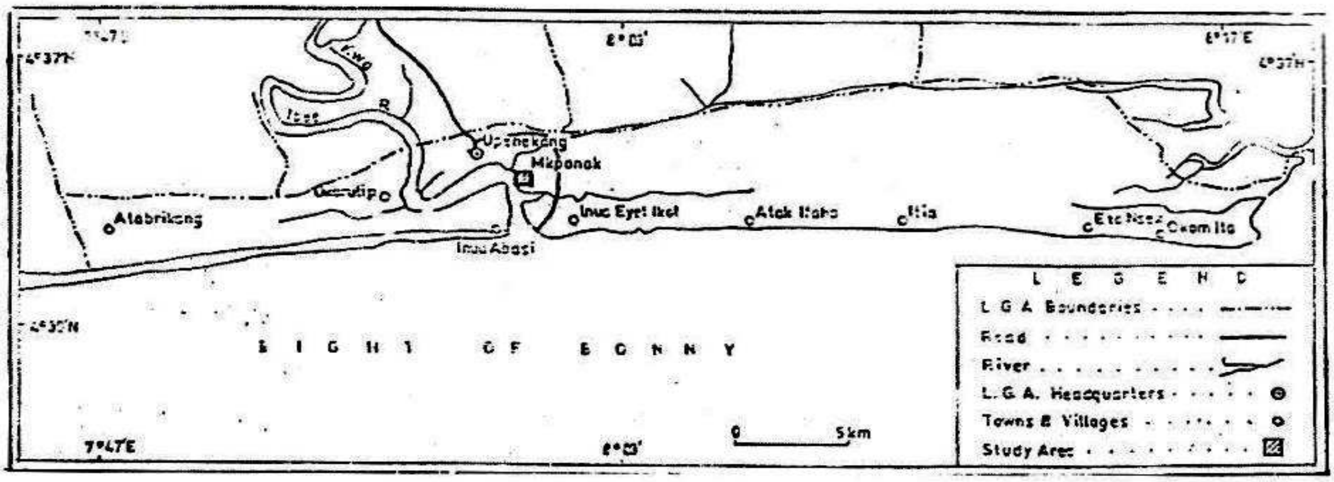

Fig.1: Ibeno Local Government Area Showing Study Area

A total of 40 soil samples were collected with a coring cylinder at the depth of 10 cm, 15 cm, 20 cm and 25 cm from 10 sampling locations (L_1-L_{10}). The samples were stored in a precleaned metal-free polythene bags and immediately taken to the laboratory for further analysis. Soil pH was measured in water in a ratio 1:1 soil/water suspension using a pH meter (Udo and Ogunwale, 1986). Particle size distributions of the soils were determined by hydrometer technique (Day, 1965). The organic carbon was determined by the modified dichromate wet oxidation method of Nelson and Somers (1982). The total nitrogen was estimated by the micro-Kjeldahl digestion and distillation method. The P-value in the soil was determined after extraction by 0.5 mol/l $NaHCO_3$ solution and exchangeable cations were determined after extractions by 1mol/l NH_4 acetate solution, using the flame photometer (AOAC, 1986; Udo and Ogunwale, 1986). Heavy metals concentrations were determined using atomic absorption spectrophotometer.

RESULTS

SOIL CHARACTERISTICS: The physical and chemical parameters of the soils from 10 sampling locations (L_1-L_{10}) are summarized in Table I. The silt fraction of the soil was generally low (in the range of 4-10%) with a mean value of 6.4% throughout the entire profiles. There were no gravels but the coarse sand fraction (57.80 to 71.80%) was generally higher than the fine sand fraction (20.20 to 32.20%) in the soil profile. The bulk density was found to be in the range of 1.3 to 1.6 g/cm^3 with a mean value of 1.51 g/cm^3 in these soils.

The total porosity of the soils ranged from 36 to 49% (Table I). The organic carbon content of the soil was generally low with a mean value of 2.90%. The effective cation-exchange capacity (ECEC) of the ultisol varied widely from 7.78 to 18.0 mol/kg. The results in Table 1 also show that pH values in water fell between 4.46 and 5.46. The exchange acidity (EA) on the other hand was relatively high with a mean value of 3.08 mol/kg in the samples.

