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EFFECT OF LAND USE ON THE DISTRIBUTION OF HEAVY METALS IN ABEOKUTA, SOUTHWESTERN NIGERIA

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ABSTRACT

To prevent risks of metal pollution and secure public health, the assessment of the pollutant load of different land use is germane in emerging cities. The study investigated the distribution of water, EDTA and HCl extractable Cd, Pb, Zn, Cu, Cr, Ni and Mn in soils of different land uses in Abeokuta, south western Nigeria. It was hypothesized that land use pattern has effect on the depth distribution of heavy metals. Profile pits were sunk and sampled systematically at 0-20, 20-40 and 40-60 cm in agroforestry arboretum, oil palm plantation, plantain plantation, fadama farm, degraded land and cassava farm. Samples collected were analyzed by standard laboratory procedures and data collected were analyzed statistically. Results indicated that water is a poor extractant for the metals. Nickel was less than 0.002 mg kg^{-} in the soils irrespective of the extractants used. The metals were more concentrated in the degraded soil followed by soils of plantain plantation, agroforestry, oil palm, cassava and least in fadama. Zinc and Mn are concentrated in 0-20 cm, Pb in 20-60 cm, Cr in 40-60cm. Efficiency of metal extraction was in the order: EDTA > HCl > water. Soil lead, Zn, Cr and Mn are positively correlated.

Keywords: Heavy metals, Land use, Pollution, Soil profile

INTRODUCTION

Heavy metals are metals and metalloid having density greater than 5 g cm^{-3} and usually associated with pollution and toxicity, although some (essential metals) are required by organism at low concentration (Vaaramaa *et al.*, 2010). The concentration of soil heavy metals in soils are determined by either anthropogenic factors or natural causes. Naturally occurring heavy metals in the atmosphere and those from weathering of parent materials (Vaaramaa *et al.*, 2010), are attached to aerosol particle in the atmosphere, and deposited on the ground as wet and dry deposition. This is their main source on the surface soil (Olivia and Espinosa 2007).

High concentration of heavy metals such as Pb, Cd and Zn are found in arable soil because of the use of dumpsite materials as manure in crop production. The direct use of dumpsite for cultivating crops and the use of compost

sourced from dumpsite is a common practice in southwestern Nigeria (Ogunyemi *et al.* 2003, Amusan *et al*, 2005). This practice is potentially harmful to the health and well being of the populace when crops grown on such polluted soils are consumed. The use of dumpsite compost is potentially dangerous because the heavy metals in it decomposes and is released in the soil and could migrate down the soil profile. The metals may also leach from the soil and contaminate surface water or ground water (Adelekan and Alawode, 2011; Wood bury, 2005).

However, metal toxicity do not arise in natural soil even with high metal content, this is because the native plant samples would have been adapted to the high metal concentrations in the soil. Accumulation of heavy metals in soil is at times caused by the management practice engaged in the production of the crop. Different cropping patterns and land uses have different management practices. These practices have different impacts on the crop grown and the soil, for example, in cocoa plantation, copper based fungicide is used to control cocoa pod disease (Aikpokpodium *et al.,* 2010). The use of this fungicide is expected to leave a high concentration of Cu in the soils after application. Similarly effect of metal deposition is expected after the decay of soil applied anthropogenic organic materials that contain heavy metals. The use of this soil containing high concentration of heavy metals for crop production is harmful to human health. These heavy metals enter the body system when these plants are directly or indirectly consumed and also the air and water may accumulate metals with time (Adelekan and Alawode 2011; Lenntech, 2009).

Consequently the assessment of the pollutant load of different cropping pattern/land use in different component of the ecosystem is an important task at preventing risks and securing public health. The aim of this study is to investigate the distribution of water, EDTA and HCl extractable Cd, Pb, Zn, Cu, Cr, Ni and Mn in soils of different land uses in south western Nigeria.

