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Health risk assessment of heavy metals transfer from soil to *Celosia trigyna* and *Amaranthus viridis* along Lekki Peninsula, Lagos, Nigeria

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ABSTRACT

*Globally, there is growing concern about the transfer of heavy metals into human food and water due to their ability to move from soil to plants. This study evaluated the health risks associated with the transfer of heavy metals from soil to Celosia trigyna and Amaranthus viridis along the Lekki Peninsula in Lagos. Soil and vegetable samples were collected from 12 locations, and the levels of heavy metals in the samples were determined using an Atomic Absorption Spectrophotometer. Soil pH was slightly acidic (5.31 –6.82). EC values range from 121 to 382µs/cm, while low soil CEC, N, TOC and OM were recorded in all the study sites. The concentrations of heavy metals in the soils were in this order: Zn >Cu>Mn >Cd>Pb. The uptake of metals by the vegetables was in the order Cu>Zn>Mn>Cd>Pb. Estimated Daily Intake (EDI) from Consumption of C. trigyna and A. viridis ranged between 0.1320-0.000*$mg^{-1}kg^{-1}adult^{-1}d^{-1}$*. The Health Risk Index ranged from 5.23 to 0.01. The total Hazard Index was 41.75. The concentration of heavy metals in the vegetables was a function of contaminated soil and toxic elements deposition from passing vehicles. Following the hazard index result, the vegetables in locations 1 – 6 are not safe for human consumption.*

1. INTRODUCTION

The consumption of vegetables is highly beneficial for human health, as they provide essential minerals and vitamins that contribute to overall well-being. However, consuming contaminated vegetables with heavy metals (HM) is a health risk. *Celosia trigyna L.* (English name: silver spinach and Yoruba local name: 'Efo aje fo wo') *and Amaranthus viridi* (English: slender amaranth and Yoruba local name: 'tete abalaye') are two leafy vegetables that are highly regarded by the Yoruba people for their medicinal value. As a result, they are widely consumed for their health benefits and are also commonly used in the preparation of herbal remedies. Eboh et al. (2019) describe C. *trigyna* leaves as slightly bitter, but popular among the Yoruba people in Southwestern Nigeria. The vegetable is used in making Nigerian traditional medicines for treatment of diseases like skin eruption. In Sierra Leone, vegetables are useful in treatment of heart problems. Generally, the plant is used to treat women's disorders and diseases, including ovarian troubles in DR Congo (Eboh et al., 2019). The migration of metals from the soil into plant roots is known as the transfer factor (TF). The Transfer Factor (TF) of HMs is an essential indicator of HMs in soils and their availability to vegetable plants (Kim et al., 2020). Calculation of TF for HMs transferred from vegetables to plants indicates the associated health risk when contaminated vegetables are ingested by human.

Hussain and Qureshi (2020) and Kim et al. (2020) identified major factors that influenced TFs in vegetables, including vegetable species and the level of HMs in the soil. TF values can also be influenced by locations, soil nutrient management, and soil properties. The TF in vegetables is also dependent on the type of HMs. Some HMs have higher TF than others (Mirecki et al., 2015). Several studies have reported that Cd and Zn have the highest TF for leafy vegetables and other agricultural products. In a study conducted in Serbia by Mirecki et al. (2015), they observed that Cd and Zn accumulated the most, followed by Cu and then Pb (Cd and Zn > Cu > Pb). Akande and Ajayi (2017) also found similar findings. Their studies showed that Cd and Zn showed the highest TF. Their result indicates an acceptable level of HMs following the standard set by FAO/WHO for soil and vegetables. They concluded that the level of HM residues in vegetables in their study area was in the order Cd> Zn > Pb > Cu (Akande & Ajayi, 2017).

Copper (Cu), similar to Zinc (Zn) and Cadmium (Cd), has been found in various studies to exhibit a high transfer factor (TF) in food crops. Hasan et al. (2020), in their study conducted in southern Bangladesh, recorded the highest TF level for Cd compared to other heavy metals (HMs). In a study conducted in Kenya involving three leafy vegetables, Iron (Fe) exhibited the highest TF. Similarly, Hussain and Qureshi (2020) found the highest TF for Fe in vegetables studied in Dubai, United Arab Emirates (UAE). Chromium (Cr) and Fe have also been observed to have the highest TF when compared with other HMs in vegetables cultivated around industrial areas (Chowdhury et al., 2019). In contrast, a pot experiment by Zubair et al. (2019) found Arsenic (As) to have the highest TF.

In Africa, *Celosia trigyna* and *Amaranthus viridis* are consumed as vegetables and used as herbs in the treatment of several diseases such as diabetes, menstrual cramps, dysentery, chest pain, urinary disorders, liver problems, eye defects and fever. Despite the usefulness of vegetables in human diet, literature shows that there is a global concern for the transfer of HMs in human food and water due to their ability to be transferred from soil to plants. However, the health risk associated with HM transfer from soil to *Celosia trigyna* and *Amaranthus viridis* has not received the needed attention in Africa. Therefore, this study assessed the health risk of the transfer of HMs from soil to *Celosia trigyna* and *Amaranthus viridis* along Lekki Peninsula of Lagos.