The mean values of heavy metal concentrations in the soils at 10 cm, 15 cm, 20 cm and 25 cm soil depths are presented in Table 2. High (ANOVA; LSD) concentrations of Pb, Cu, Fe and Zn were obtained with the highest concentrations obtained for Fe (P=0.001). Table 3 indicates the variation of heavy metal concentrations with soil depths.

DISCUSSION

The major sources of heavy metals in the coastal plain area of Akwa Ibom State, Nigeria are industrial processes, leaching of metals from garbage, solid waste dumps and extensive crude oil exploration activities in the area by oil companies. By Le chatelier's principle a system reacts when basic conditions change. The same happens with the mobilization of heavy metals in soils. Any change in parameters like pH, salt concentration (activity) and soluble complexing organic agents can either cause mobilization or remobilization of heavy metals. These results in changing milieus discussed in this paper.

The possible effects of heavy metal pollutants on soil properties include change in redox potential, increase in soil acidity (pH), reduction in the bulk density of soil and soil porosity (Roscoe, 1989). The soil texture and structure exert a large influence on weight and pore space. The transfer of contaminants depends on diffusion through a porous medium and other variables such as soil porosity and moisture (Dragun, 1988). Although the total pore space in the test soils is low, a large proportion of it is composed of large pores that are very efficient in the movement of water and air. The percentage of the volume occupied by small pores in sandy soils is low and this accounts for the low water-holding capacity. The organic matter contents in these soils are in agreement with those observed by Udo and Ogunwale (1986). The organic carbon was observed to decrease rapidly with depth. The organic matter is the most reactive component of soil because of the low activities of the predominantly kaolinitic clay minerals found in ultisols (Udo et al; 1981).

The concentrations of the basic cations in the soil (Ca and Mg) were relatively low. A mean value of 5.16 cmol/kg for Ca and 2.67 cmol/kg for Mg were obtained. The high rainfall that characterizes the study area renders the soil strongly leached and deprived of the basic cations. Similarly, the K and Na levels in the soils were very low. The low levels of the exchangeable K however do not indicate a significant K deficiency threshold of 0.2 cmol/kg (Landon, 1984). The pH level of the soil was low (Table 1) and these soils are strongly acidic in character. This may have resulted in the high Fe concentration obtained in the soil. The availability of heavy metals and their potential to migrate is primarily governed by pH, redox potential and complexation processes. The high heavy metal concentrations indicated a contamination of the soil with the toxic metals (Table 2). However, the concentrations of Cd, Ni, As, Hg and Cr were low and not enough to pose a danger of contamination in the test soils. Pb, Cu, Fe and Zn, which occurred in considerable concentrations, are transition metals capable of forming complexes. Complexation increases the potential mobility of metals because the complexed metal is effectively more soluble and the complex formed bind what would have otherwise been free metallic ions and thereby decreases the chances of adsorption or precipitation as salts (Piwoni and Keeley, 1990).

The heavy metal concentrations in the soil samples from the study area are given in Table 2.The mean concentrations of As, Cd, Ni, Se, Hg and Cr in a tropical ultisol at different depths are shown in fig.2.There were variations in Pb, Cu, Fe and Zn concentrations with soil depths (Fig. 3). At a depth of 10 cm, the trend in the concentrations of the metal was Fe>Zn>Cu>Pb>Cr>Se>Hg>Ni>Cd>As. At a depth of 15 cm, the trend was Fe>Zn>Cu>Pb>Cr>Se>Ni>Cd>Hg>As. Similarly, the trend at a depth of 20 cm was Fe>Zn>Cu>Pb>Cr>Se>Ni=Cd>Hg>As, while at a depth of 25 cm it was Fe>Zn>Cu>Pb>Cr>Se>Cd>Ni>Hg>As. Four distinctive trends are therefore discernable viz. Hg>Cd at a depth of 10 cm, Cd>Hg at 15 cm, Ni = Cd at 20 cm and Cd>Ni at depth of 25 cm (Fig. 2). Cu, Fe and Zn concentrations were observed to decrease with depths (Fig.3). The coefficient of variation of metals at different soil depths in given in Fig. 4.

