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Heavy Metals Concentration in Rhizosphere and Tissues of Smooth Pigweed (*A. hybridus)* and Bush Okra (*C. olitorius)* cultivated on an Abandoned Dumpsite

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ABSTRACT: The study assessed the concentrations of Pb, Cr, and Cd in rhizosphere and tissues of *A. hybridus* and *C. olitorius* grown on a dumpsite converted to farmland by plant and 0-15 cm depth soil samples which were air-dried, digested and analysed using Atomic Absorption Spectrophotometry. Some physiochemical parameters that affect transport of soil nutrients into plant tissues were analysed using standard methods. The pH of the rhizosphere soil of *C. olitorius* was 6.71 and the soil of *A. hybridus* was slightly alkaline in nature with pH 7.75. The rhizosphere of *A. hybridus* had the highest concentration of Pb (123.20±90.04 mg/kg) and Cd (0.63±0.63 mg/kg) while Cr was highest in the rhizosphere of *C. olitorius* (36.57±8.61 mg/kg). The result showed total and bioavailable metal concentrations in the soils were in the order of Pb > Cr > Cd. The order of metal uptake varied with vegetable crop. Metal concentration in tissues of *A. hybridus* followed the order of Pb > Cr > Cd while *C. olitorius* was Cr > Pb > Cd. Concentrations of Cd, Pb and Cr exceeded the maximum permissible limit in soil and within allowable limit in the tissue. *C. olitorius* had transfer factor (TF) < 1 for Cd, Pb and Cr. *A. hybridus* had similar transfer factor except for Cr with TF > 1. The study concluded that the dumpsite converted to farmland is highly contaminated with Pb, Cr, and Cd and highly accumulated by the vegetables.

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Industrial development, increased population and unplanned urbanization have partially or completely turned our environment to dumpsites (Alimba *et al.,* 2006). Lack of urban planning, lack of enforcement of relevant laws/acts on waste disposal and lack of organized landfill sites enhance the existence of dumpsites within living areas in developing nations. The industrial revolutions have also given birth to environmental pollution and the greater volume of industrial chemical discharges has added to the growing pack of untreated domestic waste which contains heavy metals. The disposal of domestic, commercial and industrial garbage may contain toxic metals such as Pb, Cu, Cd, Hg, Mn, Zn from batteries, insecticides, nail polish cleaners, polyvinyl chloride made containers, pesticides and various products introduced into the environment is a dilemma that continues to grow with human development. Research has shown that most forms of waste disposal have negative consequences on the environment, public health, and local communities (Pacyna, 2002). The non-biodegradable nature and long biological half-lives allows heavy metals to accumulate in different body parts making them potentials harmful. Most of heavy metals are extremely toxic because of their solubility in water. Even low concentrations of heavy metals have damaging effects to man and animals because there is no good mechanism for their elimination from the body. Nowadays heavy metals are ubiquitous because of their excessive use in industrial applications.

Table 1: International Allowable Limits Of Heavy Metals (Mg/Kg) In Plants and Soil

	FAO/WHO, 2001	**CCME, 2007**
METALS	SOIL(mg/kg)	PLANT(mg/kg)
Lead	0.3	70
Chromium	2.3	64
Cadmium	0.2	1.4

According to Abdul-Salam *et al.* (2011), dumpsite is a place where unwanted materials are disposed and one of the ancient methods of waste management. Dumpsites are common sites around the world (Adedara *et al.,* 2014). Due to deposition of varieties of wastes, municipal waste dump soils are always rich in organic matter (Anikwe and Nwobodo, 2001), a significant determinant of soil fertility, physical and chemical properties. Studies have shown that the chemical composition of the municipal waste include organic combustible and non-combustible materials (Isirimah, 2002). But extreme input of unsorted municipal waste may likely lead to changes in soil

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physical and chemical properties (Nyles and Ray, 1999). Dumpsites are common sites across Nigeria and in most African countries. The fertile nature of soils in these sites warrants the conversion of dumpsites to medium for plant growth, especially vegetables and fruits. Despite the high rate of turnover from dumpsite farming, high concentrations of heavy metals associated with myriads of waste deposits expose crops to contamination leaving farmers to choose between yield and quality. Plants on dumpsites bio-accumulate heavy metals from the rhizosphere and transfer them to the food chain when consumed by human beings and animals (Segura-Munoz *et al.*, 2006). Heavy metals accumulate in the tissues and organs of living organisms and pose serious health effects (Rotich *et al.*, 2006).

