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Bioaccumulation of heavy metals by *Vigna unguiculata* (cowpea) grown on Olusosun Dump Site soil, Lagos, Nigeria

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Abstract

As a result of African beliefs that dumpsite soils improve plant growth, many local farmers have relied on growing crops on dumpsite soils. For this purpose, this study investigated the presence and level of heavy metals (HM) in Olusosun dumpsite soil and *Vigna unguiculata* grown on the dumpsite, with a particular reference to the relationship between the dumpsite soil HM content and the rate of bio-accumulation by plants and also, a comparison of the HM levels in the test plant with WHO and NAFDAC standard for HM in food and vegetable products. HM concentration was determined through Atomic Absorption Spectrophotometer (AA 6800, Shimadzu) and the seeds of *V. unguiculata* were obtained from Borno State Agricultural Development Program (BOSADP). The result obtained showed the presence of Zinc (Zn), Lead (Pb), Chromium (Cr) and Nickel (Ni) in the dumpsite soil and also in the test plant. Zn was detected to have the highest concentration (12.25 Mg/Kg) while Ni was the lowest (6.1 Mg/Kg). A comparison between the level of HM obtained and the WHO/NAFDAC standard for HM in food and vegetables revealed Zn level in the test plant was within the standard (50-60 Mg/Kg). However, Pb, Cr and Ni were detected to be above the standard (2.0 Mg/Kg) and therefore may pose serious health risk if consumed. The transfer factor (Tf) revealed that plants grown on Olusosun dumpsite soils accumulated higher HM (1.30-9.20). Generally, the result shows that there was an increase in the level of HM in all the sample sites and test plants than the control. This research clearly indicated those consuming *V. unguiculata* grown on Olusosun dumpsite soil are at risk of Pb, Cr and Ni poisoning.

Keywords: Heavy metal, *Vigna unguiculata*, Bioaccumulation and Health risk

Introduction

Soil contamination by heavy-metals as a result of anthropogenic activities in dumpsites is a major environmental concern all over the world (Cortez and Ching, 2014). Heavy metals are described as those metals with specific gravity higher or more than 5 g/cm. Most common heavy metals are Chromium (Cr), Lead (Pb), Cadmium (Cd) and Iron (Fe). Some heavy metals, such as Fe and Ni are essential to the survival of all forms of life, if they are low in concentrations (Khan *et al,* 2011). However, heavy metals like Pb, Cd and Zn are toxic to living organisms even at low concentrations (Helmenstine, 2014). Urban areas generate more waste as a result of high level of industrial activities and therefore subjected to the menace of resultant indiscriminate disposal of both domestic and industrial waste (Helmenstine, 2014). These wastes however contain heavy-metals such as lead (Pb) and

Zinc (Zn) which are of great ecological significance due to their toxicity at certain concentrations. Plants have a natural propensity to take up metals and also accumulate as human feeds on it. (Khan *et al*., 2011). For example, accumulation of Pb affects brain development in children (Yilmax, 2005). Human exposure to heavy metals occurs through three primary routes, i.e. inhalation, ingestion and skin absorption (Ogunyemi *et al,* 2003). The environmental problem with heavy metals is that they are available to biological systems, toxic to organisms and are persistent in the environment (Asuquo *et al.,* 2004).

A dumpsite is a site for disposal of waste materials. Waste is any discarded or abandoned materials can be solid, liquid, or semi-solid and are always sourced from homes, schools, hospitals, and other business areas (EPA, 2011). Dumpsites have been the most organized common methods of waste disposal (Oluyemi *et al.,* 2008). The use of dumpsites or their soil as farm land is a common practice in urban and sub-urban centers in Nigeria because of the belief that decayed and composted wastes enhance soil fertility (Ogunyemi *et al.,* 2003). Theses wastes often contain heavy metals in various forms and at different contamination levels. Heavy metal pollution is considered to be a worldwide threat now-a-day. Heavy metal pollution of the environment results in accumulative health effects and it is considered among the leading health concerns all over the world. For example, bioaccumulation of Cd in human body interferes with the functioning of mitochondria, thereby impairing respiration, and also causes constipation, paralysis and eventual death (EPA, 2011). The situation is even more worrisome in the developing countries where research efforts towards monitoring the environment have not been given the desired attention by the stake holders.

