

Spatial Concentrations of Heavy Metals in Soils and Plants of a Landfill site in Uyo, Akwa Ibom State

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Abstract: Landfill sites are known to harbor *inter alia* unsorted waste such as plastics, old batteries, electronics and electroplated metals. These sites serve as important sources of organic manure for vegetable and crop production. Consequent upon this, monitoring heavy metal proportions and toxicity from these landfills becomes necessary for ecosystem integrity and human well-being. In line with this, the present study investigated the concentration of heavy metals in and around a popular landfill area within the central axis of Uyo metropolis. Four sampling sites around the landfill were chosen for the investigation. Sites included; the landfill, farmland, streambed and floodplain-wetland. Twenty-four soil samples from the four sites were collected using a soil auger. Additionally, plant shoots from the most dominant flora species, *Cytospermum senegalensis* (Scott) Engl. around the landfill area was collected. Shoots were harvested from mature plants growing five metres inwards of the landfill and in three other locations not farther than twenty meters. Five metals namely; Lead (Pb), Cadmium (Cd), Iron (Fe), Zinc (Zn) and Aluminum (Al) were determined using an Atomic Absorption Spectrophotometer (AAS). Of the five metals tested in both the soil samples and plant shoots, Fe was the most abundant metal. Notably, the highest value was from soil (197.9mg/kg) and plant (19.40mg/kg) samples obtained from the farmland. The farmland also had the highest level of Pb in both soil and plant samples; soil (9.9mg/kg) and plant (10.9mg/kg). The landfill site was second to the farmland in heavy metals concentration, while the streambed had the least concentration of heavy metal. Also, Transfer factor threshold for Pb and Cd in both landfill and farmland exceeded unity (> 1). More so, Cd levels clearly exceeded regulatory standards. Furthermore, the floristic composition of the study area was a mixed flora of food crops and those typical of riparian vegetation. The high concentrations of heavy metals within the study area have severe implications for crop production, particularly as Pb and Cd are known to be carcinogenic. Beyond the direct consumption of crops grown around the landfill, is the issue of downstream users of the river basin. In light of this, we argue for a relocation of this landfill and immediate remediation of the site. Also, the use of landfill areas such as those of the study areas for farming activities should be discouraged through awareness mobilization at farmers-agriculture extension service platforms.

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1. Introduction

Waste management is an intractable environmental problem in Nigeria. This problem has manifested in the form of piles of indiscriminately disposed heaps of uncovered wastes and illegal dumpsites along major roads and at street corners in cities and urban areas. This problem is compounded by the rapid urbanization and population growth which has led to the generation of enormous quantities of wastes which are often discarded by open dumps.

Landfilling is the most common method for waste disposal globally (Kollikkathara *et al.*, 2009). From an environmental perspective such disposal is inherently problematic since landfills are also well-known sources for various pollution problems such as long-term methane emissions and leaching of hazardous substances (Mor *et al.*, 2006). Soil pollution by heavy metals has become a critical environmental concern due to its adverse ecological effects. Although heavy metals occur naturally at low

concentrations in soils, they are considered soil contaminants due to their widespread occurrence, as well as their acute and chronic toxicity (Youn-Joo, 2004). They bio-accumulate in soil and due to their long persistence in the soil, ultimately enter the food chain and may bio-magnify along trophic lines through plants or animals (Dosumu *et al.*, 2003). The rapid urbanization of Sub Saharan African communities and increase in slum dwellers (UN-Habitat, 2012), puts pressure on available natural resources including arable land. As a strategy for maximum plant growth and yield, small-holder farmers in cities such as those of the study area, tend to obtain surface soils from around landfills. Sometimes where access is granted crops are grown within the perimeter of these landfills. In light of the growing health risk of heavy metal toxicity, the present research aimed at testing concentrations of the following heavy metals (Pb, Cd, Fe, Zn and Al) in and around a popular landfill with Uyo metropolis.