Due to the poor quality of savannah soils, farmers in Ilorin have resorted to the growing their vegetable crops on dumpsite for its fertile nature and high yield. There is concern of the health safety for leafy vegetables, especially *A. hybridus* and *C. olitorius* sold at Oja-tuntun - a major vegetable market in the Ilorin metropolis. There is therefore the need to ascertain heavy metal pollution status of dumpsites converted to farmlands and determine the metal mobility into vegetables and other crops in order to determine the safety of consuming the farm produce, hence this study. The present study investigates Pb, Cr and Cd concentrations in rhizosphere and tissues of *Amaranthus hybridus* and *Corchorus olitorius* grown on abandoned dumpsite converted to cropland in Ilorin metropolis.

The objectives of this study is to determine the levels of Pb, Cd and Cr in *A. hybridus* and *C. olitorius* samples grown on abandoned dumpsite; and assess mobility of the metals from the rhizosphere to the vegetables.

MATERIALS AND METHODS

Sampling Area: Ilorin metropolis, the capital of Kwara state is one of the rapidly growing urban centres in Nigeria, not just because it houses many universities, but it has for long served as an important commercial centre linking most northern and central parts of the country. The study was carried out on a dumpsite converted to cropland around Oja-tuntun (new market) which lies between latitude 8°29”17.64” N and longitude 4°32”1.96” E. The entire dumpsite was divided into two sections (A and B) based on the major vegetable crops (*Amaranthus hybridus* and *Corchorus olitorius*) cultivated. Section A with *A. hybridus* measured 24 m by 20 m while section B with *C. olitorius* measured 15 m by 9 m.

Sample Collection and Digestion: The plant samples were harvested from Oja-tuntun dumpsite converted to farmland and collected at the same point as the soil using transect sampling techniques (Melville and Welsh, 2001) at a distance of 0-8 m, 8 -16 m, 16-24 m apart for *Amaranthus hybridus* and 0-3 m, 3-6 m, 6-9 m apart for *Corchorus olitorius* along the transect. The soil samples were taken from the upper 0-15 cm rooting zone (Ebong, 2007) of each vegetable crop, with a sharp edged plastic spatula into clean polyethylene bags. Plant samples were collected at full maturity – 60 days and 40 days for *A. hybridus* and *C. olitorius* respectively. Fifteen plant and soil samples were collected from each of the sections, totalling thirty plant and soil samples. The samples were labelled and transported in a plastic bag to the laboratory for detail analysis. Plant tissues were cleaned to remove dust, soil and other particles by putting them through a three step washing sequence. Plant samples were dried in an oven at 80 ºC, and pulverized to fine powder using a ceramic mortar and pestle. The soil samples were air dried, crushed and passed through a 2 mm sieve. Aqua regia method was adopted for the digestion of plant and soil samples. One gram of each sample was weighed into a digesting tube, 15 ml of concentrated HNO_3 and 5 ml of concentrated HCl (3:1) was added to the sample. The solution was cooled, filtered and made up to 50 ml. The filtered samples were transferred into separate plastic sample bottles and labelled for further chemical analysis.

Determination of Bioavailable Cd, Pb and Cr Concentrations in the Soil: One gram of soil sample was extracted in 8 ml of 1 M of magnesium chloride ($MgCl_2$) and subjected to continuous shaking at 1000rpm for one hour under normal room temperature (Chojnaka *et al.*, 2005). The extract fraction was filtered using Whatman filter paper-1 into a 50 ml volumetric flask and made up to 25 ml with deionized water. The concentration of Cd, Cr and Pb in the digests and extracts were analysed using the Atomic Absorption Spectrophotometer (AAS).

Soil Physicochemical Analysis: Soil pH was measured in a 1:2:5 soil/water suspension using an electronic glass electrode pH meter (PHS-3C MODEL). Soil organic carbon (OC) was determined by wet oxidation methods of Walkley and Black (1934). The hydrometer method was used for the particle size distribution while Soil electrical conductivity was determined using digital electrical conductivity meter.

Statistical Analysis: Data obtained were subjected to Student’s t-test using Statistical Package for Social

Science (SPSS) version 17. The level of significance was set at P=0.05 (two-tailed).