Vigna unguiculata also known as Cowpea is a herbaceous, annual plant in the pea family Fabaceae. The domestication of *V. unguiculata* originated in West Africa. It is one of the most widely used legumes in the semiarid tropics including Asia, Africa, southern Europe and Central and South America (Tanee *et al.,* 2009). Hundreds of experiments have been conducted on this legume to understand its morphology, physiology, as well as to understand the effect of different stresses on it. However, a meager work has been reported on heavy-metal bioaccumulation potential of cowpea and the morphological changes when grown in heavy-metals polluted sites. (Tanee *et al.,* 2009). Therefore the purpose of this study was to assess the concentrations of certain heavy metals (Pb, Ni, Cr and Zn) in Olusosun dump site soil and *V. unguiculata* grown on the soil and compare with WHO and NAFDAC standard for heavy metals in food and vegetables.

Materials and Methods

Sample site

For this study, Olusosun dumpsite located in Ojota, Lagos state of Nigeria with geographical coordinates of latitude 6.441158ºN and longitude 3.417977º was used as the sample site. Three pots (13cm in height and 35cm in diameter) were filled with 9kg (7cm layer) of the dumpsite soil and were labeled A_1, A_2 and A_3 following the method of Musa *et al.,* 2017. The specific points where the three samples were collected was chosen at random. For the control soil, a pot was filled with a semi-arid soil and labeled B. All the soil samples were screened for heavy metals presence before the experiment (Plates 1 – 3).

Source of seeds

Seeds of *V. unguiculata* were obtained from Borno State Agricultural Development Programme (BOSADP) Maiduguri on 12th of October, 2018.

Planting Procedure

Seeds of *V. unguiculata* were surface sterilized in 0.1% $HgCl_2$ solution and washed with distilled water prior to germination at controlled temperature. The seeds were dispersed in experimental pot containing semi-arid soil that is free from heavy-metals for germination. After five days, 12 best seedlings were transplanted into each experimental pot A1, A2, A3 containing the dumpsite soil and control (B) at 2.5cm depth in a Randomized Complete Block Design (Three replicates) following the method of Musa *et al.,* 2017. This experiment was carried out in a screen house that shielded the plants from rainfall and pests. The soils were stirred once every week to enhance aeration and no chemicals used to ensure no additional heavy-metal input. Distilled water was used to irrigate the plant twice a week.

The Experiments lasted for 45days, during this period, the plants were harvested at 15th, 30th and 45th days after germination. For each pot, samples at each of the above dates were taken at the root and stem. The samples were analyzed for Pb, Zn, Cr and Ni uptake. Also, the dumpsite soils A1, A2, A3 and Control were analyzed for heavy-metal presence before sowing and after sowing using atomic absorption spectrophotometer (AA 6800, Shimadzu). The results obtained were statistically analyzed calculating the standard deviation and error bars based on standard deviation using analysis of Variance and post hoc test. Graphs were plotted to depict the results obtained and heavy metal transfer factors (TF) from soil to plants were estimated. TF (%) = $Conc._{Soil}/Conc._{Plants}$ where Conc. is the Concentration.

Results and Discussion

The results in Figure 1 indicates the average concentration in Mg/kg of Zn, Cr, Pb and Ni in all the dumpsite soils before sowing and for the control. High concentration of heavy metals was detected in Olusosun Dumpsite soil obtained from the three different points with Zn being relatively highest. While for the control, significantly low heavy metal was detected. This may be due to the extent of pollution as a result of anthropogenic release of heavy metals containing substances on the Olusosun Dumpsite. This result is consistent with the work of Abdus-Salam, 2009 who also discovered high presence of heavy metals on Yan'an dumpsite in China.

