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HEALTH RISK OF HEAVY METALS IN *Celosia argentea* L. GROWN ON MUNICIPAL WASTE SOILS IN IBADAN, NIGERIA

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Abstract

This paper assessed the appropriateness of dumpsites in Urban and Peri-urban Agriculture (UPA). The bioaccumulation and potential heavy metal-toxicity risk of consuming Celosia argentea L. grown on four different dumpsites soils (Ajibode, Sasa, Moniya and Akinyele) and reference soil from University of Ibadan Training and Research Farm was also evaluated. The soil samples were analysed for Cd, Cu, Fe, Ni, Pb and Zn using Atomic Absorption Spectrophotometry (AAS). None of the heavy metals was above European Union (EU) guidelines for safe limits of soil heavy metals in agricultural soils. The Pollution Load Indices (PLIs) were mostly>1, which indicated the deterioration of the sites quality in relation to specific heavy metal(s); ranging between 0.92-13.1. The daily intake of heavy metals (DIMs) and Health Risk Indices (HRIs) were evaluated based on the maximum recommended limit (MRL) by WHO/FAO standard. Most of the heavy metals were significantly low, but lead (Pb) was above the MRL. HRIs were between 0.02-0.03, 0.07-0.11, 0.61-4.43 and 0.03-0.04 for Cu, Fe, Pb and Zn respectively, Ni was found to have insignificant level (<0.0001). Only lead (Pb) has potential health risk (HRI>1) in all the sites except Moniya (0.61; HRI<1, safe) which might be as a result of vehicular exhaust and type of waste disposed. Soil test to ascertain the pollution status and crop type to produce should precede cropping have been recommended

Key Words: *Bioaccumulation, Dumpsite, Heavy metal, Health Risk, Toxicity*

Introduction

In Ibadan and other cities of Nigeria, cultivation and collection of waste dumpsites as soil amendment is on the increase due to the need for urban gardeners to obtain maximum yield from marginal lands (Taiwo *et al.,* 2003). Vegetables obtained from dumpsites and those grown in urban and peri-urban gardens in Ibadan city contained high levels of heavy metals (Pb and Cd) (Ogunyemi *et al*., 2003). According to World Health Organisation (WHO) about a quarter of the diseases facing mankind today occur due to prolonged exposure to environmental pollution (Prüss-Üstün and Corvalán, 2006; Kimani, 2007). These sites contain heavy metals in various form and different contamination levels. Some heavy metals like As, Cd, Hg and Pb are particularly hazardous to plants, animals and humans (Alloway and Ayres, 1997). However, plants can absorb heavy metals and store in leaves and other edible parts. These metals are then transferred through food consumption to humans and animals. For humans, a high intake of heavy metals can damage organs and increase the risk of cancer (Jan *et al.,* 2010). Metal accumulation in vegetables taken from the Oke-ogi, dumpsite in Iree, Nigeria varies significantly from one element to the other (Olufunmilayo *et al.,* 2014)

An important part of estimating the risks of health effects from exposure to toxicants involves extrapolation from experimentally observation data, and identification of the hazard source is also very important. Many metals act as biological poisons even at parts of per billion (ppb) levels. The toxic elements accumulated in organic matter in soils are taken up by growing plants (Dara, 1993). Perceptions of what is regarded as 'better quality vegetables' are however subjective. Health Risk Index (HRI) of some heavy metals (Pb, Cd, Cr, Cu and Zn) in *Amaranthus hybridus* sampled from some farmlands in Ibadan for dry and rainy seasons differs significantly (Fayinminnu and Adekunle-Jimoh, 2015).

The main objectives of the study therefore, were to assess the safety level and potential health risk of consuming *Celosia argentea* grown on heavy metals contaminated sites and their appropriateness for Urban and Peri-urban Agriculture (UPA).

Materials and Methods

Study Area

The experiment was carried out at roof top garden (07° 27' N, 003° 53' E) of the Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria. Five (5) different domestic dumpsites soils were collected within Ibadan Metropolis viz: (TRF = Training and Research Farm, University of Ibadan (Control/Reference), AJI = Ajibode, SAS = Sasa, MON = Moniya, AKI = Akinyele). Twenty five (25) kg/Site of surface soil (0-30cm) samples were collected using soil auger from 16-20 points in each site and made to a composite sample. Geo-references were recorded with a Handheld GPS; Model: Garmin etrex 10 ver.2.90. The experiment was laid in a completely randomized design (CRD) with 5 treatments replicated 5 times. Seeds of *Celosia argentea* were obtained from Institute of Agricultural Research and Training (I.A.R. &.T) Moor Plantation, Ibadan, Nigeria. Composite soil of each treatment/site was placed (4kg soil/pot),watered for two days before sowing to provide optimum moisture content which would enable germination. Plants were later thinned to 4 plants/pot two weeks after sowing.

