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# DISTRIBUTION OF SOME HEAVY METALS IN THE SOIL-CLAY-SILT PARTICLE FRACTIONS OF REFUSE DUMPSITES IN ENUGU STATE.

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## ABSTRACT

***The indiscriminate use of open land as dumpsites in Nigeria without appropriate measures to prevent environmental hazards has resulted in the contamination of soil and the exposure of human populations to environmental and health hazards. Soil is a part of the environment that receives pollutant from all types of human activities. Heavy metals originating from various organic waste sources and industrial activities accumulate in the soil and their accumulations depend on the amount and types of waste applied and also on the soil properties as soils differ in their ability to retain nutrient elements. This research was carried out to investigate distribution of some heavy metals in the soil-clay-silt particle fractions of refuse dumpsites in Enugu state. Soil samples were collected from the vicinity of the dumpsites from two locations – Ugwuaji (along Enugu-Port Harcourt Express Way) and Nsukka central town, at predetermined depth intervals of 0-20cm, 20-40cm and 40-60cm. The result of samples analysed showed that heavy metal concentration at both locations was far below the critical limits. The clay fraction retained more heavy metals (Zn, B, Cd and Mn) and prevented them from leaching into the ground water especially in 0-20cm and 20-40cm depth than the silt fraction. This implies that dumpsites should be sited in soils that are high in clay content than in silt content to prevent ground water pollutions by heavy metal through leaching.***

**Key words**: distribution, heavy metals, clay-silt fraction, dumpsites.

## INTRODUCTION

Soil is a vital resource for sustaining basic human needs, supplying quality food and creating a habitable environment (Wild, 1995). It serves as a sink and recycling factory for both liquid and solid wastes. Municipal solid waste has been found to contain appreciable quantity of heavy metals such as Cd, Zn, Pb, and Cu, all which may eventually end – up in the soil and are leached down the profile (Alloway and Aryes, 1997). There is no doubt that soil is a primary recipient of solid waste and that millions of tons of these wastes from a variety of sources: Industrial, domestic and agricultural, finds their way into the soil (Nyles and Ray, 1999). Higher concentrations of heavy metals in soils have been reported to inhibit plant growth, nutrient uptake and physiological and metabolic processes.

This also results in chlorosis, damage to root tips, reduced water and nutrient uptake and damage to enzymes (Sanità di Toppi and Gabbrielli, 1999).

Refuse generation, dumping and management have become a serious environmental problem in many urban areas in Nigeria. The volume of waste generated in many of these urban areas has been on the increase in recent times. Many human factors such as: technology, industrialization, agricultural practices, transportation, education, construction trade, commerce, nutrition, and most importantly population increase are directly responsible for increase in refuse generation in any human society (Ojeshiria, 1999). Although solid waste can be an asset when properly managed, it poses the greatest threat to life amongst all the classes of waste since, it has the potential of polluting the terrestrial, aquatic and aerial environments (Bishop, 2000). As it is in most cases, soils in municipal waste dumpsites commonly serve as fertile ground for the cultivation of a variety of fruits and leafy vegetables and the soils are also used as 'compost' by farmers with little regard to the probable health hazards the heavy metal contents of such soils may pose (Amusan et al., 2005).

The indiscriminate dumping of damaged parts of imported electronic materials and other similar locally produced materials in different forms can alter the distribution and concentration of these metals in the environment. As a result, heavy metal present in the waste accumulates in the environment through leaching of these metals during degradation process thus resulting to underground water contamination. Leachetes from refuse dumpsite constitute a source of heavy metals pollution to both

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soil and aquatic environments (Ebong et al., 2008). Although some works have been done on heavy metal in refuse dumpsites, the general objective of this work was to evaluate heavy metal distribution in dumpsites. The specific objective was to assess the distribution of these heavy metals in the soil-clay-silt particle size.

## MATERIALS AND METHODS

**The study site**

The study was carried out in two designated dumpsites in Enugu state, South Eastern Nigeria. These are: Ugwuaji located within the state capital along Enugu PortHarcourt express way which is located by latitude 06$^o$ 30$^1$N and longitude 07$^o$30$^1$E and the other dumpsite is located in Nsukka town behind Ikenga Hotel. Nsukka is located by latitude 06$^o$52$^1$N and longitude 07$^o$24$^1$E with an elevation of 447m above the sea level. The neighbouring areas surrounding the dumpsites in both locations are used for vegetable production such as green vegetables (Amaranthus spp.), maize, okra and tomatoes.

**Climate**: a tropical wet and dry climate prevails in the study area. The area is characterized by high temperature and high rainfall. The rainfall pattern is bimodal between April and October, while the dry season is between November and March. The mean temperature ranges between 24$^o$C – 27$^o$C while relative humidity is between 60 – 80% (ENADEP, 1993).