2. MATERIALS AND METHODS

2.1. Study area

Twelve vegetable gardens were selected along Lekki Pennisula in Lagos. An initial survey was conducted, and a free survey approach was used to determine 5 sampling points per garden (Figure 1). The vegetables were irrigated with water from hand-dug wells and boreholes. A combination of chemical fertilizer and poultry droppings was applied to the vegetable plants during the growth period at locations 1-6 while locations 7-12 were far from the road and the farmers majorly used poultry droppings without the use of herbicides.

2.2. Sample collection

Edible parts of the vegetable *(Celosia trigyna L.* (English name: silver spinach and locally called ‘Efo aje fo wo’) *Amaranthus viridi* (English: slender amaranth and locally called ‘tete abalaye’) were collected for laboratory analyses. Samples were collected in February, March, April, May, and June 2022. These are the peak months of vegetable production in Lagos State.

1 kg of soil samples were collected from 0-10cm depth. This depth is the active root zone of the vegetable plants. Ten vegetable plants were collected from each sampling point. Only the edible parts of the plants were analyzed in the laboratory.

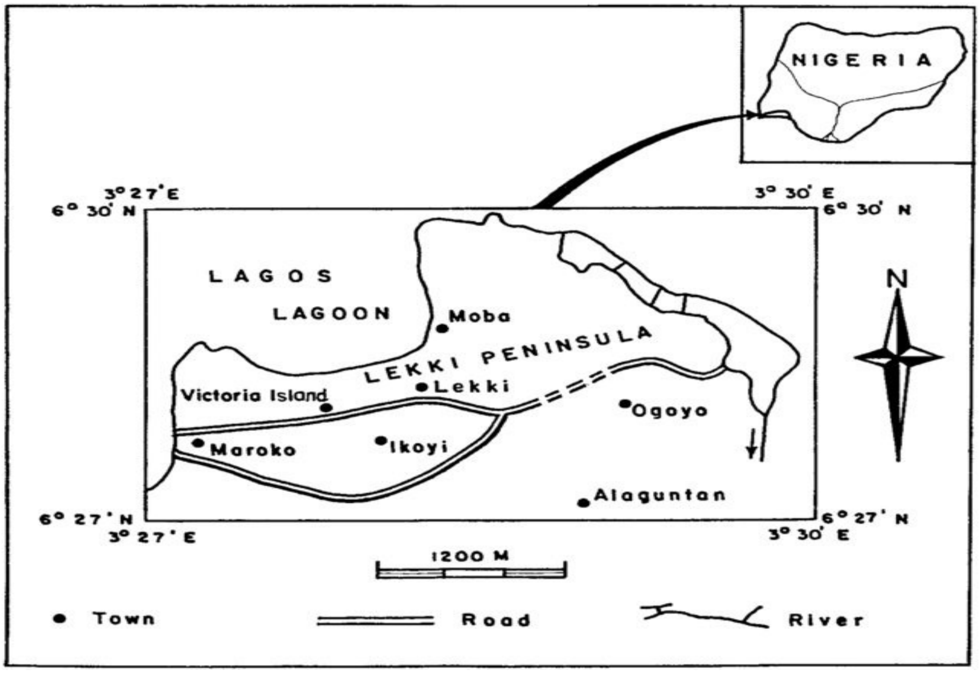

Figure 1. Map showing Lekki Peninsula area of Lagos, Nigeria

(Source: Adepelumi & Olorunfemi, 2000)

2.3. Sample analysis procedures

The soil and vegetable samples were analyzed for physiochemical parameters and HMs at the Department of Chemistry, University of Lagos, Nigeria.

pH Determination: A glass electrode pH meter was used to determine the pH of the soil samples. 20 ml of a solution containing 0.01M $CaCl_2$ was added to 10g of air-dry soil sample. The contents were stirred with a glass rod and allowed to settle before the glass-electrode pH meter was introduced and the reading was taken.

Determination of Organic Matter: The Walkley-Black method was first used to determine the % of organic matter in the collected soil samples. 10 ml of $K_2Cr_2O_7$ solution was added to 1g of air-dry sieved soil. The mixture was swirled to disperse the soil. 20 ml of concentrated H_2SO_4 was added to the suspension. 3 drops of 0.5 ferrous sulphate solutions were used as indicators during the titration. The result was calculated with the formula:

$$\% \text{ organic in soil (air} - \text{dry basis)} = \text{me KCr2O2} - \text{meFeSO4} \times 0.003 \times 100 \times (\text{f}) \frac{\square}{\square}$$

(g of air-dry soil).

Where f (correction factor) was taken to be 1.33

$$\text{me} = \text{Normality of solution} \times \text{ml of solution used.}$$

The organic matter was calculated thus: $\%\ \text{OC} \times 1.729$

Determination of N in soil: Regular Macro-Kjeldahl Method was used to determine total Nitrogen.