Soil Preparation for Heavy Metals

Soil samples were air-dried at ambient temperature (27±3.5°C) for 12 days, passed through 2mm sieve and mixed thoroughly. A 1g of each was transferred to 100ml tall-form beaker, 20ml of 1:1 HNO_3 (analar grade) was added using measuring cylinder and boiled inside fume cupboard until the volume of nitric acid was reduced to about 5ml then add 200ml of de-ionised water and boiled gently again until the volume was approximately 10ml. The suspensions were cooled and filtered through a Whatman No.540 filter paper. The beaker and filter paper were washed with small portion of de-ionised water until the volume of about 25ml was obtained. The filtrates was transferred to a 100-ml graduated flask and made up to the mark with de-ionised water.

Vegetable Preparation for Heavy Metals

The vegetable samples at maturity (8 weeks) were harvested and washed thoroughly under running tap water and rinsed with distilled-water. They were partitioned into root and shoot tissues and oven-dried at 60°C for 72 hours, then ground using QASA grinder (QBL-15L40 model) and passed through 2mm mesh size. Half a gram (0.5g) of each sample was weighed and put into porcelain crucible .They were ignited in a muffle furnace for 6-8 hours at 450°C-500°C until greyish-white ashes were obtained. A 5ml of 2N HNO_3 was added to each sample in a test-tube, then filtered using Whatman No.540 filter paper. The filtrates were transferred to 100ml graduated flask and made up to the mark with distilled water. The filtrates were transferred to sample-bottles and taken for heavy metals analysis (Ogundiran, 2007).

Trace metals (Cu, Cd, Fe, Ni, Pb and Zn) were analysed using AAS (Buck Scientific Model 210 VGP) following the procedure of Association of Official Analytical Chemist (AOAC, 2003). The instrument setting and operational conditions were done in accordance with the manufacturers' specifications.

Data/Statistical Analysis

Pollution Load index (PLI), Daily Intake of Metal (DIM) and Health Risk Index (HRI).

The following mathematical equations were also used:

$PLI = C_{soil} \div C_{reference}$ (Liu *et al*., 2005).

Where; C_{soil} =Metal Concentration (Dumpsite soil), $C_{reference}$ = Metal Concentration (Control soil).

$DIM = (C_{metal} \times C_{factor} \times D_{food\ intake}) / (B_{average\ weight})$ (Rattan *et al*., 2005; USDA, 2007)

Where; C_{metal} = Conc. in plants (mg/kg), C_{factor} = Conversion factor (0.085).

$D_{food\ intake}$ = Daily intake of vegetables (kgd^{-1}), 100g was used (Lanre-Iyanda and Adekoye, 2013), $B_{average\ weight}$ =average body weight (kg) 70kg was taken as an average adult weight for this study. Reference oral Dose (RfD) was used to obtain the health risk index;

$HRI = DIM \div RfD$ (US-EPA, 2002). If HRI is < 1, the exposed population is said to be safe and if ≥ 1, the population will experience health risk (IRIS, 2003).

Where; RfD = Oral Reference Dose; the highest amount of a metal, in mg/day, that the body can be exposed to without yielding a hazardous outcome during a lifetime (IRIS, 2003).

Table 1: Oral reference dose (RfD) for heavy metals analysed

Heavy Metals	(RfD) in $mgkg^{-1}d^{-1}$
Cd	1×10^{-4}
Cu	4×10^{-2}
Fe	7×10^{-1}
Ni	2×10^{-2}
Pb	4×10^{-3}
Zn	3×10^{-1}

Source: IRIS, 2003.

The data were analysed using a statistical package, DSAASTAT Ver.1.101+ MS Excel 2013.

Results and Discussion

Table 1: Heavy metal contents ($mgkg^{-1}$) of the domestic dumpsites prior to planting in Ibadan, Southwestern Nigeria, April 2015

	Site					
	$mgkg^{-1}$					
Heavy metal	TRF*	AJI	SAS	MON	AKI	EU(2002)
Cd	ND	ND	ND	ND	ND	3
Cu	10.00	131	18.00	24.00	14.00	140
Fe	5759	8863	11229	27852	8812	-
Ni	1.00	8.00	ND	7.00	ND	75
Pb	101	143	93.00	103	151	300
Zn	75.00	193	214	175	161	300

*=Reference soil (Control), ND=Not Detected, EU (2002) = European Union standards; Guideline for safe limits of soil heavy metals (2002). TRF=University of Ibadan Training and Research Farm, AJI=Ajibode, SAS=Sasa, MON=Moniya, AKI=Akinyele.

