ASSESSMENT OF Pb CONCENTRATION OF ARABLE SOILS AROUND OIL EXPLORATION SITES IN NIGER- DELTA, NIGERIA

U.N. Nkwopara[a], J. O. Omeke[b], and S.N. Obasi[a]

(a) Department of Soil science and Technology, Federal University of Technology, P.M.B. 1526 Owerri.
(b) Crop and Forestry National Agricultural Extension and Research Liaison Services, Ahmadu Bello University, Zaria.
* Corresponding author: ugoiken2003@yahoo.com

Abstract

Thirty- two samples were analyzed for their properties and lead concentration in polluted and unpolluted sites of Niger-delta region, Nigeria. A free survey technique was used in the choice of sampling sites. Polluted soils were more acidic (pH =3.97) than unpolluted ones (pH = 4.35). Higher average value of organic matter was recorded in unpolluted soils (mean value =18.2) unlike 13.0 found in polluted soils. Lead concentration was higher in polluted soil (mean value =2.12 mg/kg) contrasting with 0.70 mg/kg obtained in their unpolluted counterparts. Stronger relationship existed between exchangeable bases and lead status in unpolluted soils (R = 0.99, R^2 = 0.98, N = 32) as opposed to values in polluted soils (R =0.77, R^2 = 0.60, N = 32). Exchangeable acidity had higher positive correlation with lead in polluted soils. The relationship was significant at 5 % level of probability.

Keywords: Lead, arable soils, Oil prospecting, Pollution, Niger-delta.

Introduction

Lead is one of the most ubiquitous and toxic heavy metal ions affecting the environment. It is considered to be a risk to human health when soil concentration exceed 400 – 500 mg kg^{-1} soil (USEPA, 2001) and drinking water standard exceed 0.05 mg L^{-1} and 10 µg L^{-1} according to current EPA and WHO report (Modher et al. 2009). It is the labile fraction rather than the total soil Pb that is critical when assessing its availability in soils (Sauve- et al., 2000; Naidu et al., 2008). However, lead availability to plant and soil micro-organism is dependent on the concentration of dissolved metal species in soil solution and the capacity of soil solid phase to replenish the soil solution. Crude oil exploration is a major economic venture in Nigeria which Aiyesanmi (2005) noted has resulted to the release of heavy metals into soils and water bodies through oil spillage. In soils, petroleum hydrocarbon creates conditions which lead to availability of heavy metals toxic to plants (Akamigbo and Jidere, 2002). It implies that the soil remains unsuitable until the crude oil is degraded to a tolerable level (Odu, 1981). This study investigated the lead concentration in crude oil polluted soils of Niger-delta region, Nigeria compared to unpolluted ones.