2. Material and Methods

2.1 Study Area

This study was carried out in four sampling sites around a landfill in Uyo metropolis, Akwa Ibom State. They include; landfill, farmland, streambed and floodplain-wetland. Uyo is located at latitude: 5° 03' 4.57" N and longitude 7° 56' 0.60" E within the South-South region of Nigeria. This city has a tropical climate with an average annual temperature of 26.4°C. The annual rainfall averages 2509 mm (AKSG, 2018). Uyo is geographically bounded on the East by Uruan Local Government Area, Abak Local Government Area in the West, Ibiono Ibom Local Government Area in the North and Ibesikpo Asutan Local Government Area by the South.

2.2 Plant Collection/Sample Preparation

The plant shoots of the most abundant plant species (*Cyrtosperma senegalense*) growing 5m inwards of the landfills and three other locations around the landfills not farther than 20 metres were harvested. The harvested plant materials were washed off dirt using water. The harvested shoots were grouped based on the sites of collection into four assemblages (landfills, farmland, streambed and wetland) and taken to the laboratory for heavy metals assay.

The samples in each of the sites were air dried to remove the moisture and water droplets simultaneously. They were then dried to constant weight in an oven maintained at 105°C, and pulverized to fine powder using a laboratory grinder. The ground leaves were stored in labeled polythene bags and placed in a desiccator. 3.0 g of each samples was carefully weighed into a clean platinum crucible and ashed at 450- 500°C before being cooled to room temperature in a desiccator. The ash was dissolved in 5 ml of 20% hydrochloric acid and the solution was carefully transferred into a 100 ml volumetric flask. The crucible was well rinsed with distilled water and transferred to the flask and made up to the mark with distilled water and shaken to mix well. The resulting sample solutions were then taken for the determination of the heavy metal concentrations using Atomic Absorption Spectrophotometer (AAS).

2.3 Vegetation Sampling/Soil Samples Collection and Analysis

Plant species in the studied sites were identified to species levels. Soil samples from the four sites were collected in a ring form at a rooting depth of 1.35m from 6 different points (3 from each for consistency across the site) and stored in labeled ziploc bags. In all, a total of 24 soil samples were collected. These were taken to the laboratory for digestion and analysis for heavy metals.

In the laboratory, Soil samples were ground, mixed, and divided into fine particles that could pass

through a 0.5-mm sieve. Soil samples were digested by adding 2 g of soil to 15 ml of concentrated nitric acid and perchloric acid at a ratio 1:1, and allowed to stand for 135 minutes until the mixture became colourless. The samples were filtered and washed with 15 ml of deionized water, and made up the filtrate to 100 ml in a standard flask. Six heavy metals (Fe, Zn, Cd, Pb and Al) were determined in the filtrate at their respective wavelengths using Unicam 939 Atomic Absorption Spectrophotometer (AAS).

2.4 Statistical Analysis

Mean and standard error were computed from triplicates of soil physico-chemical parameters using SPSS 20.0. Transfer factor analysis was also done to ascertain the amount of heavy metals or contaminants accumulated in plants as a fraction of the soil totals. Cluster analysis was done using PAST 3.0 to show heavy metals source apportionment and site similarities.

2.4.1 Determination of Transfer Factor (TF)

Metal concentration in the extracts of soils and plants were calculated on the basis of dry weight. The plant transfer factor (TF) was established using the formular (Olănescu, 2007)

$$TF = \frac{M_p}{M_s}$$

Where TF = Transfer Factor; M_p and M_s = Metal content in plant (mg/kg) and soil (mg/kg), respectively.

3. Results

3.1 Floristic Composition

Table 1 shows the floristic composition of the study sites. A total of 30 plant species belonging to twenty two (22) families were encountered. *Cyrtosperma senegalense* occurred most in all the sites with frequency value of 80% while *Bazella alba*, *Cucumis melo*, *Dioscorea dumentorum* and *Zea mays* had the least frequency values of 10%, respectively.