In the pre-planting soils analysed Cadmium (Cd) was not detected in all the sampling sites, iron (Fe); ranged between 5759-27852 $mgkg^{-1}$ followed by zinc (Zn); 75.0-214 $mgkg^{-1}$ were the highest concentrations. The total heavy metals in all the sites were on these trends: TRF (control); Fe>Pb>Zn>Cu>Ni, Ajibode; Fe>Zn>Pb>Cu>Ni, Sasa; Fe>Zn>Pb>Cu, Moniya; Fe>Zn>Pb>Cu>Ni, and Akinyele; Fe>Zn>Pb>Cu .None of the heavy metals was above European Union (EU, 2002) guideline for safe limits of soil heavy metals (Table 1) . The background soil (TRF) has unity (1.00) in all the heavy metals, donating only baseline pollution level of the pollutants. The heavy metal concentrations followed the trends in the order of AJI; Cu> Ni > Zn > Fe, SAS; Zn > Fe > Pb > Cu, MON; Ni > Fe > Cu > Zn > Pb and AKI; Zn > Fe > Pb > Cu. Most of the heavy metals in all the sites had pollution load indices (PLIs) greater than 1.00, this implied deterioration of the site quality in relation to the metals studied, but lead (Pb) in SAS site < 1 (0.92); implies perfection of a specific heavy metal.

Table 2: Pollution load index (PLI) of some domestic dumpsites in Ibadan southwestern Nigeria, April 2015

	Pollution Load Index (PLI)					
Site	Cd	Cu	Fe	Ni	Pb	Zn
TRF	ND	1.00	1.00	1.00	1.00	1.00
AJI	ND	13.10	1.54	8.00	1.42	2.57
SAS	ND	1.80	1.95	ND	0.92	2.85
MON	ND	2.40	4.84	7.00	1.02	2.33
AKI	ND	1.40	1.53	ND	1.50	2.15

PLI < 1 denote perfection; PLI = 1 present that only baseline levels of pollutants are present and PLI > 1 indicate deterioration of site quality (Tomlinson *et al.*, 1980).

The pollution load index (PLI) of the domestic dumpsite soils studied follow the pattern as carried-out by Stewart *et al.* (1974; Radojevic and Bashkin 2006). The PLIs were in the sequence of copper (Cu); TRF<AKI<SAS<MON<AJI, iron (Fe); TRF<AKI<AJI<MON<SAS, nickel (Ni); TRF<MON<AJI, lead (Pb); SAS<TRF<MON<AJI<AKI and zinc (Zn); TRF<AKI<MON<AJI<SAS which indicated the control (TRF) lowest level in almost all the metals analysed, and they were below the tolerable recommended limits by European Union (EU) as shown in Table 2.

Table 3: Daily intake of metal (DIM) by *C. argentea* grown on different domestic dumpsite soils in Ibadan Southwestern Nigeria, 2015

	Daily Intake of Metal (DIM) (mgkg^{-1}day^{-1})				
Site	Cu	Fe	Ni	Pb	Zn
TRF	1.3E-03	8.0E-02	-	1.8E-02	1.0E-02
AJI	1.5E-03	4.7E-02	1.2E-04	8.0E-03	1.2E-02
SAS	1.1E-03	6.4E-02	-	8.1E-03	8.4E-03
MON	8.5E-04	4.6E-02	-	2.4E-03	7.5E-03
AKI	1.0E-03	5.3E-02	-	8.0E-03	1.2E-02
MRL	4.0E-02	7.0E-01	-	4.0E-03	3.0E-01

E-n=$\times 10^{-n}$, DIM (mgkg^{-1}day^{-1}), MRL=Maximum recommended limit; WHO/FAO (Codex Alimentarious Commission, 2013)

Health risk assessment is a very important tool to evaluate the consequences of human action and measures the adverse effect to public health. Our study is in agreement with the work of Khan *et al.* (2007) that, there may be potential health risks associated with cultivation and consumption of crops and vegetables grown on contaminated soils. The soil uptake of the heavy metals may probably be related to the differences in organic matter of the soils.

The daily intake of heavy metals via consumption of the plant (*C. argentea*) was determined using 100g as an average adult vegetable consumption of vegetable for the study. The estimated DIM through the food chain was compared with the World Health Organisation (WHO) / Food and Agriculture Organisation (FAO) recommended maximum limit (MRL) of dietary intake for vegetables. Most of the heavy metals analysed (Cu, Fe, Ni, Pb and Zn) in the vegetable (*C. argentea*) were significantly lower in all the sites but lead (Pb) was above the MRL in all the sites, with increase in order of TRF > MON > AJI/AKI > SAS (Table 3).