Heavy metal uptake in V. unguiculata at 15th, 30th and 45th days of harvest.

The result in tables 1 and 2 shows the average heavy metal uptake of the test plant at 15th, 30th and 45th days of harvest at the three dumpsite soil pots and controls. The results were average of the heavy-metals detected at the root and stem of *V. unguiculata*. There was a significant ($p<0.05$) uptake of heavy metals at the root and stem of the test plant at the three harvest days. Significant difference between the heavy-metals detected in the root and stem was also obtained. The heavy-metals appeared to be more concentrated at the root than the stem for all the heavy-metal analyzed (Figure 2). While for the control, no heavy metal was detected (tables 1 and 2). This could be attributed to the high metal contents of Olusosun dumpsite soils which are eventually accumulated by the plants grown on them. This also indicates that the concentrations of metals in plants are dependent upon their concentrations in the habitual soil environment and this is in agreement with findings by Udosen (2014). The levels of As and Co in water leaf, spinach from both sites A and B were above those of the control samples. The mean levels of Zn in the test plant studied were below the levels recommended by WHO/FAO, NAFDAC and EC/CODEX for metals in foods and vegetables and are also within the normal range of metals in plants. However, the mean levels of Cr, Pb and Ni in the test plant were significantly higher than the recommended limit by WHO/FAO, NAFDAC and EC/CODEX for metals in foods and vegetables (Table 1, 2 and 3). This shows people depending on Olusosun Dumpsite soil as their source of food are indirectly ingesting heavy metals. Animals in grazing pasture may also ingest considerable amounts directly as soil and materials coatings the leaves and are thus exposed to these even without direct plant uptake. Therefore, there is high risk on the environment and health associated with the use of dumpsite soil for food crop production. Alloway and Davies (2012) and Grant and Dobbs (2017) reported that plant grown on soils possessing high heavy metal concentration have increased heavy metal ion content. The uptake of metals ions has been shown to be influenced by the metal species and plant parts (Juste and Mench, 2002).

Furthermore, the plant showed different concentration of heavy-metals intake with Zn as the highest in all the Plant samples at all harvest dates and Ni was lowest (Figure 2). This may indicate that *V. unguiculata* uptake Zn more than other heavy-metals. Changes in the color of *V. unguiculata* plant was also noted from 12th day with respect to the control. This is suspected to be as a result of the considerable amount of heavy metals accumulated in the plant within the experimental period. Similar work by Ademoronti (2005) showed that vegetable accumulate considerable amount of heavy metals in roots and leaves. Anikwe and Nwobodo, (2002) and Amusan *et al.,* (2009) reported high concentrations of heavy metals in vegetables grown in waste dumpsite soils. The level of concentrations of these metals in soil and plant harvested from the waste dumpsite raises serious environmental concern.

The transfer factor (tf) of heavy metals from the soil to plants, are presented in (Table 4). The transfer factor can be defined as the ratio of the concentration of metals in plants to the total concentration in the soil. It was observed that the transfer factors at day 45 for all the heavy metals in the dumpsite were significantly different from those for control. Pb and Cr has high transfer factors which are 9.20 and 9.00 respectively. The highest transfer factor value obtained was Pb in the stem of sample 3 of Olusosun dumpsite soil. The study gave a generalized transfer coefficient in the soil plant system as: Cr, Pb, Ni, and Zn (1.30-9.20). The transfer factors of Pb, Zn and Ni are within normal range in plant. Plants are known to take up and accumulate trace metals from contaminated soil (Abdul Kasheem, 1999); hence detection in plant leaves and crop samples was not surprising. However, transfer factor in Cr is above normal range in Plant.