3.2 Heavy metals Concentration in the Soil Samples

Table 2 reveals the mean concentration (in mg/kg) of five (5) heavy metals in soils of the selected sites. Iron was the most abundant of all the heavy metals assessed in the sites while Pb was the least abundant. Farmland had the highest concentrations of Fe (197.90 mg/kg), Zn (93.06 mg/kg) and Pb (9.9 mg/kg) while Landfills recorded the highest concentrations of Cd (9.3 mg/kg) and Al (34.22 mg/kg). Stream bed recorded the least concentrations of all the heavy metals studied.

3.3 Heavy metals Concentration in the Plants

Table 3 reveals the mean concentration of five (5) heavy metals in the plant's tissues (*Cyrtosperma senegalense*) obtained from four selected sites in and around the landfills. The concentration of Fe (19.40

mg/kg), Pb (10.09 mg/kg) and Al (16.8 mg/kg) were highest in the plant tissues obtained from farmland, while the concentrations of Zn (19.40 mg/kg) and Cd (11.2 mg/kg) were highest in plant tissues obtained from landfills.

Table 1. Plant distribution in and around the Uyo Metropolitan landfills

Species	Family	Frequency (%)
<i>Alchornea cordifolia</i> Muell. Arg.	Euphorbiaceae	50
<i>Atenantha sessilis</i> (L.) R.Br. ex DC.	Amaranthaceae	50
<i>Anchomanes difformis</i> (Bl.) Engl	Araceae	70
<i>Anthocleista vogelli</i> Planch	Loganiaceae	30
<i>Bambusa vulgaris</i> Schrad. Ex Wend.	Poaceae	40
<i>Baphia nitida</i> Lodd.	Papilionaceae	20
<i>Bazella alba</i> L.	Basellaceae	10
<i>Bryophyllum pinnata</i> (Lam.) Oken	Crassulaceae	30
<i>Caladium bicolor</i> Vent.	Araceae	40
<i>Calapogonium muconoides</i> Desv.	Leguminosae	50
<i>Chromolaena odorata</i> (L.) King & Robinson	Asteraceae	50
<i>Cleome spinosus</i> Jacq.	Asteraceae	20
<i>Cnestis ferruginea</i> DC	Connaraceae	20
<i>Commelina benghalensis</i> L	Asteraceae	40
<i>Costus afer</i> Ker-Gawl	Costaceae	40
<i>Cucumis melo</i> L.	Cucurbitaceae	10
<i>Cyrtosperma senegalense</i> (Schott) Engl.	Araceae	80
<i>Dioscorea dumetorum</i> (Kunth) Pax.	Dioscoreaceae	10
<i>Elaeis guineensis</i> Jacq.	Araceae	20
<i>Ipomoea batatas</i> (L.) Lam.	Convulvaceae	20
<i>Justicia schimperii</i> (Hochst) Danby	Acanthaceae	30
<i>Manihot esculenta</i> Crantz	Euphorbiaceae	20
<i>Nymphaea odorata</i> Aiton	Nymphaeaceae	20
<i>Physallis angulata</i> L.	Solanaceae	30
<i>Pityrogramma calomelanos</i> (L.)	Pteridaceae	20
<i>Rauvolfia vomitoria</i> Afzel.	Apocynaceae	20
<i>Sacciolepis africana</i> C.E Hubb & Snowden	Poaceae	40
<i>Vossia cuspidata</i> (Roxb.) Griff	Poaceae	40
<i>Zea mays</i> L.	Poaceae	10

Table 2. Heavy metals concentration (mg/kg) of Soil in the Study Sites

	Fe	Zn	Cd	Pb	Al
Landfills	156	91.83	9.3	4.7	34.22
Farmland	197.9	93.06	8.7	9.9	26.15
Wetland	121.9	49.33	3.6	2.1	28.2
Stream bed	90.25	35.92	1.03	0.62	19.72

Table 3. Heavy metals concentration (mg/kg) in Plant

	Fe	Zn	Cd	Pb	Al
Landfills	16.69	19.40	11.2	5.4	14.37
Farmland	19.40	8.06	7.6	10.9	16.8
Wetland	11.14	3.32	1.6	1.3	1.4
Stream bed	6.32	4.46	0.31	0.2	11.72

3.4 Transfer Factor Threshold

Figures 1 to 5 shows a graphical representation of transfer factor threshold of individual metals in studied locations. It relates a peak value exceeding unity (> 1) for Pb and Cd in Landfills and (or) farmland.