Heavy metal contamination of soil and the mobility of the metal ions in the soil environment have been established as a function of the physicochemical properties of the soil. The mobilization mechanism is controlled by the changing parameters such as pH, redox, complexation and ion activity. Recent research studies by Udosen et al. (2001) have indicated heavy metal pollution of the coastal plain area of the Niger Delta, Nigeria. This work confirms the high concentration of heavy metals such as Pb, Cu, Fe and Zn in the ultisol.

The migration of these metal ions in the case of tropical ultisols is essentially and extensively influenced by the acidic nature of the soil, which aids in the partitioning of the metals to more soluble and mobile species. The problems of toxic metal contamination of the surface soil and possible biomagnification by accompanying co-reactions may prolong the path of toxic metal invasion by migration into the sphere of other milieus and consequently permit their easier uptake by living organisms and degradation of agricultural land with an accompanying undesirable consequences. In view of the soil structure and its peculiar chemical characteristics, and in consideration of the high concentration of Pb, Cu, Fe and Zn it is pertinent to note the possible danger of heavy metal ions migration with percolation (seepage) into the groundwater, which can result in a cycle of pollution. Leaching tests under different conditions should clarify the remobilization of heavy metals and its impacts on soil and groundwater quality. The understanding of these becomes essential for the complex evaluation of quality and remediation of soils in the tropics.

Table 1: The levels of physicochemical parameters in soil

							Exchangeable Bases									Particle Size		
	PH	EC	organic	Total N	Avail. P	Moisture Content	Ca	Mg	Na	K	EA	ECEC	B.S	Bulk Density	Total Porosity	Sand	Silt	Clay
Location	(H_2O)	ds/m	%	%	Mg/kg	%		meq			(mol/kg)		%	g/cm^3	%	%	%	%
1	5.33	0.1940	3.89	0.19	21.66	20.00	9.60	4.82	0.10	0.25	2.27	17.49	84.44	1.57	40.75	71.80	8.00	20.20
2	5.23	0.3680	3.26	0.16	10.66	13.60	4.80	2.40	0.29	0.32	2.74	10.55	74.03	1.42	46.42	69.80	6.00	24.20
3	4.70	0.8260	2.61	0.13	9.33	21.70	10.32	4.20	0.23	0.30	2.96	18.01	83.56	1.68	36.60	56.80	6.00	28.20
4	4.61	1.561	2.28	0.11	4.66	16.40	4.80	2.40	0.23	0.40	3.10	10.93	71.64	1.36	46.68	67.80	6.00	26.20
5	4.46	0.600	4.52	0.23	2.49	17.00	2.88	1.92	0.27	0.27	2.44	7.78	68.63	1.33	49.81	65.80	4.00	30.20
6	4.49	0.0159	3.00	0.15	5.46	14.40	4.80	2.88	0.30	0.26	3.96	12.20	67.54	1.57	40.75	63.80	4.00	32.20
7	5.10	0.0195	1.62	0.10	2.83	12.90	4.80	2.40	0.22	0.29	3.72	11.53	67.74	1.68	36.60	67.80	8.00	24.20
8	4.97	0.4630	2.61	0.12	1.66	20.40	3.60	2.16	0.21	0.29	2.93	9.16	68.01	1.40	48.10	69.80	6.00	24.20
9	4.71	0.6880	3.53	0.18	4.36	18.20	3.60	1.92	0.35	0.30	2.70	8.91	69.69	1.42	46.42	63.80	6.00	30.20
10	5.46	0.0153	1.75	0.11	4.36	13.10	2.40	1.68	0.16	0.31	3.60	8.15	55.83	1.67	36.40	57.80	10.00	32.20
$\bar{X}$	4.90	0.4750	2.90	0.14	6.74	16.70	5.16	2.67	0.23	0.29	3.08	11.47	71.11	1.51	43.05	66.40	6.40	27.20
S.D.	0.34	0.564	0.871	0.0399	5.68	3.07	2.54	0.98	0.68	0.039	0.48	3.42	7.23	0.13	5.13	4.78	1.74	3.82
C.V.(%)	6.99	96.10	30.05	28.5	84.41	18.38	49.19	36.6	29.6	13.16	15.54	29.84	10.17	8.73	11.92	7.19	27.24	14.04