**Topograghy:** the landscape is generally flat to slightly undulating at the Enugu dumpsite with no sign of erosion while the Nsukka dumpsite is a gully which is due to long period of sand excavation.

**Sample Collection and Analyses Procedure:**

Soil samples were collected from the two locations (dumpsites). In each location, two sampling points were selected and soil samples at 0 - 20 cm, 20 – 40 cm and 40 – 60 cm depths were collected. Eight Undisturbed core samples were also collected at each sampling points to determine the soil bulk density, hydraulic conductivity and total porosity. pH was determined with pH meter in a soil: solution ratio of 1:25. Bulk density was determined using the core method as described by Anderson and Ingram (1993). Total porosity was determined using the method described by Carter and Ball (1993). Saturated hydraulic conductivity was measured on soil core using a constant head parameter as described by Bouwer (1986). Soil particle analysis was done using Bouyoucous hydrometer method (Day, 1965).

### Analysis of Heavy Metals

The heavy metals (Cu, Zn, Fe, Pb, B, Mn and Cd) content of the soil samples were extracted using the wet-acid digestion method. Digestion of soil sample for heavy metals was carried out with a mixture of Conc. $HClO_4$ and $HNO_3$ at a ratio of 2:1 and heavy metals were extracted using 0.5m HCL (Lacatusu, 2002). The heavy metals concentrations in the supernatant were determined using Atomic Absorption spectrophotometer meter Alpha 4 model.

**Statistical analysis**

The data collected were analyzed using Genstat Discovery Edition 2.

## RESULTS AND DISCUSSION

The physical and chemical characteristics of the soil samples from Nsukka and Enugu refuse dumpsites are shown in Table 1. The soil textural classes vary with depth in the two locations. The textures are mostly sandy clay loam to clay loam on the surface soil and loam to loamy sand at the sub surface in Nsukka dumpsites and loam to clay loam in Enugu dumpsites. This soil texture allows for free drainage and ease of mobility of ions within the soil.

The soil pH of the samples analysed at the different depths indicated that the soils were slightly acidic to moderately acidic (Table 1). Soil pH has a major influence on the availability of heavy metals that present predominantly as cations ($Cu^{2+}$, $Zn^{2+}$, and $Pb^{2+}$) and lower pH would favour availability, mobility and redistribution of the metals Pb and Cd in the various fractions (Oviasogie and Ndiokwere, 2008). Lombi and Gerzabek (1998) reported that soil pH is very important for most heavy metals, since heavy metal availability is relatively low when pH is around 6.5 to 7 and that under acid conditions, sorption of heavy metal cations by soil colloids is at a minimum and the solution concentrations are relatively high. Table 2 shows the physical characteristics of the undisturbed soil samples from both locations. Both locations have relatively low bulk density. This could be attributed to their high porosity.

Total pore space is significant in determining soil drainage and movement of nutrients and pollutants in the soil. In the soil under study, total pore space appears high but a large proportion of it is composed of small pores that are very efficient in the movement of water and air. Soil texture and structure are keys in exerting influence on soil physical and chemical properties notably: drainage, aeration, water holding capacity, nutrient retention and movement of contaminants within the soil profile. The mobility of elements, nutrients and metal ions depend on diffusion through porous medium and other variables such as soil porosity and moisture content. Table 3 shows the critical and normal limits of heavy metals in soil. Table 4 shows the some of the harmful health effects of excessive levels of heavy metals in drinking water due to ground water pollution by heavy metals.

**Table1. Some physical and chemical characteristics of the studied soil samples**

| Location | Sampling points | Depth (cm) | pH ($H_2O$) | pH (KCl) | % Clay | % Silt | % sand | Texture |
|---|---|---|---|---|---|---|---|---|
| Nsukka | 1 | 0 – 20 | 5.5 | 5.2 | 28 | 2.8 | 69.2 | Sandy clay loam |
| | | 20- 40 | 4.8 | 4.8 | 20 | 6.8 | 73.2 | Sandy clay loam |
| | | 40-60 | 5.3 | 5.3 | 32 | 6.8 | 61.2 | Clay loam |
| | 2 | 0 -20 | 6.9 | 6.6 | 18 | 20.8 | 61.2 | Loam |
| | | 20- 40 | 6.9 | 6.6 | 32 | 4.8 | 62.2 | Clay loam |
| | | 40-60 | 5.6 | 5.4 | 8 | 6.8 | 85.2 | Loamy sand |
| Enugu | 1 | 0 -20 | 7.0 | 6.5 | 32 | 12.8 | 55.2 | Clay loam |
| | | 20- 40 | 5.0 | 4.1 | 22 | 12.8 | 65.2 | Loam |
| | | 40-60 | 5.4 | 4.6 | 36 | 6.8 | 57.2 | Clay loam |
| | 2 | 0 - 20 | 4.8 | 4.1 | 24 | 12.8 | 63.2 | Loam |
| | | 20- 40 | 4.5 | 3.8 | 36 | 14.8 | 49.2 | Clay loam |
| | | 40-60 | 4.4 | 3.7 | 30 | 10.8 | 59.2 | Clay loam |