Materials and Methods

Niger –delta region of Nigeria comprising Akwa – Ibom, Bayelsa, Delta ,Edo, Cross – River , Ondo, Imo , Abia and River states is located between longitude 3^0 and 9^0 E and latitude 4.5^0 and 5.33^0 N, covering a total area of about 75,000 km^2 (Alatise et al., 2008) . The area is believed to be one of the world's most prolific tertiary delta, accounting for about 5 % of the world's oil and gas production (Alatise et al., 2008). It has a humid tropical climate (Nnaji et al. 2002), with temperature uniformly high throughout the year. Soils are mainly ferrallitic and derived from coastal plain sands (SSSN, 1981). The vegetation is described as rainforest. Seasonal flooding characterized the sites. Farming is a major socio-economic activity in the site. Soil fertility regeneration is by bush fallow whose length is drastically shortened by increasing population (Onweremadu, 1994). This study was conducted before the rains in 2008 at Uzere, Oroni and Egbema, Niger –delta, Nigeria. Guided by identification of potentially impacted areas after a reconnaissance survey of the study area, stratified random sampling were done covering polluted and unpolluted sites. Eight pedons were sunk with six being on polluted and the remaining ones on unpolluted land. Four major horizons were identified and sampled from at depths of 0 -20 cm, 20 – 40 cm, 40 – 80 cm, 80 – 200 cm, giving total of 32 soil samples. Soil samples were air –dried and sieved in preparation for laboratory analysis. Particle size distribution was estimated by hydrometer method (Gee and Bauder, 1986). Bulk density was determined by clod method (Blake and Hartge, 1986). Soil pH was obtained by method of Hendershot et al. (1993). Total carbon was measured using Walkley and Black wet digestion method (Nelson and Sommers, 1982). Exchangeable bases (EB) were determined by the complexometric titration method (Jackson,1958). Exchangeable acidity (EA) was evaluated titrimetrically (Mclean, 1965). Effective cation exchange capacity was got by summation. Digestion of soil sample for lead was carried out using a mixture of concentrated $HCl0_4$ and $HN0_3$ at a ratio of 2: 1 and metal was extracted using 0.5 *M* HCl (Lacatusu, 2000). The aliquots obtained were measured for lead using Atomic Absorption Spectrophotometer (Alpha 4 model). The digestion and analytical procedures were checked by analysis of DOLT -3 Matrix Certified Reference Material with known concentration for heavy metals (Cantillo and Calder, 1990). Data on soil properties and Pb were subjected to correlation and regression analyses using Microsoft Excel 2003.

3. Results

3.1. Soil properties

Particle size distribution in the study site was similar, Table 1 and 2, implying that soils had a common origin and of similar oil pedogenic conditions. However, slightly 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).Bulk density increased with depth in both unpolluted soils (1.36 – 1.59 g cm^{-3} and polluted soils (1.38 – 1.59 g cm^{-3}). Generally, the polluted pedons had higher bulk density (mean value = 1.50 g cm^{-3}) in comparison with the unpolluted (mean value = 1.48 g cm^{-3}). 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. There were lower values of organic matter in polluted soils (2.90 – 24.6 g kg^{-1}) when compared with unpolluted soils (9.10 – 32.4 g kg^{-1}).Organic matter decreased with depth in the study site. This is contrary to earlier study in the same oil- rich Niger-delta, Nigeria by Onweremadu and Duruigbo (2007) who observed that upper horizon of polluted soils had higher bulk densities and higher organic matter than unpolluted soils. Exchangeable acidity increased with pollution (mean value = 0.92 cmol kg^{-1} against 0.56 cmol kg^{-1} in unpolluted pedons. Results of exchangeable bases showed that higher values were obtained in unpolluted soils (mean value = 0.89 cmol kg^{-1}) while polluted soils exhibited lower values (mean value = 0.43 cmol kg^{-1})

Table 1： Soil properties of unpolluted study site (average of pedon results)

Depth (cm)	Clay	Silt	Sand	pH(0.1 mol L^{-1} KCl)	Bulk density ($g\ cm^3$)	OM ($g\ kg^{-1}$)	EA	EB	ECEC
		($g\ kg^{-1}$)					($cmol\ kg^{-1}$)		
0-20	17.5	39.5	923.0	4.66	1.36	32.4	0.61	1.07	6.00
20-40	27.0	84.5	888.5	4.54	1.50	19.1	0.64	0.99	5.20
40-60	91.0	70.0	839.0	4.40	1.46	12	0.52	0.78	4.20
60-80	111.0	95.0	794.5	3.79	1.59	9.1	0.48	0.71	4.10
Mean	61.6	72.3	861.3	4.35	1.48	18.2	0.56	0.89	4.90

OM= Organic matter, EA = exchangeable acidity, EB = exchangeable bases, ECEC = effective cation exchange capacity

Table 2： Soil properties of polluted study site (average of pedon results)