2.4. Heavy metals

Atomic Absorption Spectrometer Perkin Elmer Analyst 200 produced by PerkinElmer, United States of America, was used to determine the HM in soil and the vegetable samples in this study. The samples were air-dried for 2 days thereafter, the collected samples were mashed and sieved using a 2 mm sieve. 10 ml of concentrated HNO_3 was added to 0.25g of the soil and vegetable samples. The mixtures were left in a fume cupboard to cold digest and later heated for ½ hour in a microwave, allowed to cool before 10 ml of double-distilled H_2O was added and filtered. Levels of Fe, Cu, Zn, Mn and Pb in the vegetables and soil were determined.

2.5. Transfer factor (TF)

Plant transfer factor (PTF) = Cplant/Csoil (Yamashita et al., 2013), where Cplant represents the HM concentration in the vegetable's extracts while Csoil represents the HM concentration in extracts of soils on a dry weight basis.

2.6. Daily intake of metals (DIM)

According to Akande and Ajayi (2017), DIM of Fe, Cu, Zn, Mn and Pb are to be calculated as DIM = DC × MVMC. DC = Daily vegetable consumption and MVMC = Mean Vegetable Metal Concentration (mg/kg) (Akande & Ajayi, 2017). Following FAO/WHO (1999) guidelines, the average daily intake of vegetables for an average adult taken as 300 g/day/adult of 70 kg.

2.7. Health risk index (HRI)

HRI for the consumption of contaminated vegetables was estimated as DIM/to the reference oral dose (RfD) for each metal (Akande & Ajayi, 2017). The HRI < 1 means the exposed population is safe for humans. According to Akande and Ajayi (2017), reference oral doses given are 0.0035, 0.0005, 0.04, 0.3 and 0.14 mg/kg/day for Lead, Cadmium, Copper, Zinc and Manganese respectively (Akande & Ajayi, 2017).

2.8. Hazard index

The hazard index (HI) as developed by USEPA (2002) was calculated as HI = HRIPb + HRIZn + HRICu + HRICd + HRIMn.

2.9. Data analysis

The data collected was analysed using means and standard deviation.

3. RESULTS

The pH, TOC, OM and TN of the soil samples are shown in Figure 2 below. Na in the soils from various farms in this study ranged from 0.16 and 0.9 Meq100g with the highest Na recorded at Farms 1 and 3 and lowest at Farm 5. Ca levels ranged between 0.19 to 1.5 Meq100gs, with the highest at Farm 5 and lowest at Farm 2. The level of K in the soil ranged between 0.07 -0.9 Meq100g while Mg ranged between. Mg was found to range between 0.3 and 0.78 Meq100g. The highest Mg was found at Farm (location 3) while the least Mg was found at Farm 1 (Figure 3).

3.1. Soil and vegetable heavy metals

Figures 4-8 show the analytical result for analysed Zn, Cu, Mn, Cd and Pb. The result shows that the soil and the vegetable samples contain varied concentrations of Zn, Cu, Mn, Cd and Pb. The result revealed that Zn is the most abundant element, with a range of 0.12 and 88.02 mg/kg (Figure 5). This was closely followed by Cu with a range of 45.01-0.02 mg/kg (Figure 7), while Pb has the lowest concentration with a range of 0.35–0.00 mg/kg (Figure 4). The order of decreasing mean values was Zn > Mn > Cu > Cd > Pb. The highest concentration of Pb was at Farm 6, Cd at Farm 5, Zn at Farm 9, and Cu and Mn at Farm 5. The concentration of the metals was within the FAO/WHO permissible level.