Table 2: Variation of heavy metal concentration with soil depths

Heavy metals (µg/g)	Soil depth			
	10cm	15cm	20cm	25cm
Pb	40.05	29.08	24.49	21.45
Cd	0.00	0.05	0.04	0.04
Ni	0.09	0.06	0.04	0.025
Se	0.445	0.43	0.43	0.42
Hg	0.04	0.04	0.02	0.02
Cr	0.595	0.61	0.595	0.555
Cu	126.25	107.75	97.85	79.55
Fe	6375.0	5716.45	4770.00	3795.96
Zn	254.5	201.65	143.30	130.25

Table 3: Mean metal concentrations in a tropical ultisol at different soil depths

Depth (cm)	Pb	Cd	Ni	As	Se	Hg	Cr	Cu	Fe	Zn
10	40.05	0.00	0.00	0.00	0.44	0.04	0.66	126.25	6375.00	254.50
15	29.18	0.05	0.006	0.00	0.43	0.04	0.61	107.75	5716.45	201.65
20	24.49	0.04	0.04	0.00	0.43	0.02	0.60	99.60	4770.00	143.30
25	21.46	0.00	0.025	0.00	0.42	0.02	0.56	79.55	3795.96	130.25
Mean	28.80	0.02	0.02	0.00	0.43	0.03	0.61	103.29	5164.35	182.43
S.D.	8.15	0.03	0.02	0.00	0.01	0.01	0.04	19.36	1125.24	57.21
C.V.(%)	28.30	116.89	102.90	0.00	1.90	38.49	6.80	18.76	21.79	31.56

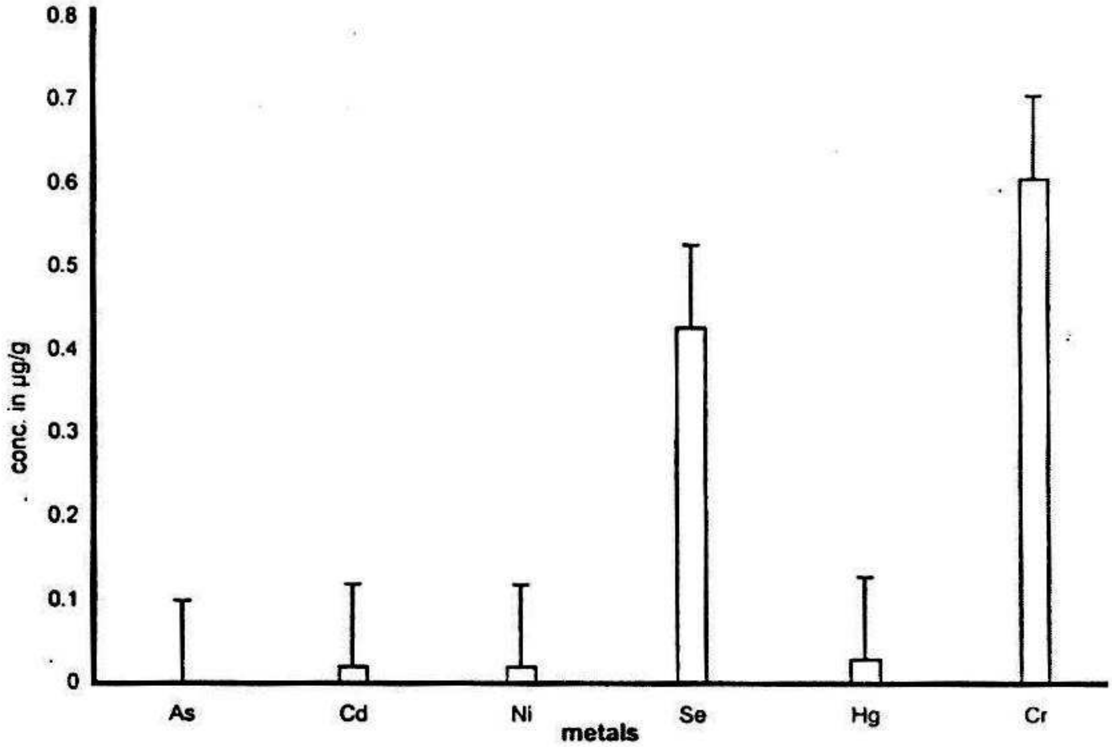

Fig. 2: Mean concentration of As,Cd,Ni,Se,Hg and Cr in a tropical ultisol at different soil depths