MATERIALS AND METHODS

Site Description and Experimental Procedures

The study was carried out at the Federal University of Agriculture, Abeokuta. Soil samples were taken from six sites within the University. The location of sampling includes: (1) Agro-forestry arboretum, (2) Oil palm plantation, (3) Plantain plantation, (4) Fadama (lowland) farm, (5) Degraded land left for fallow, and (6) Cassava farm. The detail description of the land use, soil classification and the GPS coordinates of the sites are shown in Tables 1 and 2. From each sampling site, profile pits were sunk and soil samples were collected at the depths of 0-20 cm, 20-40 cm and 40-60 cm each. The samples were immediately placed in plastic bags and tightly sealed and were transported to the laboratory. The soil was then air-dried at room temperature and sieved with 2mm screen sieve. The surface soil samples from each land use were analysed for their pH in water 1:1 soil to water ratio, organic carbon content using wet oxidation procedure and clay content by the hydrometer method.

Five gram of each of the air dried and sieved soil samples from the horizon were extracted with 50 ml of distilled water, 0.1 M of EDTA and 0.1 N HCl. The soil solution was then filtered and the extracts analysed for Cd, Pb, Zn, Cu, Cr, Ni and Mn. The metals were then determined using Buck atomic absorption spectrophotometer (Model, 210VGP) with detection limit (mg kg^{-1}) of the metals being: Cd =0.02, Pb=0.49, Zn=0.03, Cu=0.002, Cr=0.003, Ni=0.002.

Data Analysis

Data collected were subjected to analysis of variance (ANOVA) and correlation analyses were done by using statistical analysis system (SAS) package. The significant treated means were separated using least significant difference (LSD) at 5 % significant level of probability.

RESULTS AND DISCUSSION

The description of the different land use locations used for the experiment is shown in Table 1. The land use types are typical of humid and sub-humid tropical environments. The properties of the top soil of the experimental land use types are shown in Table 2. The pH ranges from acidic to slightly acidic. Soil from cassava farm and plantain plantation is very acidic. The cassava soil is sand in texture and this could have encouraged the leaching of basic cations. The values indicate that soils from the plantain and cassava land use needs to be limed for optimal crop production. The organic carbon (OC) content of the agroforestry arboretum and plantain plantation are higher than other land use types while that of the cassava farm is very low. The high OC in these land use types might be due to the high residue turn over in the two land use. The large foliage and residue biomass and the high environmental temperature might have contributed to the high rate of organic matter turn over and hence the high soil organic carbon. The value in the fadama soil is lower than those of agroforestry and plantain plantation but higher than the value from the oil palm plantation. Fadama soil, being a lowland soil might have accumulated organic materials eroded from the upper slope. The decomposition of organic material under a poorly drained soil as in the fadama soil is also low. The soil texture is predominantly loamy sand except cassava farm soil that is sand. Generally the soils are low in clay content and this might impact on the soil cation exchange reactions. The soils are classified as Alfisol except fadama soil that is an Inceptisol. The particle size distribution indicated that the soils of the different land use examined were predominantly sandy in the surface layers. The implication of this is that soils would be well drained in the surface, and may have poor water and nutrient holding capacity. It also implies that leaching of metals in the soil could be high.

The water extractable heavy metals in the land uses are below the detection limits of the instrumentation employed (Table 3). However, the chromium content of the soils is not significantly different from each other. There is higher concentration of manganese in the oil palm plantation soil; the value is similar to that recorded in the agroforestry arboretum soil but significantly higher than those of cassava farm, degraded and fadama soils. The higher content of soil Cd, Pb, Zn, Ni and Mn in the agroforestry arboretum soil might be due to anthropogenic factors. The land use is located very close to the ceremonial road of the University; this is constantly used by vehicles, trucks and lorries. Automobile density has been reported to impact on the heavy metal content of soil (Azeez *et al*., 2013; Moller *et al*., 2005). Agroforestry soil has more Cd, Pb and Ni but more Zn at oil palm soil. Oil palm and agroforestry soils have more Mn.

The heavy metal content of the soils extracted with ethylene diamine tetra acetic acid (EDTA) is shown in Table 4. Cadmium and nickel content of the soils are very low and hence not detected by the instruments. Soil content of Pb was highest in agroforestry arboretum, plantain plantation and the degraded soils, the values were significantly higher than for other land uses. Fadama soil had the lowest amount of soil Pb extracted with EDTA while the value in soil from oil palm plantation is significantly higher than that of cassava farm. The zinc content of the soil from the degraded soil is significantly higher than those of other land use. Plantain plantation had soil Zn significantly higher than