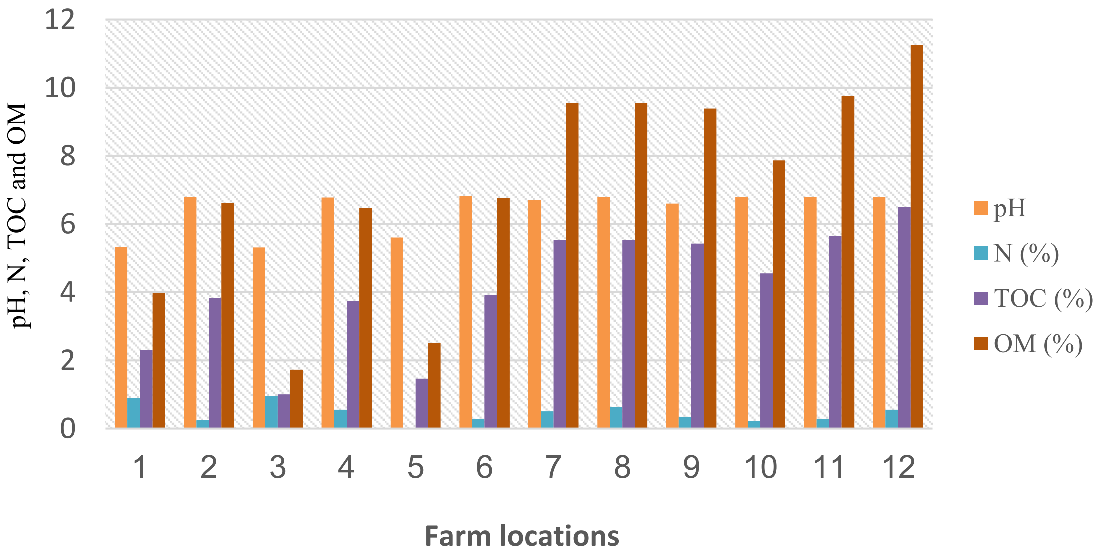

Figure 2. Soil pH, TOC and OM in soil

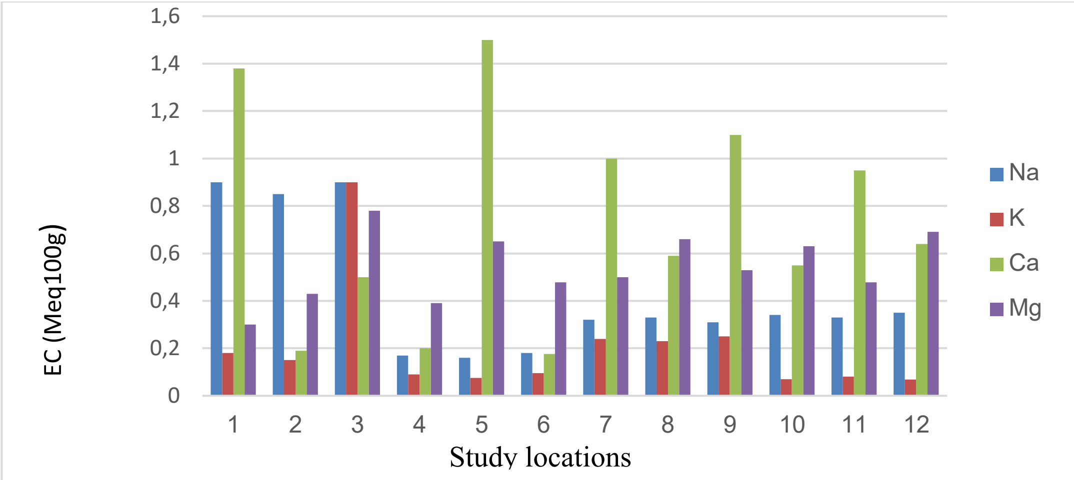

Figure 3. Level of Na, K, Ca, Mg in the study locations

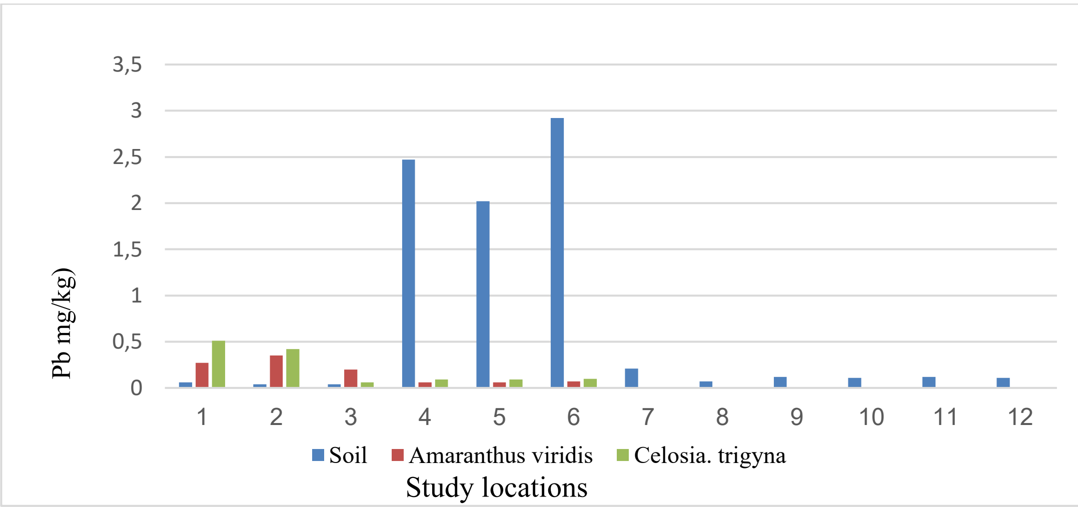

Figure 4. Level of Pb in the study locations

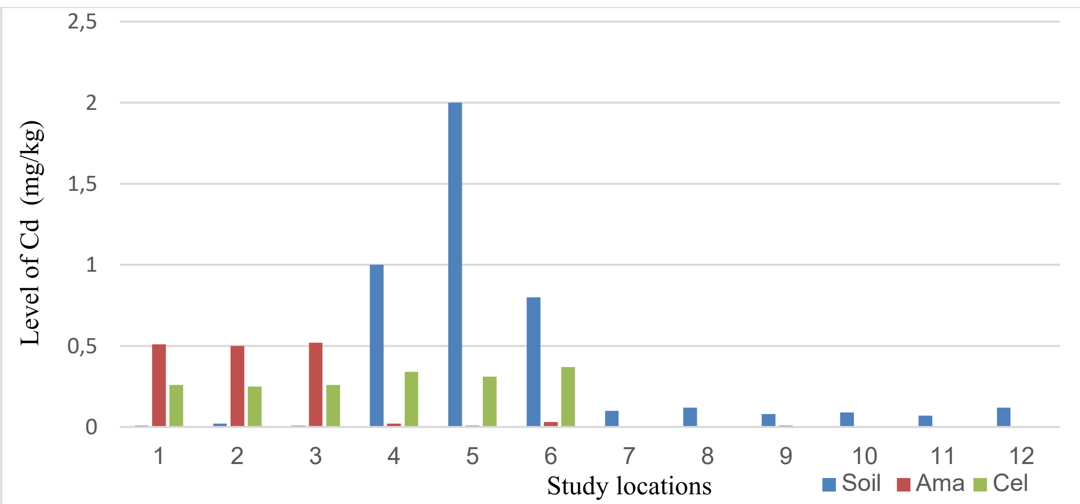

Figure 5. Level of Cd in the study locations

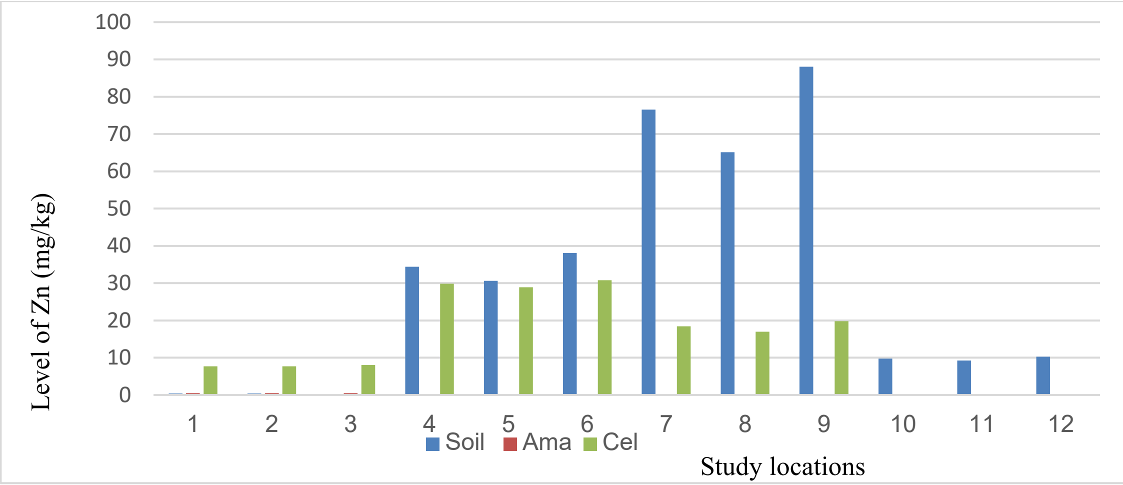

Figure 6. Level of Zn in the study locations

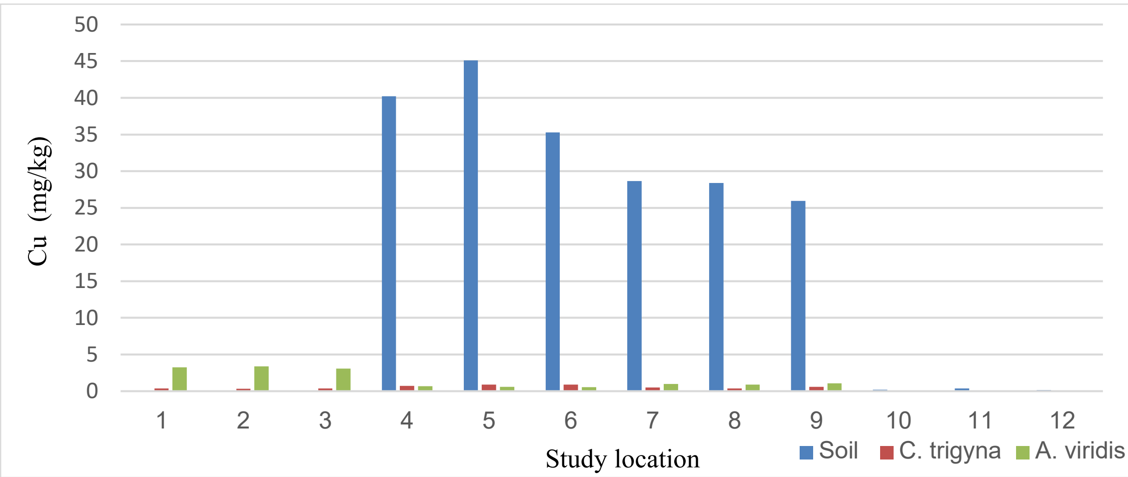

Figure 7. Level of Cu in the study locations

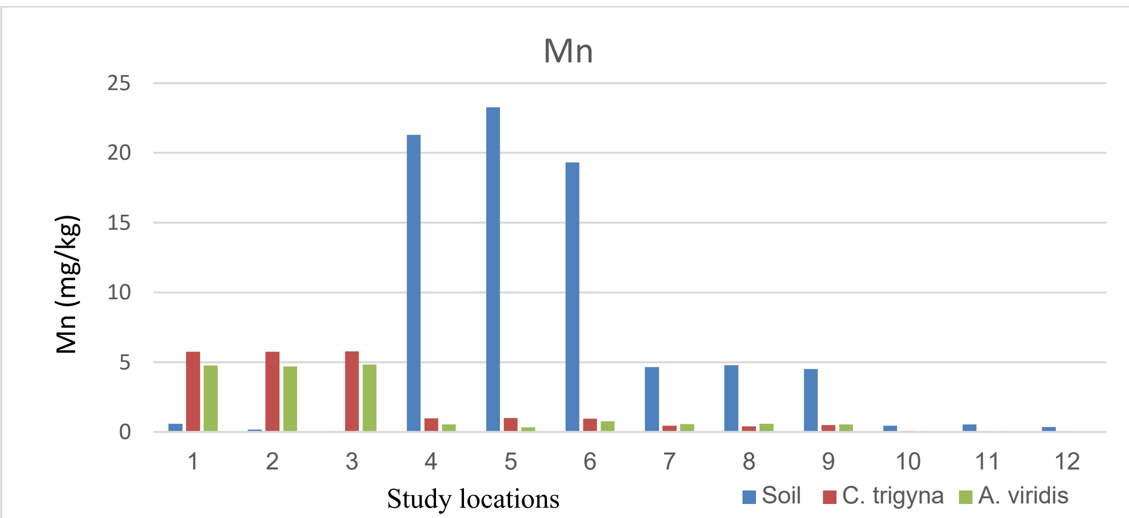

Figure 8. Level of Mn in the study locations

The highest level of Pb (0.51 mg/kg) in *C. trigyna,* was recorded at Farm 1. For *A. viridis* highest concentrations of Cd (0.51 mg/kg) at Farm 1 (Figure 4). These values are higher than WHO/FAO recommendations. Zn was highest in *C. trigyna* with a concentration of 30.80 mg/kg at Farm 