Depth (cm)	Clay	Silt	Sand	pH(0.1 mol L^{-1} KCl)	Bulk density ($g\ cm^3$)	OM ($g\ kg^{-1}$)	EA	EB	ECEC
		($g\ kg^{-1}$)					($cmol\ kg^{-1}$)		
0-20	23.4	22.9	953.8	4.30	1.38	24.6	1.07	0.50	4.10
20-40	29.9	32.9	937.1	4.04	1.47	15.1	1.05	0.41	3.80
40-60	37.0	61.4	901.6	3.97	1.56	9.3	0.79	0.38	3.00
60-80	51.9	97.2	848.5	3.57	1.59	2.9	0.77	0.43	2.97
Mean	35.6	53.6	910.3	3.97	1.50	13.0	0.92	0.43	3.50

OM= Organic matter, EA = exchangeable acidity, EB = exchangeable bases, ECEC = effective cation exchange capacity

Concentration of lead

Lead concentration in the study site is shown in Table 3. In both unpolluted and polluted pedons, lead decreased with depth. This is similar to an earlier study on cadmium by Onweremadu and Duruigbo (2007). This shows that there is a relationship between Pb and Cd. Thus, a unit increase in Pb will result in a unit increase in Cd which can enhance the bioavailability of these metals. Yet lead concentration was higher in polluted soils (mean value = 2.12 mg kg^{-1}) while unpolluted soils had a mean value of 0.70 mg kg^{-1}. Relationship amongst lead with selected soil properties

Table 4 indicates the degree of association between lead concentration and exchangeable cations, organic matter and bulk density. In unpolluted soils, lead concentration correlated positively with exchangeable acidity (R =0.87, R^2 =0.75, N = 32) at 5 % level of probability although this association was stronger in polluted soils (R =0.94, R^2 =0.88, N =32). Conversely, the association between lead and exchangeable bases was stronger in unpolluted soils at 5 % level of probability (R =0.99, R^2 =0.98, N =32) when compared with polluted soils (R = 0.77, R^2 =0.60, N = 32). This is in line with earlier study on cadmium by Onweremadu and Duruigbo (2007).Stronger relationship existed between lead concentration and both bulk density and organic matter in polluted soil (R = 0.99 and R =0.97) when compared with unpolluted soils (R =0.69 and R = 0.88).However, Pb concentration was negatively correlated to bulk density. Soils of the study site were derived from the same parent material which predisposes them to sandiness hence they were similar in texture

Table 3: Average values of the distribution of lead in the study site (mg/kg)

Depth (cm)	Unpolluted	Polluted
0-20	1.11	2.75
20-40	1.04	2.28
40-60	0.39	1.77
60-80	0.24	1.69
Mean	0.70	2.12

Table 4: Relationship between lead concentration and selected soil properties ($p \leq 0.0$ 0.05)

Soil property	Unpolluted				Polluted			
	Regression equation	R^2	R	N	Regression equation	R^2	R	N
Exchangeable acidity	Y = 0.1024Pb+ 0.5113	0.87	0.75	32	Y= 0.3087Pb + 0.2648	0.94	0.88	32
Exchangeable bases	Y= 0.3799Pb + 0.6235	0.99	0.98	32	Y= 0.08Pb + 0.2602	0.77	0.60	32
Organic matter	Y= 20.692Pb + 3.7693	0.88	0.78	32	Y= 18.198Pb – 25.65	0.97	0.95	32

However, dense crude oil may have compacted soils in the polluted site which is geo-spatially related to the unpolluted soils resulting in increased bulk density in polluted soils. In addition to this, crude oil clogs pore spaces thereby increasing bulk density. Polluted soils were more acidic (3.97) than unpolluted soils (4.35) and this affects solubility and bioavailability of lead (Dayton et al., 2009) which reduces with increase pH (Mench et al. 2000). It implies that lead in the soil may be unavailable especially in unpolluted soils. This goes to reduce the availability and possible toxicity of lead to plants growing in the study site. Earlier, concentration level of lead in polluted soils is generally below critical level to constitute a hazard (Federal Environmental Protection Agency, 1991). Given more spillages, there could be a build up of lead and other contaminants beyond limits of maximum tolerance.

