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Health Risk Assessment of Lead and Zinc Uptake in Spinach (*Amaranthus hybridus*) Grown on Dumpsite Soil in Zaria, Nigeria

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ABSTRACT

Heavy metals pose great health challenges to human worldwide. This study investigated the level of lead (Pb) and zinc (Zn) and assessed the health indices to human consumers of the heavy metals in spinach *(Amaranthus hybridus) grown* on dumpsite humus at four sampling sites coded A1, SHA, STA and RTA in Palladan, Sabon Gari Local Government AREA, Zaria, Kaduna State, Nigeria. The plant samples were analyzed for the metals using atomic absorption spectrophotometry (AAS). The Igeo indices were -6.83 to -3.800 for Pb and -5.67 to -8.29 for Zn. The target hazard and hazard index for children range from 4.99E-07 to 4.1E-06 for Pb and 8.03E-09 to 5.87E-08 for Zn; and 9.57E-09 to 4.28E-06 respectively, with all being <1 showing no harmful effect when A. hybridus is consumed. Also target hazard and hazard index for adults ranged from 2.14E-07 to 1.81E-06 for Pb; and 2.95E-07 to 2.16E-06 for Zn, and 3.51E-07 to 3.97E-06 respectively. The study also indicated that carcinogenic risk is not associated with Pb and Zn consumption in *A. hybridus* by children and adult, as all values were generally < 1. The Igeo, target hazard quotient, hazard index and cancer risk assessment indicate that the *A. hybridus* grown on the dumpsite humus is safe for consumption. However, caution is needed in the use of dumpsite humus for nutrient enhancement.

Keywords: Absorption, heavy metals, **s**pinach (*Amaranthus hybridus*), Palladan, dumpsite

INTRODUCTION

A dumpsite is a designated location or area where waste or trash is disposed, often in an open and non-regulated manner [1]. Dumpsites can be used for household, industrial, or hazardous waste and can include garbage, refuse, and discarded matter [2]. A dumpsite can be a mound of domestic refuse containing shells and animal bones marking the site of a prehistoric settlement [3]. It can also be a location where toxic wastes can be or have been disposed of often illegally. The dumpsite has organic and inorganic pollutants which contaminate the environment, one of which is the soil, because it contains heavy metals like lead, zinc, cadmium, nickel and these pose health risks to nearby communities [4]. Toxic metals are among the serious pollutants in contaminated soils.

Across the globe, the pollution of soil by toxic metals through dumpsite has received considerable attention due to its risk to human health. The toxic metals may originate from natural and artificial sources such as mineral weathering, anthropogenic processes, agrochemicals, industrial and domestic wastes from animals receiving metals from food supplements and deposits from the atmosphere are of primary concern [5]. The increasing rate of toxic metals cause imbalance to the ecosystem and accumulation of these metals in high amounts are detrimental to the food chains [6]. Diseases like tumor, congestion of nasal mucous membranes and pharynx, muscular reproductive, neurological, gastrointestinal and genetic malfunctions, head stuffiness [7]. Prolonged exposure to lead has been linked to mental retardation, coma and eventual death. Also zinc may cause kidney problems such as nephritis and anuria. Furthermore, the interactions associated with heavy metals exposure may induce more severe human health consequences than might be expected from low individual metal concentration alone. Thus, humans are exposed to heavy-metal contaminated plants like spinach food products grown on affected soil [8].

A study in Anyigba, Nigeria found that *Amaranthus hybridus* grown on dumpsite soils accumulated elevated levels of lead (up to 0.1820 mg/kg) and zinc (up to 0.4540 mg/kg), with hazard indices exceeding one, indicating potential health risks from their consumption [9]. Further, spinach grown at the bank of Nyabunkaka River, in Jalingo, Taraba State revealed that lead concentrations was above FAO limits, while zinc and other metals remained within safe thresholds, suggesting localized contamination risks [10].

Another investigation across Nigerian urban areas showed that although most heavy metals in *Amaranthus hybridus* were within FAO/WHO limits, cobalt and cadmium levels in stems exceeded safety thresholds, raising long-term public health concerns [11].

The economic situation in Nigeria has led to sales of dumpsite humus soil for agricultural activities as alternative to the exorbitant inorganic fertilizer. Though previous studies have not implicated dumpsite humus as a source of heavy metal at health risk levels; the rampant use of wide range of dumpsite humus, of recent, in Northern Nigeria, triggers the need to have a comprehensive study of the health risk assessment of metals of health concern that are up-taken by vegetables grown on dumpsite soil.