fadama soil while the values in agroforestry arboretum, oil palm plantation and cassava farm are statistically similar. The soil Cr in the fadama soil is very low, the values recorded in the soils from agroforestry arboretum, plantain plantation and degraded soil are very high. The values in these soils are significantly higher than those of oil palm plantation and cassava farm. The manganese content of the oils is in the order: degraded soil > plantain plantation, soil > fadama soil > oil palm plantation > cassava farm = agroforestry soil. EDTA lead is more in agroforestry, plantain and degraded soil, plantain and degraded soil have more Zn; soil Cr is more in agroforestry, plantain and degraded soils while Mn is concentrated in the plantain and degraded soil. The HCl extractable Cd, Pb, Cu and Ni are below the detection limit for most of the soils except agroforestry arboretum soil and oil palm plantation soil for Pb and oil palm plantation soil for Cd (Table 5). The Zn content of the soil is significantly higher in the degraded soil, this is closely followed by the value in the plantain plantation, fadama soil, oil palm plantation soil, agroforestry arboretum and lowest in the cassava farm. Hydrochloric acid extractable Cr is significantly higher in soil from oil palm plantation while the values from other land uses are similar. Degraded and plantain plantation soils had higher concentrations of soil manganese significantly higher than soil Mn in other land uses. Oil palm and agroforestry have more Pb, degraded soil has more has Zn, oil palm soil has more Cr, degraded and plantain plantation soils have more Mn. Generally, the distribution of the metals among the land uses shows an erratic pattern. However, in the EDTA and HCL extractions, degraded soils seem to have higher metals (Zn, Mn, Pb, Zn and Cr). It should be noted that the soil have been exhausted of its nutrients (basic plant nutrients) before being left for fallow. This could have promoted the accumulation of the heavy metals in soil colloidal site that have hitherto been occupied by soil nutrients mined by cultivated crops. The source of these metals is probably anthropogenic (Sterckeman *et al*., 2000). The consistent low values in the amount of Cd and Pb extracted by the two acids indicate that the only reason for their low values is due to low soil concentration and not low potency of the extractants as earlier opined in this study.

The depth distribution of the soil heavy metals as extracted by different chemicals is shown in Table 6. There were no significant differences in water extractable Zn, Cr, and Mn between the soil depths but the metals seems concentrated at 20-40 cm depth. There is evidence of high Pb concentration at the 40-60 cm while soil Zn and Cr seem to have moved down the depths. The amount of the metals extracted by 0.1 M EDTA is higher than that extracted by distilled water. There was no significant difference in soil Pb between the depths but higher amount of lead was concentrated in the 20-40 cm depth. The amount of soil Zn and Mn at the 0-20 cm depth was significantly higher than those of other soil depths, while the concentrations of Cr in the soil was similar at the different depths. The concentration of some of the metals in the surface depths might have reflected a superficial accumulation of non-indigenous metals that could have originated from the spreading of waste or from atmospheric fallout of industrial contamination (Sterckeman *et al*., 2000; Li and Shuman, 1996). The 0.1 N HCl extractable Cd is higher at the 20-40 cm depth; this was similar to the amount at 40-60 cm depth while the soil Pb was concentrated at the 40-60 cm depth. Soil Zn at the 0-20 cm depth is significantly higher than the concentrations at other depths. The amount of Cr in the soil at the different depths is statistically similar while Mn seems concentrated at the top soil. Zinc and Mn are concentrated at 0-20 cm, Cr is evenly distributed, while is concentrated > Pb at 20-

60 cm. The general decrease in the soil metals with increase in soil depth is expected because some researchers have reported a link between soil metals and organic matter (Azeez *et al*., 2011) which decreases down the profile. Similar results were observed by Godin (1986) and reported by Sterckeman *et al*. (2000), On comparison (Table 7), HCl extractable Cd was significantly higher than the values from other extractants. EDTA extracted more of Zn, Mn (not significantly different from HCl extraction) and Cr while the amounts of Cu extracted by the chemicals were similar. The trend observed is thought to be a reflection of the strength of the acids, HCl is presumed to be a stronger mineral acid than EDTA, and hence expected to extract more metals, but the results is showing otherwise. The reason for this is probably due to the ability of EDTA to form soluble complexes with some of the metals and hence extract deeper into the soil micelles compared with the ability of HCl.