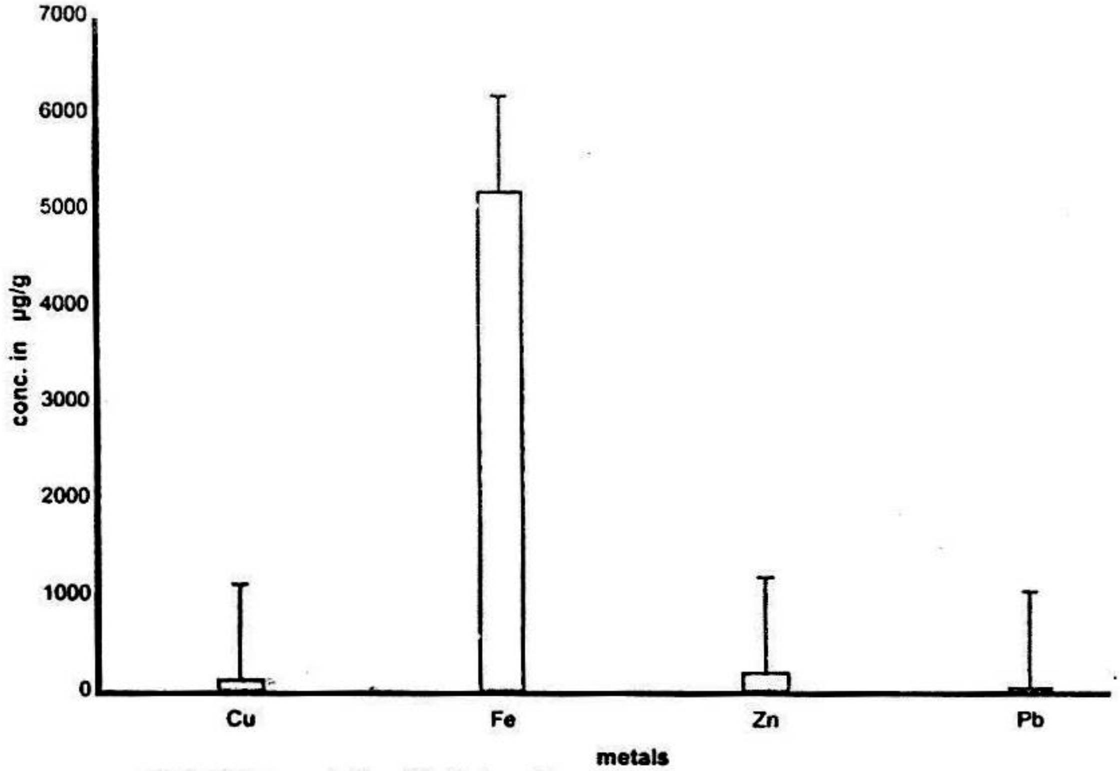

Fig. 3: Mean concentration of Cu,Fe,Zn and Pb in a tropical ultisol at different soil depths