**Table 2. mean effects of two location on the properties of the undisturbed soil samples.**

| Location | BD ($gcm^{-1}$) | H.conductivity K($cm^3$/hr) | Tp (Vol) (%) | Mac. P (%) | Mic. P (%) |
|---|---|---|---|---|---|
| Enu | 1.54 | 19.8 | 51.3 | 9.8 | 41.6 |
| Nsk | 1.31 | 3.2 | 49.8 | 12.0 | 37.8 |
| LSD | NS | NS | NS | NS | NS |
| CV | 32.8 | 12.9 | 26.8 | 25.4 | 31.6 |

BD: Bulk density. H. C: Hydraulic conductivity. Tp: Total porosity. Mac. P: Macro-porosity. Mic. P: micro-porosity

**Table 3: Normal and critical limits of heavy metals in soil (mgkg-1)**

| Heavy metal | Normal range | Critical Limits |
|---|---|---|
| Pb | 2 – 300 | 400 |
| Zn | 1 – 900 | 90 – 400 |
| Cu | 2 – 250 | 60 – 125 |
| Cd | 0.01 – 20 | |
| | - | - |

Normal range = Bowen (1979), critical range = Kabata – pendias and Pendias (1984).

The distribution of heavy metals in both location and at varying depths as shown in Table 5 was not significantly different. The result of analysis indicated that dumpsites in Nsukka were high in Zn, Cd, B, Mn accumulation than those of Enugu. This could be due to the type and duration of refuse at Nsukka dumpsite.The accumulations of these heavy metals were higher in the top soil (0-20 cm) but decreases with depth except for B and Cd whose accumulations in the 40-60cm depth were higher than that in 20-40cm depth. The accumulation of Cu, Fe and Pb was low in both location and at their varying depths. This indicates low ground water pollution by such heavy metals but with time, because of the solid waste (batteries, drugs, various dyes etc.) which characterised the dumpsite, heavy metals can infiltrate through the soil and pollute the ground and surface waters which go through the plants can reach to humans through food chain (Taseli, 2007; El-Fadel *et al*., 1997; Daskalopoulos *et al*., 1997; Tchobanoglous *et al*., 1993). The mobile forms of these heavy metals constitute a risk as they may leach into groundwater that is used for human or animal consumption (Alloway, 1996).

Generally, though there was no significant difference in the distribution of heavy metals in the soil-clay-silt fraction; Mn, Zn and Cd had higher concentrations which decreased with depth except for Fe and Pb (Table 5). The concentration of the heavy metals was very low, indicating low potentials for contamination of the soil (Table 3). This is not in line with the study conducted by Kimani (2010) in Kenya on the Dandora waste dumpsite in Nairobi which showed high levels of heavy metals, in particular Pb, Hg, Cd, Cu and Cr in the soil samples obtained on the site. This discrepancy could be attributed to age of the dumpsites. The concentrations of the heavy metals in the dumpsites are below the critical levels as proposed by Kabata – pendias and Pendias (1984), Bowen (1979) and FEPA (1991) to constitute hazard.

**Table 4: Harmful Health Effects of Excessive Levels of Heavy metals (mg/l) in drinking water**

| Heavy metal | Harmful health effects | WHO guideline value (mg/l) |
|---|---|---|
| Cadmium | Neurotoxin, hypertension, carcinogenic, teratogenic, mutagenic, liver and kidney dysfunction | 0.003 |
| Chromium | Chronic toxicity (above 5mg/l), bleeding of the gastrointestinal tract, cancer of the respiratory tract, ulcers of the skin and mucus membrane | 0.05 |
| Cobalt | Possibly carcinogenic. High concentrations cause vomiting, nausea, vision problems, heart problems, thyroid damage | None yet |
| Lead | High blood levels can inhibit haem synthesis, cause irritation, mental retardation, brain damage; produce tumour | 0.01 |
| Nickel | Carcinogenic. Negatively affects reproductive health | 0.02 |

Source**:** Adelekan and Alawode (2011)