The correlation (Table 8) between soil Cd and other metals studied was not significant and negatively related. This is however, contrary to the positive relationship observed between Cd and Zn by McBride *et al*. (1997). Soil Pb has positive and significant correlation with soil Zn, Cr and Mn (0.32, 0.92, 0.36, respectively p = 0.01) while the correlation between soil Zn and Cr, Mn were positive and significant (0.24, 0.92; p = 0.01). The relationship between Pb and Zn has been reported positive and significant by Jopony and Young (1994) and Sauve *et al.* (1997). The relationship between soil Cr and Mn was also significant and positive (0.28, p = 0.01). The concentration of the metals in the soil is much related, indicating that they are likely to have emerged from the same source of pollution.

CONCLUSIONS

From the results of this study, it could be concluded that water is a poor extractant for the metals. Nickel was less than 0.002 mg kg^{-} in the soils irrespective of the extractants used. The metals were more concentrated in the degraded soil. The trend in the distribution of the metals along soil depths was erratic. EDTA extracted more metals than others probably due to its ability to form soluble complexes with the metals. Lead, Zn, Cr and Mn are all positively and significantly correlated.

Table 1: Description of land use locations

LOCATION	LAND USE
Agroforestry arboretum	Consist of tree species as *Treculia africana*, *Acacia nilotica*, *Tectona grandis, and Gmelina arborea*, established in 1990.
Degraded land (short fallow*)	Secondary natural regrowth of about 4years with herbaceous shrubs, few trees and grasses (*Panicum maximum*)
Fadama (lowland)	In existence for about 11years with shrubs and grasses; Also used for the cultivation of dry season vegetables, lowland rice, and pepper.
Oil palm plantation	Established in late 2007, and planted to oil palm and sometimes intercropped with maize
Plantain plantation	Planted to plantain and was established in late 2007
Cassava farm	Planted to cassava since 2011, adjoining land is used for soil and gravel mining

*Fallow of about 2-3 years

Table 2: Some selected characteristics of the top soil of the experimental sites

Land Use and GPS coordinate	pH (H_2O)	Org C. %	Clay	Texture	USDA classification*
Agroforestry arboretum N 07º13.6390`, E003º26.8932` 144m above sea level	6.00	3.75	8.80	Loamy sand	Typic Kandiudalf
Oil palm plantation N 07º16.2081`, E003º24.7664 149m above sea level	6.80	2.35	8.80	Loamy sand	Aquic Paleustalf
Plantain plantation N07º17.2563`, E003º24.1308 125m above sea level	5.30	3.83	10.80	Loamy sand	Arenic Haplustalf
Cassava farm N 07.24388^0 E 003.46198^0 144m above sea level	5.20	0.33	6.00	Sand	Typic Kandiudalf
Fadama (lowland) N 07º13.6390`, E003º26.8932` 144m above sea level	5.90	2.89	8.80	Loamy sand	Hydraaquentic Humaquept
Degraded land (short fallow) N 07.23803^0 E 00.44531^0	6.20	1.96	5.40	Loamy sand	Aquicarenic Hapludalf

*Classified by Sonuga 2011.

Table 3: Effect of land use on water extractable heavy metals*

Land Use	Cd	Pb	Zn	Cu	Cr	Ni	Mn
	mg kg^{-1}						
Agroforestry arboretum	0.020a	0.53a	0.20 ab	BDL	0.05a	0.02a	0.73ab
Oil palm plantation	BDL	BDL	0.42a	BDL	0.05a	BDL	1.23a
Plantain plantation	BDL	BDL	BDL	BDL	0.04a	BDL	0.11bc
Cassava farm	BDL	BDL	BDL	BDL	0.04a	BDL	0.07c
Fadama (lowland)	BDL	BDL	BDL	BDL	0.05a	BDL	0.08c
Degraded land (short fallow)	BDL	BDL	BDL	BDL	0.04a	BDL	0.06c

*Mean across soil depths; Means with the same letter along the same column are not significantly difference

BDL- Below Detection Limit; Detection limit (mg kg^{-1}): Cd =0.02, Pb=0.49, Zn=0.03, , Cu=0.002, Cr=0.003, Ni=0.002