Although the levels of these metals are within normal range for plants, however continual consumption could lead to accumulation and adverse health implication particularly for Pd and Cr (Opabunmi and Umar, 2010). Also, the variation in values obtained for these heavy metals in the soil and crop plant samples as against those from control sites is an indication of their mobility within the dumpsites, particularly through leaching and run offs. This is in agreement with the report of Oluyemi *et al,* (2008).

Conclusion

Nine plants grown on three soils of Olusosun dumpsite were investigated for heavy metals Zn, Pb, Cr and Ni accumulation and health risk assessment. This study revealed that Olusosun dumpsite soil has high heavy metals Zn>Pb>Cr>Ni as a result of waste deposited on it. Consequently, *V. unguiculata* grown on Olusosun dumpsite soils accumulated the heavy metals. Concentration of Zn detected in the test plants grown on Olusosun dumpsite were below WHO and NAFDAC permissible levels for food and vegetable products. Cr, Pb and Ni concentrations were all above the WHO and NAFDAC standard and therefore dangerous to human health. Also, strong transfer factor (1.30-9.20) from the soil to the plant was also recorded at 45 days. Therefore, continuous consumption of such plant may lead to bioaccumulation of heavy metals in organism system. This study suggested that consumption of *V. unguiculata* grown on Olusosun soil may cause health disorders, contrary to the belief of many that dumpsites are rich in manure therefore seen as better option for farming. Frequent observation of the quality of soil and plants will be of good idea to know the changes in chemistry of the environment and perhaps introduce remedial measures.

Conflict of Interests

The authors declare no conflict of interest

Tables, Figures and Charts

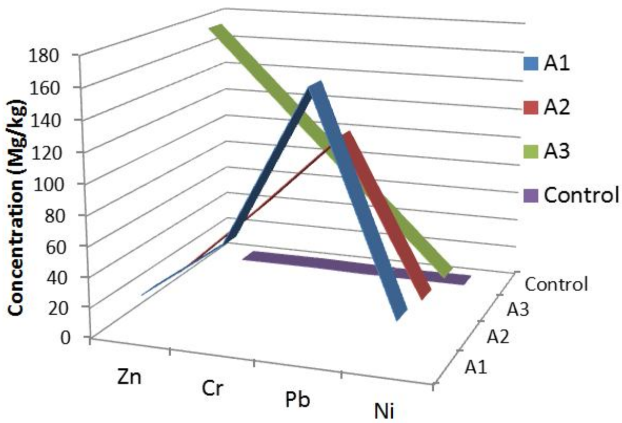

Figure 1: Concentration of heavy metals in dumpsite soil before sowing.

Table 1: Heavy-metals uptake in Root of *V. uguiculata* root at 15, 30, 45th days and Control, using p=0.5 and n=3.

Element (mg/Kg)/Days	Zn	Cr	Pb	Ni
15th	4.3 ± 0.04	4.6 ± 0.02	4.4 ± 0.08	0.8 ± 0.02
30th	11.8 ± 0.06	7.5 ± 0.04	8.1 ± 0.10	4.0 ± 0.04
45th	17.8 ± 0.03	11.4 ± 0.02	16.5 ± 0.06	9.5 ± 0.01
Control	ND	ND	ND	ND

Table 2: Heavy-metals uptake in Stem of *V. unguiculata* at 15, 30, 45th days and Control, using p=0.5 and n=3.

Element (Mg/Kg)/Days	Zn	Cr	Pb	Ni
15th	0.6 ± 0.08	0.4 ± 0.01	1.6 ± 0.08	1.0 ± 0.04
30th	2.9 ± 0.02	2.2 ± 0.06	1.4 ± 0.08	1.7 ± 0.06
45th	6.7 ± 0.03	3.8 ± 0.04	2.7 ± 0.04	2.7 ± 0.01
Control	ND	ND	ND	ND

Table 3: FAO/WHO guideline for metals in food and vegetables.