Discussion

The geological material (coastal plain sands) from which soils were formed may have influenced the distribution of Pb in the study site. Soils are sandy due to parent material origin and act as a filter (Donahue, et al., 1990) as labile Pb is leached away from pedosphere. Soils of sandy area are porous (Onweremadu, et al., 2007) and given high rainfall amount of Southeastern Nigeria (Onweremadu, 2006), the concentration of Pb in both polluted and unpolluted soils are low as translocatory pedogenic processes, such as eluviation resulted in losses in the soilsphere. However, ground- and surface- water assessment of the site was not conducted to ascertain Pb – concentrations as it is suspected that lost Pb in studied soils may have cause non –point –source Pb pollution in the area. Values of Pb in unpolluted soils (0.24 – 1.11 mg $kg^{-1)}$ were below recommended value of 400 – 500 mg kg^{-1} (USEPA, 2001). Similar findings were made by Benson and Ebong (2006) in unpolluted sandy soils of a vegetable garden in Uyo, Akwa Ibom state Nigeria. Generally, both polluted and unpolluted soils were far below 120 mg kg^{-1} recommended by EPA/ ROC (1989) as critical levels in soil of Taiwan.

Conclusion

These facts suggest that arable farmers can go on with crop production as minimal phytotoxicity is expected in these studied soils. Crude oil spillage alters soil properties which affects the overall capacity of soils to allow optimum growth and development of crops especially if such occurrences are associated with heavy metal like Pb?

The concentration of Pb in these soils is not yet constitutes serious agronomic and environmental hazards as they are below critical levels. This may not be conclusive as further investigations need to be conducted relating lead to other heavy metals as well as to soil properties.

Acknowledgements

Authors are indebted to staff of SHELL GLOBAL ENVIRONMENTAL CONSULTANT LIMITED WARRI NIGERIA. We also thank Mr. Ibrahim Ali for helping in the statistical analysis of this work.

References

Aiyesanmi, A.F. (2005). Assessment of heavy metal contamination of Robertkiri oil field's soil. Nigerian J. Soil Sci., 15, 42-46

Alatise, O.O; Babalola, I.A and Olowofela, J.A. (2008). Distribution of some natural gamma-emitting radionuclides in the soils of the coastal areas of Nigeria. J. Environmental Radioactivity 9 (2),1746 -1749.

Akamigbo, F.O.R and Jidere, C.M (2002). Carbon – nitrogen dynamics in organic wastes amended crude oil polluted wetland soil. Agro – Sci., 3 (1), 20 – 26

Benson, N.U and Ebong, G.A. (2006). Heavy metals in vegetables commonly grown in tropical garden ultisol. J. Sust. Trop. Agric. Res., 16, 77-80.

Blake, G.R and Hartge, K.H. (1986) Bulk density. In: Klute, A (Ed) Methods of soil analysis, Part 1. 9 ASA, Madison, Wisconsin. 362 -382.

Cantillo, A and Calder, J. (1990). Reference material for marine Science. Fresenius J. Anal. Chem., 338, 380 – 382.

Donahue, R.L; Miller, R.W and Shickluna, J.O. (1990). An introduction to soil and plant growth 5th edition. Prentice Hall, New Delhi, India.

Dayton, E.A; Basta, N.T; Payton, M.E; Bradham, K.D, Schroder, J.C and Lanno, R.P. (2009). Evaluating the contribution of soil properties to modifying lead phytoavailability and phytotoxicity. J. Environmental Toxicology and Chemistry 25 (3), 719 -725.

EPA / ROC (Environmental Protection Agency) (1989). Final reports of heavy metals contents in Taiwan Agricultural soils. 4 Vols. Tapei, Taiwan, ROC.

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

Federal Environmental Protection Agency (1991). Guidelines and Standard for industrial effluents, gaseous emissions and hazardous wastes management in Lagos, Nigeria.53 pp.

