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Assessment of Cd concentration of crude oil polluted arable soils

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ABSTRACT: Thirty soil samples were analyzed for their properties and cadmium concentration in polluted and unpolluted sites of Isikwuato, Abia State, Nigeria. Polluted soils were more acidic (pH = 4.38) than unpolluted ones (pH = 5.22). Bulk density increased in polluted soils (1.51 g/cm^3). Higher average value of organic matter was recorded in polluted soils (mean value = 1.42 %) unlike 0.98 % found in unpolluted soils. Cadmium concentration was higher in polluted soils (0.76 mg/kg) contrasting with 0.02 mg/kg obtained in their unpolluted counterparts. Good relationship existed between exchangeable acidity and cadmium status in polluted soils (R = 0.83, R^2 = 0.77, N = 30) as opposed to values in unpolluted soils (R = 0.58, R^2 = 0.49, N = 30).

Keywords: *Assessment, cadmium, oil spillage, pollution*

INTRODUCTION

Cadmium is a biotoxic heavy metal regarded as an important environmental pollutant in agricultural soils because of the potential adverse effects it poses to food quality and soil health. It is the labile fraction rather than the total soil Cd content that is critical when assessing its availability in soils (Gray, *et al*., 2004). However, cadmium availability to plants and soil micro-organisms 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 unavailability 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 cadmium concentration in crude oil polluted soils of Isikwuato, Abia State Nigeria compared with unpolluted ones.

MATERIALS AND METHODS

Isikwuato is located within latitude 4° 59' 50''.460 and 6° 56' 43''.310 N and longitude 8° 55'56''.110 and 9° 05' 55''.210 E. It has a humid tropical climate (Nnaji, *et al*., 2002), with temperature uniformly high throughout the year. Soils are mainly ferrallitic and derived from sandstones and shales (Enwezor, *et al*; 1989). The vegetation is described as rainforest. 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 2005 at Mbalano, Isikwuato, Southeastern Nigeria. Guided by identification of potentially impacted areas after a reconnaissance survey of the study area, stratified random sampling was done covering polluted and unpolluted sites. Six pedons were sunk with three being polluted and the remaining ones on unpolluted land. Five major horizons were identified and sampled from at depths of 0 – 20 cm, 20 – 40 cm, 40 – 60 cm, 60 – 80 cm and 80 – 100 cm, giving a total of 30 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 acidity (EA) was estimated using a method outlined by Barnhisel and Bertsch, (1982).

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

Unpolluted									
Depth (cm)	Clay (%)	Silt (%)	sand (%)	pH (1NKCl)	Bulk density (g/cm^3)	OM (%)	EA (cmo1/kg)	EB (cmo1/kg)	ECEC (cmo1/kg)
0-20	7	3	90	5.20	1.33	2.3	2.3 1.5	2.8	4.3
20-40	11	4	85	5.10	1.37	1.1	1.1 2.1	2.6	4.7
40-60	20	3	77	5.30	1.41	0.8	0.8 1.6	2.8	4.4
60-80	28	2	70	5.30	1.46	0.5	0.5 1.4	3.4	4.8
80-100	15	2	83	5.20	1.50	0.2	0.2 1.9	3.2	5.1
Mean value	16.2	2.8	81	5.22	1.41	0.98	0.98 1.70	1.98	4.6
Polluted									
Depth (cm)	Clay (%)	Silt (%)	Total sand (%)	pH (1NKCl)	Bulk density (g/cm^3)	OM (%)	EA (cmo1/kg)	EB (cmo1/kg)	ECEC (cmo1/kg)
0-20	6	5	89	4.4	1.51	3.3	2.6	1.1	3.7
20-40	12	4	84	4.0	1.55	2.0	2.8	0.9	3.7
40-60	22	4	74	4.5	1.52	1.1	3.2	1.6	4.8
60-80	27	3	70	4.5	1.48	0.6	3.0	1.8	4.8
80-100	16	3	81	4.5	1.51	0.1	3.1	1.5	4.6
Mean value	16.8	3.8	79.8	4.38	1.51	1.42	2.94	1.38	4.32

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

Exchangeable bases (EB) were determined by the complexometric titration methoid (Jackson, 1958). Effective cation exchange capacity was got by summation. Soil samples were digested for cadmium using a mixture of concentrated $HCIO_4$ and HNO_3 at a ratio of 2:1 and metal extracted with 0.5 ml HCl (Lacatusu, 2000). The aliquots obtained were measured for cadmium 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 cadmium were subjected to correlation and regression analyses using SAS statistical software.