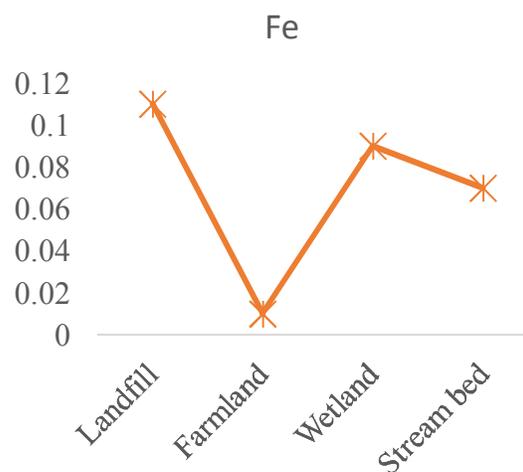


Figure 1. Transfer Factor threshold for Fe in the study sites

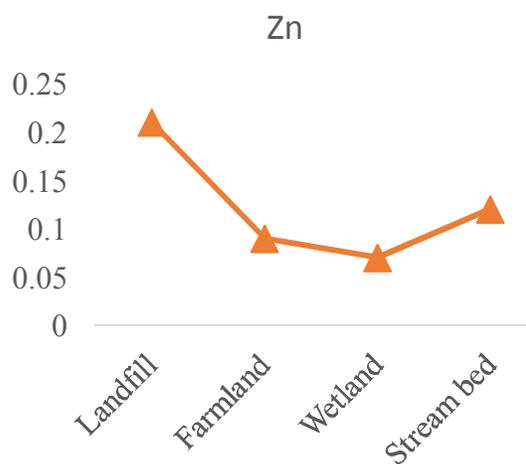


Figure 2. Transfer Factor threshold for Zn in the study sites

3.5 Cluster Analysis

Figure 6 shows the source apportionment for individual metals using multivariate techniques. Three (3) cluster groups were identified based on the sources of the heavy metals namely; the crustal source (Fe), anthropogenic source (Zn) and the intermediate or combined group (Cd, Pb and Al). Figure 7 shows the grouping of the four studied sites based on similarities. Here, two (2) cluster groups were delineated namely;

impacted sites (landfills and farmlands) and relatively unimpacted sites (wetland and stream bed).