Metals (Mg/Kg)	WHO/FAO	NAFDAC	EC/CODEX	Normal Range in Plant
Zn	60	50	<5.0	20 - 100
Cr	2	1.0	0.1	<2.0
Pb	2	2	0.3	0.50 - 30
Ni	-	-	-	0.02 - 50

Source: FAO/ WHO

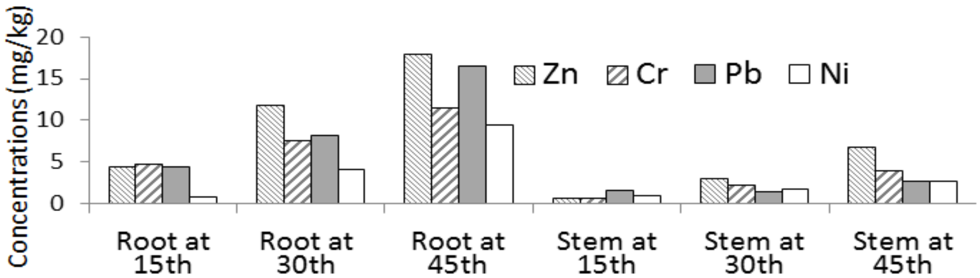

Figure 2: Comparing Root and Stem heavy metals accumulation.

Table 4: Transfer factor (tf) of heavy metals from soil to plants using three replicates per treatment.

		Metals			
Samples	Samples	Zn	Cr	Pb	Ni
A1	Root	1.40	5.70	4.06	2.63
	Stem	3.90	7.10	4.81	7.89
A2	Root	1.28	3.90	1.84	2.19
	Stem	2.40	7.44	9.20	2.63
A3	Root	1.30	9.00	4.50	1.33
	Stem	1.34	3.50	5.55	2.36
Control	Root	ND	ND	ND	ND
	Stem	ND	ND	ND	ND

ND= Not Detected (<0.001)

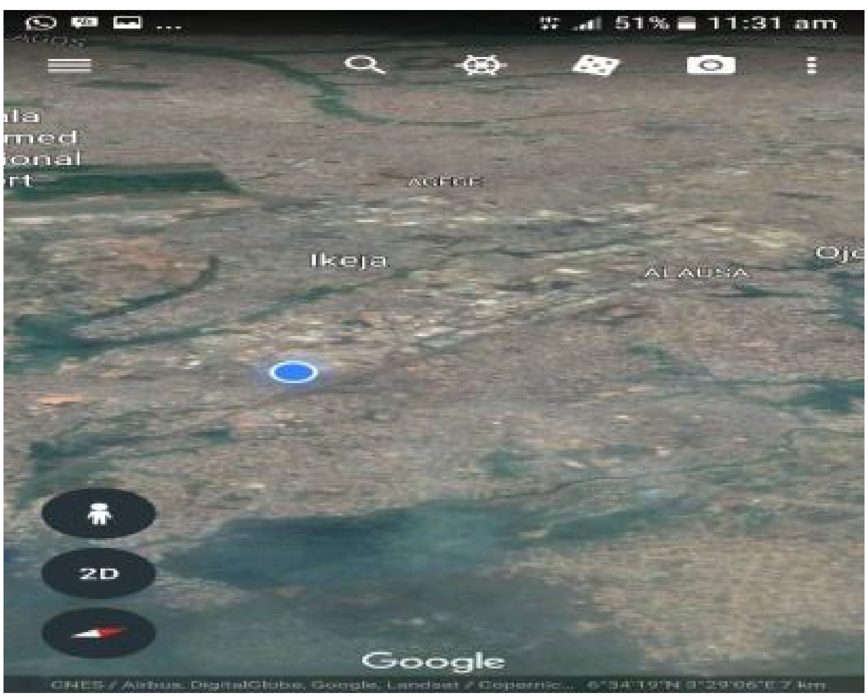

Plate 1: Olusosun Dumpsite, Ojota Lagos Nigeria (google earth)

Plate 2: Olusosun Dumpsite **Plate 3**: Soil Sample of Olusosun Dumpsite.

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