Therefore, this study assessed some health risk indices to human consumers of Pb and Zn in spinach *(Amaranthus hybridus)* planted on dumpsite humus in Palladan, Sabon Gari Local Government, Zaria, Kaduna State, Nigeria.

MATERIALS AND METHODS

Sample collection and treatment

Dumpsite humus at four sampling sites coded A1, SHA, STA and RTA in Palladan, Sabon Gari Local Government area of Kaduna State, Nigeria were collected after removing the solid wastes. Composite sample of each site was taken to the laboratory. All reagents used were of analytical grade purchased from Sigma Aldrich.

Pot Culture Experiment

In order to study the phytoavailability of the Pb and Zn in the spinach (*Amaranthus hybridus*) called “aleyafu” in Hausa, “Inine” or “Opotoko” in Igbo and “Efo” in Yoruba; it was planted on 10 kg of the humus collected in pots having no hole at the bottom. Three seedlings per pot after germination were cultured (watering twice a day, weeding manually, and exposed to sunlight and with adequate plant protection measures). The pot culture experiment was carried out in a glass house at Crop Protection Department, Institute of Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. After each week, the changes in leaf length and width, leaf colour were recorded and compared with the control group planted on uncontaminated soil, obtained from a fallowed land. [12].

Digestion of Amaranthus hybridus

The spinach (*Amaranthus hybridus*) was harvested after six weeks from the pot experiment conducted. A 0.5 g dry sample each of *Amaranthus hybridus* was weighed into 100 cm^3 beaker, a mixture of 5 cm^3 of concentration HNO_3 and 2 cm^3 $HClO_4$ was added and digested at low heat using a hot plate, until the content was about 2 cm^3. The digest was allowed to cool and then filtered into a 50 cm^3 standard flask. The solution was transferred into a sample plastic bottle for analysis using AAS [13].

Geochemical-accumulation indices (Igeo)

The geo-accumulation index, widely used to quantitatively evaluate toxic metal pollution was utilized. The calculation is done as sown in equation 1:

$$Igeo = log_2(Cn/kBn) \quad (1)$$

where Igeo is the geo-accumulation index and Cn and Bn are the measured values and selected background values for each toxic metals, respectively. K is a constant usually 1.5 [14].

Target Hazard Quotient (HQ)

Concentration of heavy metals in the plant sample was employed to estimate the daily intake of the heavy metals using the Equation 2:

$$HQ = \frac{CDI}{RFDo} \quad (2)$$

Where CDI is the exposure expressed as the mass of a substance per unit body weight per time, RFDo is the Reference Dose.

CDI is expressed as shown in Equation 3:

$$\text{CDI}= \frac{C\ x\ InR\ x\ EF\ X\ ED}{BW\ x\ AT} \times 10^{-6} \quad (3)$$

Where C represents heavy metal concentration, InR is the Ingestion Frequency, EF is the Exposure Frequency, ED is the Exposure Duration, BW is the Body Weight, AT is the Average Exposure time (day) which is ED=365 [15].

Table 1 shows the values used in the calculations for CDI.

Table 1: USEPA guide for CDI in human [16]

Parameters	Children	Adult
InR (Servings/day)	0.1	0.2
EF (day)	365	365
ED (day)	6	70
BW (kg)	15	70
AT (day)	2,190	10,950
RFDo	Pb = 0.0035	Zn = 0.3

Hazard Index

For the risk assessment of multiple heavy metals contained in the plant sample, a total hazard index, HI, was estimated using Equation 4:

$$HI = \sum HQ \quad (4)$$

Where $\sum HQ$ is the sum of the individual element of heavy metals [17]

Cancer Risk

Potential cancer risks from exposure to a given dose of toxic metals in the plant sample was calculated using the expression in Equation 5:

$$CR = CDI \times CSF \quad (5)$$

Where CSF is the cancer slope factor, representing the risk associated with an average concentration of one mg/kg/day of a carcinogenic chemical over a lifetime [18].

RESULTS AND DISCUSSION

The concentration of the selected metals in the dumpsites is presnted in Table 2.