6. Cu was highest at Farm 2 with a concentration of 3.20 mg/kg. *A. viridis* contained the highest concentration of Mn (5.78 mg/kg) at Farm 3 (Figure 8).

3.2. Heavy metal TF

The mean values of TF in vegetables for Farms 1-12 for Pb ranged between 0.00 and10.50, Zn between 0.00 and 66.67; Mn between 0.01 and 96.33; Cd between 0.00 and 52.00 while CU highest TF ranged between 0.01 and 155.00 (Table 1). The highest TF for Pb (10.50) was found in *Amaranthus viridis* at Farm 2. The highest TF for Cd (52.00) was found in *Amaranthus viridis* in Farm 3. For Zn the highest TF (66.67) was found in *Amaranthus viridis* of Farm 3. Farm 3 *Amaranthus viridis* also recorded the highest TF for Cu while Mn highest TF was found in *Amaranthus viridis* with a value of 96.33 in Farm 3 (Table 1).

Table 1. Heavy metals TF from soil to *C. trigyna* and *A. viridis* (mg/kg)

Farm	TFPb	TFZn	TFMn	TFCd	TFCu
1.	8.50[t]	1.31[t]	9.93[t]	51.00[t]	65.00[t]
	4.50[v]	19.79[v]	8.21[v]	26.00[v]	7.20[v]
2.	10.50[t]	1.16[t]	35.94[t]	25.00[t]	68.00[t]
	8.75[v]	17.91[v]	29.38[v]	12.50[v]	6.60[v]
3.	1.50[t]	4.33[t]	96.33[t]	52.00[t]	155.00[t]
	5.00[v]	66.67[v]	80.33[v]	26.00[v]	19.50[v]
4.	.03[t]	NM[t]	.05[t]	NM[t]	.02[t]
	.02[v]	.87[v]	.03[v]	.06[v]	.02[v]
5.	.04[t]	NM[t]	.04[t]	NM[t]	.01[t]
	.03[v]	.94[v]	.01[v]	.03[v]	.02[v]
6.	.03[t]	NM[t]	.05[t]	.01[t]	.02[t]
	.02[v]	.81[v]	.04[v]	.12[v]	.03[v]
7.	.01[t]	NM[t]	.09[t]	.01[t]	.03[t]
	NM[y]	.24[y]	.12[y]	.02[y]	.02[y]
8.	.02[t]	NM[t]	.08[t]	.01[t]	.03[t]
	.01[y]	.26[y]	.12[y]	.01[y]	.01[y]
9.	.02[t]	NM[t]	.11[t]	.13[t]	.04[t]
	.02[y]	.22[y]	.12[y]	.04[y]	.02[y]
10.	NM[t]	NM[t]	.15[t]	NM[t]	.18[t]
	NM[y]	.02[y]	.13[y]	NM[y]	.22[y]
11.	NM[t]	NM[t]	.08[t]	NM[t]	.10[t]
	NM[y]	.02[y]	.10[y]	NM[y]	.06[y]
12.	NM[t]	NM[t]	.16[t]	NM[t]	.21[x]
	NM[v]	.02[v]	.12[v]	NM[v]	0.24[v]