**Table 5. Mean Distribution of Heavy Metals (mg/kg) in the Clay and Silt Fractions of the Soil.**

| | **Clay fraction** | | | | | | | **Silt fraction** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Depth (cm)** | $Zn^{+2}$ | $B^{+2}$ | $Pb^{+2}$ | $Cu^{+2}$ | $Cd^{+2}$ | $Fe^{+2}$ | $Mn^{+2}$ | $Zn^{+2}$ | $B^{+2}$ | $Pb^{+2}$ | $Cu^{+2}$ | $Cd^{+2}$ | $Fe^{+2}$ | $Mn^{+2}$ |
| **0-20** | 25.3 | 6.83 | 0.03 | 0.42 | 7.54 | 1.65 | 15.4 | 15.3 | 5.69 | 0.02 | 0.38 | 3.53 | 1.24 | 9.7 |
| **20-40** | 20.0 | 7.13 | 0.03 | 0.57 | 6.08 | 1.93 | 13.1 | 12.4 | 5.94 | 0.04 | 0.91 | 5.38 | 1.37 | 9.3 |
| **40-60** | 17.9 | 7.43 | 0.02 | 0.16 | 6.00 | 2.52 | 8.90 | 9.30 | 5.95 | 0.01 | 0.09 | 5.85 | 2.13 | 8.0 |
| **LSD** | NS | NS | NS | NS | NS | 0.65 | NS | NS | NS | NS | NS | NS | NS | NS |
| **location** | | | | | | | | | | | | | | |
| **Enugu** | 13.2 | 6.73 | 0.02 | 0.26 | 5.09 | 2.33 | 11.4 | 8.70 | 6.54 | 0.02 | 0.22 | 4.26 | 8.30 | 8.30 |
| **Nsukka** | 29.0 | 7.53 | 0.03 | 0.51 | 7.99 | 1.74 | 13.5 | 16.0 | 5.18 | 0.02 | 0.07 | 5.58 | 9.60 | 9.60 |
| **LSD** | NS | NS | NS | NS | NS | 0.53 | NS | NS | NS | NS | NS | NS | 1.12 | NS |

There is a significant difference in the distribution of $Fe^{+2}$ in the clay particle fraction in the dumpsites at both location and at varying depths only at the clay fraction (Table 5). $Fe^{+2}$ increased with depth. The concentration of $Fe^{+2}$ at 0-20cm was lowest (1.65mg/kg) while 40-60cm had the highest (2.52mg/kg) $Fe^{+2}$ concentrations. According to Mbah and Anikwe (2010), many soil properties including soil PH exchangeable properties and base saturation are influenced by soil heavy metal contents. At low $P^H$, solubility and percolation of heavy metals into deeper horizons of the pedon are increased.

The Cd values range from 7.54 mg/kg to 6.00 mg/kg and 3.53 mg/kg to 5.95 mg/kg for the clay and silt fractions respectively. Though the Cd values were not significant down the soil depth, 0-20cm depth had the highest Cd accumulation levels in clay fraction. However, the reverse was the case with the silt fraction, Cd accumulation levels increased with depth having the highest values (5.95 mg/kg) at 40-60cm depth. The reason for the variability in values could not be presently ascertained. This is similar to the findings of Adelekan and Alawode (2011) where a similar situation was observed. According to him, the value of Cd obtained in Agodi at the depth of 45-60cm was 0.85mg/kg while it was below detection limit at all the upper depths. Similarly, there were high levels of Zn accumulation in the 0 – 20cm depth in the clay fraction and least in 40 –60cm depth. The same trend was observed in the silt fraction. Though Zn accumulation levels were not significant, the clay fraction retained more Zn accumulation than the silt fraction. This implies that dumpsites with high percentage of silt fraction will have higher accumulation of Zn in the ground water compared with dumpsites that have high percentage of clay fractions. Similar results were obtained for Mn which consistently decreased in value across the soil depth. According to Harter and Naidu (2001), soil pH and other factors such as the presence of competing ligands, the ionic strength of the soil solution and the simultaneous presence of competing metals can significantly affect sorption processes and leaching potential through a soil profile. The absorption of heavy metals also differs in the different soil horizons due to texture composition in different soil horizons.

## CONCLUSION

Results of the study showed lower concentration of heavy metal in the dumpsites at both locations (Table 5). This implies that the mean concentration of heavy metal at the dumpsites is far below the critical limits which are the range of values at which toxicity is considered possible (Table 3). The study showed that agricultural soil around the studied dumpsite contains lower levels of heavy metals and does not constitute health risk to human and animal health when plants – based food stuff grown along the area are consumed.

Therefore, farming around those dumpsites is encouraged. In conclusion, the clay fractions retained more heavy metals (Zn, B, Cd and Mn) and prevented leaching into the ground water than the silt fractions. This means that dumpsites should be sited in soils that are high in clay content than in silt content to prevent ground water pollutions by heavy metal through leaching.

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