Table 2: Concentration of the spinach (*Amaranthus hybridus*) from the dumpsite humus

Dumpsites	Pb (*mg/kg*)	Zn (*mg/kg*)
A1	0.222±0.000	0.264±0.000
SHA	0.264±0.004	0.062±0.025
STA	0.215±0.353	0.036±0.014
RTA	0.000±0.0	0.043±0.033

Table 3: Geo-accumulation Indices of the spinach (*Amaranthus hybridus*) from the dumpsite humus

Dumpsites	Pb	Zn
A1	-3.75763	-5.67579
SHA	-6.83925	-7.94905
STA	-3.80054	-8.54515
RTA	0	-8.29273

Table 4: Hazard Quotient and Hazard Index of the spinach (*Amaranthus hybridus*) from the dumpsite for children

Dumpsites	Pb (HQ)	Zn (HQ)	Hazard Index
A1	4.22E-06	5.87E-08	4.28E-06
SHA	4.99E-07	1.21E-08	5.11E-07
STA	4.1E-06	8.03E-09	4.11E-06
RTA	0	9.57E-09	9.57E-09

Table 5: Hazard Quotient and Hazard Index of the Spinach (*Amaranthus hybridus*) from the dumpsite for Adults

Dumpsites	Pb (HQ)	Zn (HQ)	Hazard Index
A1	1.81E-06	2.16E-06	3.97E-06
SHA	2.14E-07	4.46E-07	6.6E-07
STA	1.76E-06	2.95E-07	2.05E-06
RTA	0	3.51E-07	3.51E-07

The range of the levels of the selected heavy metals in the Amaranthus hybridus cultivated on the dumpsite soils as shown in Table 2 is: Pb 0.215±0.353 mg/kg - 0.264±0.004 mg/kg and 0.021±0 mg/kg in the control; while Zn in the vegetable is in the range 0.036±0.014 mg/kg - 0.264±0.000 mg/kg, the control had the mean 0.015±0 mg/kg.

Geo-accumulation indices (Igeo) of plant samples

The values for the Igeo of Pb and Zn for the plant sample in three different sampling points show that the Igeo ≤ 0 implies uncontaminated (Table 3). These results were contrary to the values reported by Lere et al. [19].

Target Hazard Quotient (HQ) and Hazard Index (HI)

The calculated target HQ values were presented in Table 4 for children and Table 5 for adults. The reports showed that the HQ values of Pb and Zn were < 1 in the plant samples. The HI values showed that the values were < 1 meaning that there was no harmful effect in the plant samples. The HI values were < 1, therefore the health risk of Pb and Zn exposure through the plant sample is low [20].

Table 6: Cancer risk assessment of the spinach (A*maranthus hybridus*) from the dumpsite for both children and adults

Dumpsite	Children Pb (mg/kg/day)	Adult Pb (mg/kg/day)
A1	1.74E-06	7.46E-07
SHA	2.05E-07	8.81E-08
STA	1.69E-06	7.24E-07
RTA	0	0

Cancer Risk

Among the sampling sites A1 and STA are higher for children for Pb accumulation and the sampling sites, A1 and STA are higher in adults for Pb also. The values were < 10^{-4} the limit set by USEPA. This means that a high potential health risk cannot be assigned to the values. However, this was contrary with research reported by USEPA [21]

From the results of the heavy metal contents of Pb and Zn and the health risks indices of the absorbed metals. The values for Igeo for Pb and Zn (Table 3) reveals that the plant sample is not contaminated since the indices were ≤ 0. Further, the target hazard quotient and hazard index in Tables 4 and 5, have values in both children and adults for Pb and Zn being < 1; which indicate risk-free status for consumers of the vegetable. The values for cancer risk assessment (Table 6) were considerably less than the threshold [22]. This means that no health risk assigned to the values.

The present study indicated that the plant generally bio-accumulated Pb and Zn than the control group planted on the soil not contaminated, obtained from a fallowed land. The study indicated that the total concentration of Pb and Zn in the vegetable are not above the recommended levels by FAO. And did not signal potential health implication on the consumers of vegetables planted on the dumpsite humus. Also, the result is within the values reported for selected dumpsite humus in Ibadan Nigeria [23].

CONCLUSION

This study has evaluated the content of Pb and Zn in spinach (*Amaranthus hybridus*). It was recorded that the Igeo indices of Pb and Zn were less than zero, indicating that no significant pose of health risk to humans around the residential area. The target hazard quotient and hazard index for both children and adults were < 1 signifying that the plant sample planted there is still safe for human consumption. No significant health risk posed because the cancer risk assessment values were below the threshold set by USEPA. However, in an era of costly farming inputs, fertilizers inclusive, the scavenge for cheaper nutrient enhancers has driven many to use dumpsite humus, it should be analysed before use to avert the transfer of accumulated heavy metals in dumpsites to the food web.

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