The transfer coefficient was calculated according to the method of Olowoyo (2010).

$$Transfer\ factor\ (TF) = \frac{C_{plant}}{C_{soil}}$$

Where, C_{plant} = metal concentration in plant tissue, mg/kg dry weight and C_{soil} = metal concentration in soil, mg/kg dry weight.

RESULTS AND DISCUSSION

Soil pH has strong influence on the availability of plant nutrients and can affect the soil-plant interaction with regards to metal accumulation (Husssein, 2013). From Table 2, the soil pH under *Corchorus olitorius* soil was 6.71 and *Amaranthus hybridus* soil was 7.75; slightly alkalinity of the soil. This may be attributed to the buffering effect of soil organic matter against pH changes in addition to the release of basic cations during the organic matter decomposition (Abdallah, 2011). This was also expected as most soils in the tropics have their range from acidic to slightly neutral pH (Abdallah, 2011). There was no significant difference in the organic matter content and cation exchange capacity for soils under the two vegetables. Korte *et al.* (1976) reported that the soil's ability to retain heavy metals is more closely tied to the specific surface than to the soil CEC. However, particle size distribution varies significantly and the soils were predominantly sandy with sand content higher in *Amaranthus hybridus* soil (49.30%) and clay content higher in *Corchorus olitorius* soil (40.66%). There was significant difference in the electrical conductivity of the soils (P<0.05).

There were significant differences in the concentrations of heavy metals in the rhizosphere of *A. hybridus* and *C. olitorius* cultivated on dumpsite converted to farmland. The order of the concentrations was Pb > Cr > Cd. The rhizosphere of *A. hybridus* had the highest concentration of Pb (123.20±90.04 mg/kg) and Cd (0.63±0.63 mg/kg) while Cr was highest in the rhizosphere of *C. olitorius* (36.57±8.61 mg/kg) (Table 3). Concentration of Cr in *C. olitorius* rhizosphere (36.57 mg/kg) for this study was generally lower than values obtained in similar studies (Awokunmi *et al.*, 2010) that ranged between 105–810 mg/kg. Urban soils such as that of the dumpsite receive loads of contaminants that are usually greater than the surrounding areas due to the concentration of anthropogenic activities of urban settlements (Yang *et al.*, 2006).

Table 2: Physicochemical characteristics of the rhizosphere of *C. olitorius* and *A. hybridus* cultivated on dumpsite converted to farmland

Parameters	*C. olitorius*	*A. hybridus*
pH	6.71±0.50	7.75±0.05
Electrical conductivity(mscm^{-1})	95.10±0.60	97.80±0.20
Sand (%)	45.68±0.02	49.30±0.10
Silt (%)	13.66±0.04	13.58±0.04
Clay (%)	40.66±0.02	37.12±0.12
Organic Matter (%)	2.35±0.35	2.46±0.06

Values are means ± standard deviation for n = 15.

Table 3: Concentrations of Cd, Pb and Cr in the Rhizosphere of *Amaranthus hybridus* and *Corchorus olitorius* cultivated on a dumpsite converted to farmland

Rhizosphere	Concentration (mg/kg)		
	Cadmium	Lead	Chromium
Amaranthus hybridus soil	0.63±0.64	123.20±90.04	21.00±11.18
Corchorus olitorius soil	0.23±0.37	63.80±34.34	36.57±8.61
P values	**0.045***	**0.024***	**0.00***

Values represent mean ± standard deviation for n = 15; Values with * are significantly different at P≤0.05.