Table 4: Effect of land use on EDTA extractable heavy metals*

Land Use	Cd	Pb	Zn	Cu	Cr	Ni	Mn
	Mg kg^{-1}						
Agroforestry arboretum	0.02a	7.75a	0.61d	BDL	8.77a	BDL	1.12d
Oil palm plantation	BDL	4.60b	1.15d	BDL	6.29b	BDL	2.94c
Plantain plantation	BDL	7.59a	5.12b	BDL	7.98ab	BDL	8.84b
Cassava farm	BDL	2.54c	0.81d	BDL	3.80c	BDL	1.46d
Fadama (lowland)	BDL	0.49d	2.27c	BDL	0.03d	BDL	4.07c
Degraded land (short fallow)	BDL	7.41a	6.42a	BDL	7.41ab	BDL	11.38a

*Mean across soil depths; Means with the same letter along the same column are not significantly difference

BDL- Below Detection Limit; Detection limit (mg kg^{-1}): Cd =0.02, Pb=0.49, Zn=0.03, , Cu=0.002, Cr=0.003, Ni=0.002

Table 5: Effect of land use on HCl extractable heavy metals*

Land Use	Cd	Pb	Zn	Cu	Cr	Ni	Mn
	mg kg^{-1}						
Agroforestry arboretum	BDL	0.53a	1.01de	BDL	0.03b	BDL	1.79b
Oil palm plantation	0.09a	0.60a	2.16cd	BDL	0.79a	BDL	3.75b
Plantain plantation	BDL	BDL	4.46b	BDL	0.03b	BDL	8.27a
Cassava farm	BDL	BDL	0.74e	BDL	0.04b	BDL	1.40b
Fadama (lowland)	BDL	BDL	3.14c	BDL	0.04b	BDL	2.03b
Degraded land (short fallow)	BDL	BDL	5.88a	BDL	0.04b	BDL	10.00a

*Mean across soil depths; Means with the same letter along the same column are not significantly difference

BDL- Below Detection Limit; Detection limit (mg kg^{-1}): Cd =0.02, Pb=0.49, Zn=0.03, , Cu=0.002, Cr=0.003, Ni=0.002

Table 6: Effect of soil depth on the distribution of Water, EDTA, HCl extractable heavy metals*

Soil Depth Cm	Cd Mg kg^{-1}	Pb	Zn	Cu	Cr	Ni	Mn
Water							
0-20	BDL	BDL	0.07a	BDL	0.04a	BDL	0.27a
20-40	BDL	BDL	0.18a	BDL	0.05a	BDL	0.49a
40-60	BDL	0.51a	0.12a	BDL	0.05a	BDL	0.40a
0.1 M EDTA							
0-20	BDL	4.65a	4.15a	BDL	5.33a	BDL	7.36a
20-40	BDL	5.36a	2.21b	BDL	5.81a	BDL	4.12b
40-60	BDL	5.18a	1.83b	BDL	6.01a	BDL	3.42b
0.1 N HCl							
0-20	BDL	BDL	4.13a	BDL	0.12a	BDL	5.10a
20-40	0.04a	BDL	2.30b	BDL	0.09a	BDL	4.28a
40-60	0.03a	0.56a	2.26b	BDL	0.27a	BDL	4.24a

*Mean across soil depths; Means with the same letter along the same column are not significantly difference

BDL- Below Detection Limit; Detection limit (mg kg^{-1}): Cd =0.02, Pb=0.49, Zn=0.03, , Cu=0.002, Cr=0.003, Ni=0.002

Table 7: Effect of soil extractants on soil content of heavy metals*

Soil Depth	Cd	Pb	Zn	Cu	Cr	Ni	Mn
Water	BDL	0.45b	0.12b	0.02a	0.04b	BDL	0.39b
HCl	0.03a	0.51b	2.90a	0.02a	0.16b	BDL	4.54a
EDTA	BDL	5.06a	2.73a	0.02a	5.72a	BDL	4.97a

*Mean across soil depths; Means with the same letter along the same column are not significantly difference

BDL- Below Detection Limit; Detection limit (mg kg^{-1}): Cd =0.02, Pb=0.49, Zn=0.03, , Cu=0.002, Cr=0.003, Ni=0.002

Table 8: Correlation n=162[#]

	Cd	Pb	Zn	Cr
Pb	-0.05ns			
Zn	-0.05ns	0.32***		
Cr	-0.01ns	0.92***	0.24***	
Mn	-0.05ns	0.36***	0.92***	0.28***

*** Significant at 0.1 % probability
[#] values across all the three extractants

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