RESULTS

Soil properties

Particle size distribution in the study site was similar Table 1, implying that soils had a common origin and of similar oil pedogenic conditions. But bulk density increased with depth in unpolluted soils (1.33 – 1.50 g/cm^3) while upper horizon of polluted soils had high bulk densities (1.51 – 1.55 g/cm^3). There were lower values of organic matter in unpolluted soils (0.2 – 2.3 %) when compared with polluted soils (0.1 – 3.3 %). However organic matter decreased with depth in the study site. Exchangeable acidity increased with pollution (mean value = 2.94 cmol/kg) against 1.70 cmol/kg in unpolluted pedons. Results of exchangeable bases showed that higher values were obtained in unpolluted soils (mean value = 2.98 cmol/kg) while polluted soils exhibited lower values (mean value = 1.38 cmol/kg).

Concentration of cadmium

Cadmium concentration in the study site is shown in Table 2. In both unpolluted and polluted pedons, Cadmuim decreased with depth. Yet cadmium concentration was higher in polluted soils (mean value = 0.76 mg/kg) while unpolluted soils indicated a mean value of 0.02 mg/kg. The concentration of cadmium contrasted slightly with a range of O – 2.83 mg/kg obtained in an earlier study in the same oil–rich Niger Delta, Nigeria (Aiyesanmi, 2005).

Relationship amongst cadmium with selected soil properties

Table 3 indicates the degree of association between cadmium concentration and exchangeable cations. In unpolluted soils, cadmium concentration correlated positively with exchangeable acidity ($R = 0.58$, $R^2 = 0.49$, $N = 30$) at 5% level of probability although this association was stronger in polluted soils ($R = 0.83$, $R^2 = 0.77$, $N = 30$). Conversely, the association between cadmium and exchangeable bases was stronger in unpolluted soils at 5% level of probability ($R = 0.83$, $R^2 = 0.70$, $N = 30$) when compared with polluted soils ($R = -0.11$, $R^2 = 0.01$, $N = 30$). Soils of the study site were derived from same parent material which predisposes them to sandiness hence they were similar in texture.

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. The compaction effect was very outstanding in the upper horizons unlike deeper layers which was against the trend in unpolluted soils where bulk density increased with depth, having the least value on the epipedons. In addition to this, crude oil clogs pore spaces thereby increasing bulk density. Polluted soils were more acidic (4.38) than unpolluted soils (5.22) and this affects phytoavailability of cadmium (Khoshgoftar, *et al*., 2004) which increases with alkalinity (Norvell, *et al*., 2000). It implies that cadmium in the soil may be unavailable especially in polluted soils. This goes to reduce the availability and possible toxicity of cadmium to plants growing in the study site. Earlier, concentration levels of cadmium in polluted soils are generally below critical level to constitute a hazard (Federal Environmental Protection Agency, 1991). Given more spillages, there could be a build of cadmium and other soil contaminants beyond limits of maximum tolerance.

DISCUSSION AND CONCLUSION

The geological materials (sandstones and shales) form which soils were formed may have influenced the distribution of Cd in the study site. Soils are sandy due to their parent material origin and act as a filter (Donahue, *et al.*, 1990) as labile Cd is leached away from the pedosphere. Soils of the study area are porous (Onweremadu, *et al.*, 2007) and given high rainfall amount of Southeastern Nigeria (Onweremadu, 2006), the concentrations of Cd in both polluted and unpolluted soils are low as translocatory pedogenic processes, such as elviation resulted in losses in the soilsphere. However, ground- and surface-water assessment of the site was not conducted to ascertain Cd-concentrations as it is suspected that lost Cd in studied soils may have caused non-point-source Cd-pollution in the area. Values of Cd in unpolluted soils (0.01-03 mg/kg) were below recommended value of 0.1 mg/kg (Merian, 1991). 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 10 mg/kg recommended by EPA/ROC (1989) as critical levels in soil of Taiwan.

These facts suggest that arable farmers can go on with crop production as minimal phytotoxicity is expected in these studies 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 metals like Cd.

Cd concentration in these soils are not yet constituting serious agronomic and environmental hazards as they are below critical levels. This may not be conclusive as further investigations need to be conducted relating cadmium to other heavy metals as well as to soil properties. Acknowledgement: Author is indebted to technical staff of Soil Science laboratory, Department of Soil Science, University of Nigeria, Nsukka.

Table 2: Average values of the distribution of cadmium in the study site (mg/kg)

Depth cm	Unpolluted	Polluted
0-20	0.03	1.06
20-40	0.03	0.90
40-60	0.02	0.80
60-80	0.01	0. 62
80-100	0.01	0.44
Mean	0.02	0.76

Table 3: Relationships of the cadmium concentration to selected soil properties (P = 0.05)

Soil property	Regression equation	R	R^2	N	Regression equation	R	R^2	N
Exchangeable acidity (Y)	Y = 1.05 + 0.41 Cd	0.58*	0.49	30	Y=1.18+0.79 Cd	0.83*	077	30
Exchangeable bases (Y)	Y = 0.45 + 2.35 Cd	0.83*	0.07	30	Y=1.79–0.13 Cd	NS	0.01	30

*Significant at P = 0.05; NS = not significant

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