The concentrations of bioavailable Cd, Pb and Cr in the rhizosphere of *A. hybridus* and *C. olitorius* grown on the dumpsite-converted-to-farmland was in the order Pb > Cr > Cd. There was no significant difference in the concentrations of Pb and Cd in the rhizosphere of the two vegetables. Concentration of bioavailable Cr was significantly higher in the rhizosphere of *A. hybridus* (2.20±0.99 mg /kg) compared to *C. olitorius* (0.65±0.29 mg/kg) (Table 4). Similarity in the bioavailability of Pb and Cd in the rhizosphere of the two vegetables could probably be due to similarity in the organic matter content of the soils. Bioavailability of Pb is reported to be largely influenced by organic matter. Weggler (2004) also linked Cd bioavailability in soil to the degree of uptake by plants. Chromium mobility depends on sorption characteristics of the soil, including clay content, iron oxide content, and the amount of organic matter present. The order of metal uptake varied with vegetable crop. The order for *A. hybridus* was Pb > Cr > Cd while *C. olitorius* was Cr > Pb > Cd. There was no significant difference in concentrations of metals in the tissues of the vegetables, except for Cr was significantly higher in *A. hybridus* (Table 5). The most common heavy metals found at contaminated sites, in order of abundance, are Pb, Cr, As, Zn, Cd, Cu, and Hg (USEPA, 1996). Concentrations of heavy metals in the dumpsite converted to farmland in this study may not be related to age of the site. Ideriah (2005) opined that source and composition of the waste deposition majorly determine the metal pollution status of a site. The persistence of these heavy metals in the soils of the dumpsite may lead to increase uptake by plants, even with their transfer ratio differing from crop to crop (Okoronkwo, 2005).

Table 4: Concentrations of bioavailable Cd, Pb and Cr in the Rhizosphere of *A. hybridus* and *C. olitorius* cultivated on a dumpsite converted to farmland

Rhizosphere	Concentration (mg/kg)		
	Cadmium	Lead	Chromium
Amaranthus hybridus	0.25±0.35	10.35±5.87	2.20±0.99
Corchorus olitorius	0.35±0.22	9.50±2.49	0.65±0.29
P values	**0.608**	**0.773**	**0.01***

Values represent mean ± standard deviation for n = 15. Values with * are significantly different at $P \leq 0.05$.

Table 5: Concentrations of Cd, Pb and Cr in the tissues of *A. hybridus* and *C. olitorius* cultivated on a dumpsite converted to farmland

	Tissue concentration (mg/kg)		
	Cadmium	Lead	Chromium
Amaranthus hybridus plant	0.60±0.87	45.47±93.97	29.57±10.46
Corchorus olitorius plant	0.37±0.69	4.47±4.26	12.30±5.68
P values	**0.424**	**0.103**	**0.00***

Values represent mean ± standard deviation for n = 15. Values with * are significantly different at $P \leq 0.05$.

The transfer factor (TF) of metals in *A. hybridus* was in order of Cr (1.81) > Pb (0.87) > Cd (0.62) while the TF of *C. olitorius* was Cd (0.47) > Cr (0.37) > Pb (0.11) .The result of TF in *A. hybridus* shows the plant is a good phytoextractor of Cr. According to Olowoyo (2010), transfer factor above 1.0 is indicative of phytoextraction. According to Lokeshwari and Chandrappa (2006), the transfer factors (TF) were based on the root uptake of the metals and discountenance the foliar absorption of atmospheric metal deposits. The low transfer factor of Cr, Pb and Cd, from the soil to *C. olitorius* shows the plant's ability to tolerate high contamination in the soil (Yoon *et al.,* 2006). It also indicated that the vegetables cannot serve as phytoextractor and phytostabilizer of the metals as their transfer factor were less than 1.0. Akpofure (2012) reported that much of toxic metals such as Cd and Pb get into the human body by direct ingestion of vegetables or other plants that absorbs metals from contaminated soils. The result from this study revealed that Pb, Cr and Cd concentration in the vegetables is higher than maximum permissible allowed by WHO (FAO/WHO, 2001). The result of this study on metal concentrations in the two vegetables is in line with the report of Odai *et al.* *(*2008) who also observed high concentrations of cadmium, lead, copper and zinc in vegetables grown on urban waste dumpsites in Kumasi, Ghana. High level of metals can be harmful to plants and indirectly poison humans and animals that consume the vegetable. Studies have reported that continuous intake of heavy metal in vegetables and other foodstuffs can lead to alteration of humans and animals healthiness state.

Conclusion: Concentrations of Pb, Cr and Cd in the dumpsite converted to farmland were higher than the allowable limit and only Pb in *Amaranthus hybridus* plant was above the allowable limit. High concentrations of heavy metals in the vegetables were due to high bioavailable concentrations of the metals within the rhizosphere. High bioaccumulation of Pb, Cd and Cr by *A. hybridus* and *C. olitorius* cultivated on dumpsite converted to cropland renders these products unsafe for consumption as they pose serious health risk to consumers.

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