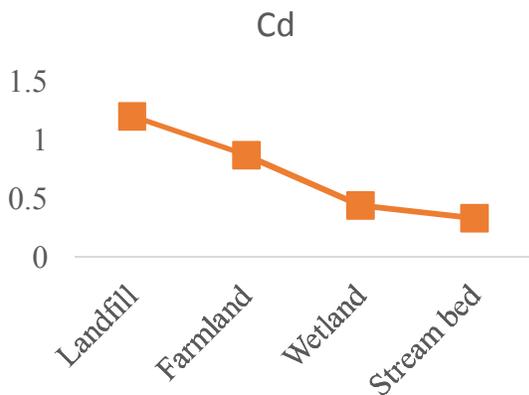


Figure 3. Transfer Factor threshold for Cd in the study sites

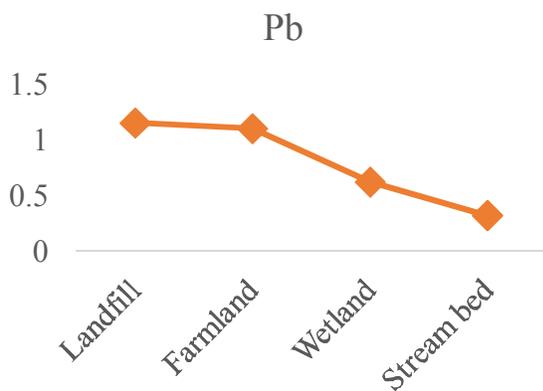


Figure 4. Transfer Factor threshold for Pb in the study sites

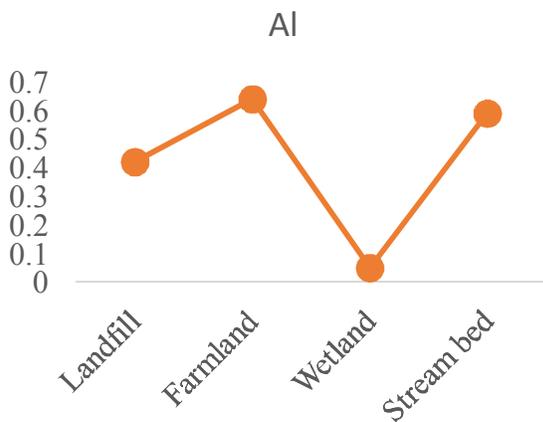


Figure 5. Transfer Factor threshold for Al in the study sites

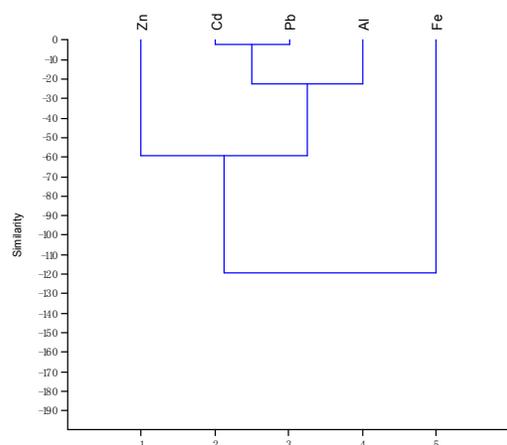


Figure 6. Cluster dendrogram showing heavy metals source apportionment

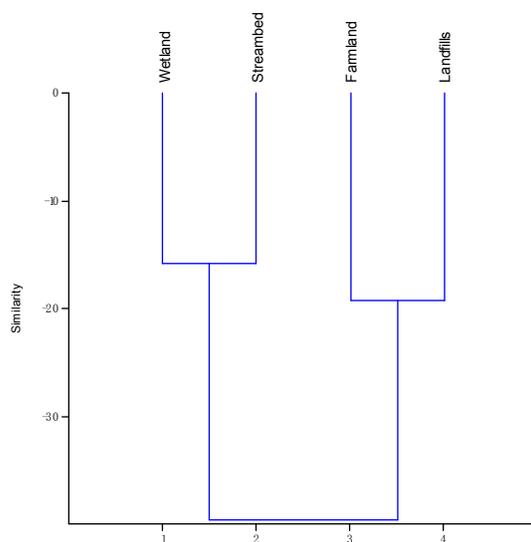


Figure 7. Cluster dendrogram showing sites similarities

4. Discussions

The result of this study revealed a total of 30 plant species growing in and around Uyo urban landfills. This number of flora species recorded in this study is high compared to that which was reported by Mbong and Ogbemudia (2013) while studying plant distribution in metropolitan dumpsites in Uyo. This disproportion could be linked to a number of factors such as age of landfills, size and location of landfills and selective exploitation of species as well as anthropogenic upheavals. Also, the species composition of the landfills is indicative of diverse

land use types. For instance, the occurrence of crops such as *Zea mays*, *Cucumis melo*, *Manihot esculenta* around the landfills may invariably point to subsistent agricultural practices going on there whereas the occurrence of species such as *Elaeis guineensis* may be an indication of the economic value attached to these area and prolonged human influence.

The heavy metal contents at the study sites followed this pattern Fe>Zn>Al>Pb>Cd. The concentrations of Cd and Pb were relatively low when compared with values obtained for other metals in plant and soil of the study sites. Similar trend was by Ita and Anwana (2017) in their study on geochemical assessment of heavy metal contamination in rural and urban wetlands. Generally, stream bed had the least concentrations of these heavy metals both in soils and in plants when compared with other sites (landfill, farmland and wetland). This could be attributed to the quantity of wastes deposited in this site. It can also be explained that this site had minimal waste deposition leading to the release of these metals in small quantities.