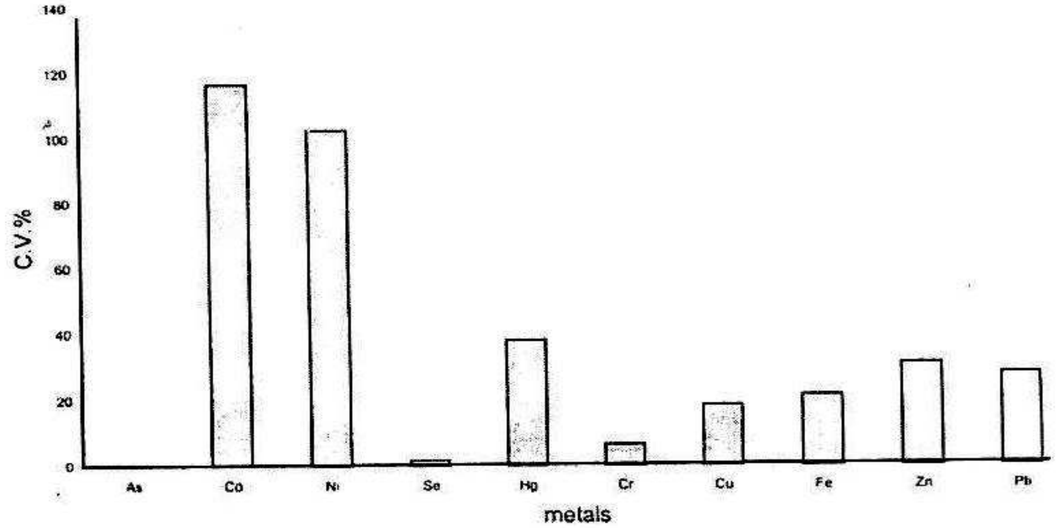

Figure 4: Coefficients of variation of metals at different soil depths

REFERENCES

AOAC.,1986. Association of Official Analytical Chemist. Official methods of Analysis. 11th Edition, Washington D.C pp.200-250.

Day, P. R.1965. Partile fractionation and particle size analysis. In "Methods of soil analysis, Vol.1 Black, C. A. (ed). Am. Soc. Agron. Inc., Madison, Wisconsin. Pp. 547 – 567.

Dean-Ross, D and Mills, A. L., 1989. Bacterial Community Structure and Function along a heavy Metal gradient. Applied and Environmental Microbiology, American Society for Microbiology. Pp 2002 – 2009.

Dragun, J. 1988. "The soil chemistry of Hazardous Materials." Hazardous Materials Control Research Institute, Silver Springs, Md. Pp. 1 – 307.

Dublin-Green, C.O., Ayinla, A.O. and Ogori, T.K., 2003. Management of fishponds built on acid Sulfate soils in Buguma creek, Niger Delta, Nigeria. Journal of Applied Sciences and Environmental Management. 7(2): 39-43

EPA (U.S.A. Environmental Protection Agency), 1987. Exploration, Development and Production crude oil and natural gas, field sampling and analysis results. EPA 30-SW-87-005.

Essien, J. P. and Udosen, E. D., 2000. Distribution of actinomycetes in oil contaminated ultisols of the Niger Delta (Nigeria). Journal of Environmental Sciences. 12(3): 296 – 302.

Landon, J. R., 1984. Bookers Tropical Soil Manual: A Handbook for soil survey and Agricultural Land Evaluation in the Tropics and Sub – Tropics. Longman Inc., New York, (U.S.A), Pp.71 – 156.

Nelson, D. W. and Sommers, L. E., 1982. Total Carbon, organic carbon and organic matter. In: Page, A. L., miller, R. H. and kenergy, D. R. (eds.) Methods of soil analysis Part 2 American Soc. of Agronomy. Madison. Pp 539-579.

Piwoni, M. D. and Keeley, J. W., 1990. "Basic Concepts of Contaminant Sorptionat Hazardous sites." U.S.EPA, Robert S. Kerr. Environmental Research Laboratory, Ada, Oklahoma. EPA/540/4 – 30/053.

Roscoe, I. L., McGrill, W. B., Nyborg, M. P., 1989. Proceedings of Workshop on reclamation of disturbed land. Alberta Information Report No. X-116. Northern Forest Research Centre, 462-470.

Udo, E. J and Ogunwale, J. A., 1986. Laboratory manual for the analysis of soil, plant and water samples. 2nd Edition, University Press, Ibadan. Pp: 174p.

Udo. E. J. Ogunwale, J. A and Mohammed, S., 1981. Characterization of five Nigeria soil profiles developed on coastal plain sands (unpublished).

Udosen, E. D., Essien, J. P. and Ubom, R. M., 2001. Bioamendment of Petroleum Contaminated ultisol: Effect on soil content, heavy metals and pH of tropical soil. Journal of Environmental Sciences, 13 (1): 92-98