Gee, G.W and Bauder, J.W. (1986). Particle size analysis. In: Klute, A (Ed) Methods of soil analysis, Part 1. 9 ASA, Madison, Wisconsin. 91 -100.

Hendershot, W.H; Lalande, H; and Duquette, M. (1993). Soil reaction, exchangeable acidity. In: Carte, M.R. (Ed) Soil sampling and methods of soil analysis. Canadian Soc. of Soil Sci. London 141 -145.

Jackson, M.L. (1958). Soil chemical analysis. Prentice Hall, Inc. Englewood Cliff, New Jersey 498

Lacatusu, R. (2000). Appraising levels of soil contamination and pollution with heavy metals. European Soil Bureau Research Report No. 4.

Mclean, E.O. (1965). Aluminium. In: Black, C.A, include all authors (Eds). Methods of soil analysis, Part 2, 1st ed. Am. Soc. of Agron. Monograph No. 9 : 986 – 994.

Mench, M; Vangronsveld, J; Clijsters, H; Lepp, N.W and Edward, R (2000) In – situ metal immobilization and phytostabilization of contaminated soils. In: T Norman and G. Banuelos (Eds), Phytoremediation of contaminated soil and water, Lewis Publishers, Boca Raton, FL pp 323 – 358.

Modler, A.H, Aishah, S and Pozi, M. (2009). Characterization of the adsorption of the lead (11) by the nonliving biomass Spirogyra neglecta (Hasall) Kutzing. Am. J. Biochem.& Biotech. 5 (2): 75 – 83.

Naidu R, Bolan N .S, Megharaj M, Juhasz A.L, Gupta S, Clothier B and Schulin R (2008). Bioavailability, definition, assessment and implications for risk assessment. In: Chemical Bioavailability in Terrestrial Environment. Amsterdam, The Netherlands: Elsevier. ISBN 978-0-444-52. 1-8.

Nelson, D.W and Sommers, L.E. (1982). Total organic carbon organic matter. In: Page, A.L (Ed) Methods of soil analysis Part 11. Am. Soc. of Agron., Madison Wisconsin. 539 – 579.

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.. Ext. 3 (1), 27 – 33.

Odu, C.T.I (1981). Degradation and weathering of crude oil under tropical conditions. The petroleum industry and the Nigerian Environment. Proceedings of 1981 international seminar held in Port Harcourt, 143 – 153

Onweremadu, E.U. (1984). Investigation of soil and other related constraints to sustainable agricultural productivity of soils of Owerri zone in Imo state, Nigeria. M.sc Thesis of the University of Nigeria, Nsukka, Nigeria 164 pp

Onweremadu, E.U. (2006). Application of geographic information system (GIS) on soils, land use and soil – related environmental problems in Southeastern Nigeria Ph.D Thesis of the University of Nigeria, Nsukka, Nigeria 330 pp

Onweremadu, E.U. and Duruigbo, C.I. (2007). Assessment of cadmium concentration of crude oil polluted arable soils. Int. J. Envion. Sci. Tech., 4 (3) 409 – 412

Onweremadu, E.U; Eshett, E.T and Osuji, G.E. (2007). Temporal variability of selected heavy metals in automobile soils. Int. J. Envion. Sci. Tech., 4 (1) 35 – 41.

Oti, N.N (2002). Discriminant functions for classifying erosion degraded lands at Otamiri, southeastern Nigeria. Agro – sci., 3 (1), 34 – 40

Sauve S, Hendershot W and Allen H.E (2000). Solid-solution partitioning of metals in contaminated soils: dependence on pH, total metal burden, and organic matter. Environmental Science and Technology, 34 (7): 1125-1131.

SSSN (Soil Science Society of Nigeria) (1981). "Acid sands" of southern Nigeria. SSSN special publication monograph No. 1 1981 165 pp

USEPA United States Environmental Protection Agency (2001) 40 CFR Part 745. Lead; identification of dangerous levels of lead; Final rule. Code of Fed. Reg. 66, pp 1206 – 1240.