Assessment of the health risk via dietary intake (DIM) for adults is presented in Table 3. The HRIs in all the sites ranged from 0.02 to 0.03, 0.07 to 0.11, 0.61 to 4.43 and 0.03 to 0.04 for Cu, Fe, Pb and Zn respectively, and Ni was found to have insignificant level (no/less than 0.0001). The indices indicated that only lead (Pb) has the potential human health risk (i.e. HRI>1) in most of the sites TRF; 4.43, SAS; 2.03, AKI; 2.00 and AJI; 1.97 with the exception of MON; 0.61 which recorded safe risk level (HRI<1), this results is in line with the finding of Fayinminnu and Adekunle-Jimoh (2015).

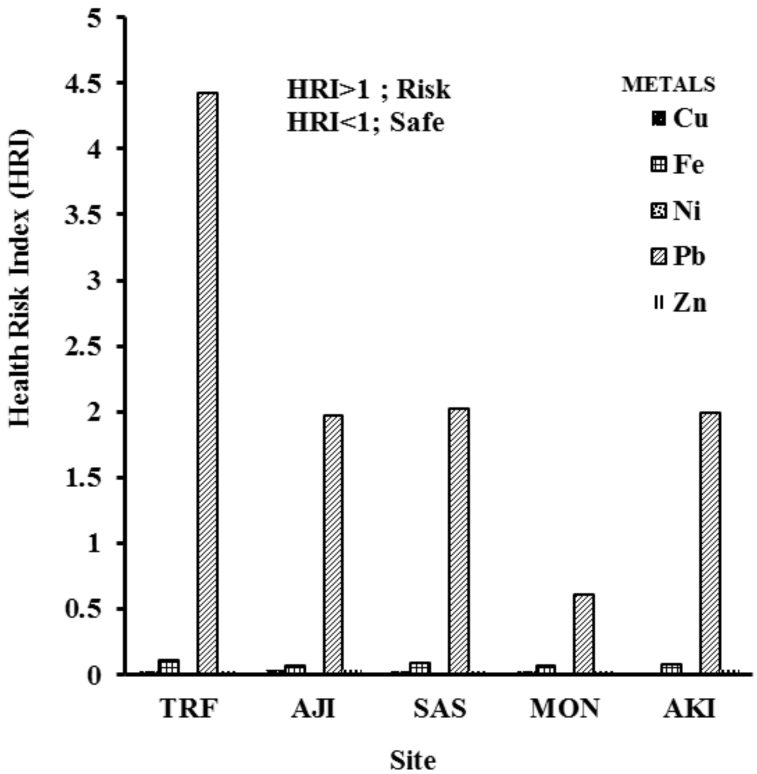

Figure 1: Health Risk Index (HRI) of heavy metals in *C. argentea* grown on different sites in Ibadan Southwestern Nigeria, 2015. (Adapted from Khan *et al.,* 2008).

Health risk indices (HRIs) of the heavy metals evaluated (Fig.1) for all the sites. The concentration of Pb at Moniya was <1, but lead (Pb) showed a significant values (>1) in the other sites (Fayinminnu and Adekunle-Jimoh, 2015). This projection might be as a result of proximity of the sampling sites to the roads leading to significant increased in lead from automobiles exhaust or the type and sources of the dumped wastes. This is in line with the findings of Dosunmu *et al*. (2003); Ogunyemi *et al*. (2003) and Okunola *et al*. (2008) that vehicles contribute to major source of heavy metals in the soil and vegetation along roadsides in Nigerian urban centres.

Conclusion

Daily intake of metals (DIM) indicates that the consumption of average amounts of these contaminated vegetables does not pose health risk, as the values obtained are below the maximum recommended limit (MRL). Nevertheless, consumption of crops with elevated levels of heavy metals for long time may lead to high level of accumulation in the body system and cause some health disorders. It is therefore suggested that regular monitoring of heavy metals in agricultural soils and vegetables is essential. This is to prevent excessive build-up of these metals in the human food chain and subsequent health implications. Besides, contaminated sites should be discouraged for commercial farming of such leafy vegetables. Instead, those areas may be replaced by some other non-metal accumulating plants. Only Pb in all the treatments was above the permissible limits set by FAO/WHO (2013) for human consumption. The levels of other metals however were within the maximum permissible limits. It can be concluded that most of the Health Risk Indices (HRIs) for the metals analysed in this study were < 1(normal consumption of vegetable posed no risk, but the HRIs of Pb was <1 in Moniya, while University TRF, Sasa, Ajibode and Akinyele had >1; which imply risk of lead toxicity to the exposed communities.

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