According to Mbong *et al.* (2015), transfer factor is a competent technique developed to assess the level of metals in plant as a fraction of the soil total. These scholars maintained that transfer factor values higher than one (1) pose a serious heavy metal risk to the ecosystem. Previous studies carried out by Amusan *et al.* (2005) and Agyarko *et al.* (2010) had showed that the uptake of metals by plants differs from one metal to another, from one plant species to another and from one dumpsite to the other. The results from this study as shown in the transfer factor threshold limits call for utmost concern and attention. The transfer factor values computed for plants obtained in the landfills and farmland show high Pb and Cd contamination. This goes a long way to confirm the result obtained for cluster analysis which assorted these two metals (Pb and Cd) (Fig. 6) and the two sites (landfill and farmland) (Fig. 7) into the same sub-cluster group. The variations in transfer factor indices of the different metals could be linked to the availability of diverse heavy metals present in the soil as a result of heterogeneous waste deposition which differ from one site to the other.

The result of this study particularly that of the transfer factor values obtained for lead and cadmium in farm land is problematic and calls for a serious concern. This is because as these metals accumulate in plant's tissues, they get magnified as they headway from one food chain to another causing series of health issues to humans who consume crops or food stuffs contaminated by them. According to Bolger *et al.* (2000), some long lasting negative impacts of Pb toxicity includes colic, constipation and anemia (blood related disorder). Children show weakness

towards Lead (Pb) noxiousness and that Pb results in harm to the central nervous system, in severe chances death may occur (Nicklow *et al.*, 1983). Under usual circumstances, more than 90 % of the lead (Pb) reserved in the body exists in the skeleton. Moreover, during lactation and pregnancy, lead moves from mother's bones to breastfed infants and fetuses (Suruchi and Khanna, 2011). Lead (Pb) is noxious and there are doubts that body weights under those at which clinical signs of Pb noxiousness shows, may result in cerebral injury in young children (Davies, 1995) and increase blood pressure (BP) in adults (Suruchi and Khanna, 2011). In addition, the carcinogenic (cancerous) and mutagenic properties of lead have been frequently proved (Michalak and Wierzbicka, 1998). Lead (Pb) toxicity results in decrease of hemoglobin production, disorder in the working of kidney, reproductive system, joints and cardiovascular systems and causes long-lasting injury to the central and peripheral nervous systems (Nolan, 2003).

Rashed (2001) observed that Cd excretion was appreciably slower than the rate of its entry into a biological system, leading to a progressive accumulation of cadmium in soft tissues of the body, particularly in kidneys and liver. Due to its gradual accumulation, much concerns have been expressed about the regularly growing levels of cadmium in cereals and vegetables. Continuous exposure of Cd in vegetables and other edibles results in accumulation of Cd in kidneys leading to kidney diseases (ATSDR, 1993). Higher contact with Cd may result in lung disorders like bronchiolitis, emphysema and alveolitis. renal effects (kidney related) may also be caused by sub chronic breathing of Cd (Young, 2005; Ogwuegbu and Muhanga, 2005).

Conclusion and Recommendations

The floristic composition of the study area revealed a diversified flora of food crops and riparian vegetation. The result of this study shows that the plant species could serve as a veritable tools in assessing the status of the environment in terms of anthropogenic disturbances and pollution. It further highlights that uncontrolled and indiscriminate refuse dumping could be a source of toxic metals cycling in the environment. Against this background, the following measures are recommended:

- i) Awareness campaigns should be organized for farmers on the ills and health hazards of cultivating crops in and around landfills and other contaminated sites.
- ii) Use of refuse incineration plants should be encouraged.
- iii) Use of recycled materials should also be encouraged.

iv) Siting of landfills and waste dumping facilities around human settlements and agricultural fields should be discouraged.

v) Cultivation of crops and vegetables by farmers around landfills should be prohibited as such crops are potential carriers of toxic metals in their tissues.

vi) Relocation of this landfill and immediate remediation of contaminated sites should be prioritized by Government and other Environmental Protection Agencies.

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