t = C. trigyna; v = A. viridis. NM = Not Determined

The EDI of heavy metals in this study for an average adult is given in Table 2. It was presumed that consumption of *C. trigyna and A. viridis are* the means through which toxic elements (Pb, Zn, Mn Cd and Cu) get to man in this study. The range of value for daily intake of Pb was lower in *C. trigyna* when compared with *A. viridis* (Table 2). Also, the range of values for EDI of Zn was lower in *C. trigyna* when compared with *A. viridis* (Table 2). The same pattern was observed for EDI for Mn, Cd and Cu (Table 2).

Table 2. EDI (mg^{-1} kg^{-1} adult^{-1} d^{-1}) for *C. trigyna; A. viridis*

Farm	EDI (Pb)	EDI (Zn)	EDI (Mn)	EDI (Cd)	EDI (Cu)
1.	.0022^{t} .0032^{v}	.0020^{t} .0022^{v}	.0020^{t} .0247^{v}	.0020^{t} .0022^{v}	.0020^{t} .0139^{v}
2.	.0018^{t} .0015^{v}	.0331^{t} .0021^{v}	.0204^{t} .0246^{v}	.0011^{t} .0021^{v}	.0015^{t} .0146^{v}
3.	.0003^{t} .0009^{v}	.0330^{t} .0022^{v}	.0201^{t} .0248^{v}	.0011^{t} .0022^{v}	.0014^{t} .0133^{v}
4.	.0004^{t} .0003^{v}	.0343^{t} .0001^{v}	.0207^{t} .0042^{v}	.0011^{t} .0001^{v}	.0017^{t} .0028^{v}
5.	.0004^{t} .0003^{v}	.1280^{t} NM^{v}	.0023^{t} .0042^{v}	.0015^{t} NM^{v}	.0032^{t} .0026^{v}
6.	.0004^{t} .0003^{v}	.1238^{t} .0001^{v}	.0014^{t} .0041^{v}	.0013^{t} .0001^{v}	.0038^{t} .0024^{v}
7.	NM^{t} NM^{v}	.1320^{t} NM^{v}	.0033^{t} .0019^{v}	.0016^{t} NM^{v}	.0038^{t} .0042^{v}
8.	NM^{t} NM^{v}	.0789^{t} NM^{v}	.0024^{t} .0017^{v}	NM^{t} NM^{v}	.0021^{t} .0038^{v}
9.	NM^{t} NM^{v}	.0729^{t} NM^{v}	.0025^{t} .0021^{v}	NM^{t} NM^{v}	.0016^{t} .0047^{v}
10.	NM^{t} NM^{v}	.0849^{t} NM^{v}	.0023^{t} .0003^{v}	NM^{t} NM^{v}	.0025^{t} .0002^{v}
11.	NM^{t} NM^{v}	.0009^{t} NM^{v}	.0002^{t} .0002^{v}	NM^{t} NM^{v}	.0002^{t} .0002^{v}
12.	NM^{t} NM^{v}	.0008^{t} NM^{v}	.0002^{t} .0002^{v}	NM^{t} NM^{v}	.0001^{t} .0001^{v}

EDI= Estimated daily intake. t = Estimated daily intake C. trigyna; v = Estimated daily intake A. viridis

NM = Not Determined

Important ways through which man is exposed to heavy metals in food are via the HRI and HI. The HRI and HI for the assayed toxic elements in this study are shown in Table 3. HRI for Pb in *C. trigyna* ranged from 0.00- 0.6245 and ranged from 0.0000-0.4286, in *A. viridis respectively*. HRI for Zn in *C. trigyna* and *A. viridis* ranged from 0.0028–0.4400 and 0.0000–0.4266 respectively. Mn in *C. trigyna* and *A. viridis* ranged from 0.0017–0.1476 and 0.0014 - 0.1769 respectively. Cd in *C. trigyna* and *A. viridis* ranged from 0.0000–4.0000 and 0.0000–4.4571 respectively. Cu in *C. trigyna* ranged from 0.0022–0.0954 and *A. viridis* ranged from 0.0034–0.3643. The HR for Cd was high for locations 1,2,3,4,5,6, and 7 for both vegetables. The calculated HI for Cd *C. trigyna* was higher than 1 in farms 1, 2, 3,4, 5,6 and 7 and in farms 1, 2, 3 and 6 for A. *viridis*, respectively.

Table 3. Potential Health Risk and Hazard Index for consuming *C. trigyna* and *A. viridis*

Farm	HRI (Pb)	HRI (Zn)	HRI (Mn)	HRI (Cd)	HRI (Cu)	HI
1.	.6245^{x} .3306^{v}	.0067^{t} .0073^{v}	.0143^{t} .1763^{v}	4.0000^{t} 4.3714^{v}	.0500^{t} .3482^{v}	4.6954^{t} 5.2339^{v}
2.	.5143^{t} .4286^{v}	.1103^{t} .0071^{v}	.1457^{t} .1760^{v}	2.2286^{t} 4.2857^{v}	.0386^{t} .3643^{v}	3.0374^{t} 5.2617^{v}
3.	.0735^{t} .2449^{v}	.1100^{t} .0074^{v}	.1439^{t} .1769^{v}	2.1429^{t} 4.4571^{v}	.0354^{t} .3321^{v}	2.5056^{t} 5.2186^{v}
4.	.1102^{t} .0735^{v}	.1143^{t} .0003^{v}	.1476^{t} .0300^{v}	2.2286^{t} .1714^{v}	.0418^{t} .0707^{v}	2.6424^{t} .3459^{v}
5.	.1102^{t} .0735^{v}	.4266^{t} .0001^{v}	.0165^{t} .0303^{v}	2.9143^{t} .0857^{v}	.0793^{t} .0643^{v}	3.5469^{t} .2539^{v}
6.	.1224^{t}	.4127^{t}	.0098^{t}	2.6571^{t}	.0954^{t}	3.2975^{t}

Farm	HRI (Pb)	HRI (Zn)	HRI (Mn)	HRI (Cd)	HRI (Cu)	HI
	.0857^{v}	.0004^{v}	.0294^{v}	.2571^{v}	.0600^{v}	.4327^{v}
7.	.0012^{t}	.4400^{t}	.0236^{t}	3.1714^{t}	.0954^{t}	3.7316^{t}
	.0012^{v}	NM^{v}	.0135^{v}	.0086^{v}	.1050^{v}	.1283^{v}
8.	.0026^{t}	.2630^{t}	.0171^{t}	.0171^{t}	.0525^{t}	.3524^{t}
	NM^{v}	NM^{v}	.0122^{v}	.0086^{v}	.0943^{v}	.1151^{v}
9.	NM^{t}	.2430^{t}	.0178^{t}	.0086^{t}	.0407^{t}	.3101^{t}
	NM^{v}	.0001^{v}	.0150^{v}	.0857^{v}	.1168^{v}	.2176^{v}
10.	.0012^{t}	.2829^{t}	.0165^{t}	.0257^{t}	.0632^{t}	.3895^{t}
	.0012^{v}	NM^{v}	.0020^{v}	NM^{v}	.0038^{v}	.0070^{v}
11.	.0026^{t}	.0029^{t}	.0017^{t}	NM^{t}	.0047^{t}	.0119^{t}
	NM^{v}	NM^{v}	.0014^{v}	NM^{v}	.0038^{v}	.0051^{v}
12.	NM^{t}	.0028^{t}	.0017^{t}	NM^{t}	.0022^{t}	.0066^{t}
	NM^{v}	NM^{v}	.0017^{v}	NM^{v}	.0034^{v}	.0051^{v}
THI			41.7522			

t = HRI for C. trigyna; v = HRI for A. viridis HR = Health Risk. HI = Hazard Index. THI = Total Hazard Index. NM= Not Determined

4. DISCUSSION

The migration of metals from the soil into plant roots is quantified by the Transfer Factor (TF). The TF from soil to plant is a key pathway through which humans are exposed to heavy metals via the food chain (Dhaliwal et al., 2020). This factor is crucial for assessing the level of human exposure to heavy metals present in the soil. In this study, it was hypothesized that the consumption of *Celosia trigyna* and *Amaranthus viridis* is a significant route for the intake of toxic elements (Pb, Zn, Mn, Cd, and Cu) by humans. The range of values for the daily intake of Pb was lower in C. *trigyna* compared to A. viridis. Similarly, the estimated daily intake (EDI) values for Zn, Mn, Cd, and Cu were also lower in C. *trigyna* compared to A. *viridis*. This pattern indicates that A. *viridis* has a higher potential for transferring these heavy metals to humans than C. *trigyna*.

It was apparent that differences in the TF in species in different locations may be attributed to prevailing agricultural management practices such as excessive application of fertilizers and other agrochemicals, the distance of the farm from the road and the type of farming system practised. Important ways through which humans are exposed to heavy metals in food are via the HRI and HI. HRI for Pb in *C. trigyna* ranged below 1 while in *A. viridis* was below 0.5. The HRI values in this study for Cd and Pb were high but low values for Cu and Zn for *A. viridis*. This may be due to the different vegetable types in the study. The HR for Cd was high for locations 1, 2, 3, 4, 5, 6, and 7 for both vegetables. The calculated HI for Cd *C. trigyna* was greater than 1 in farms 1, 2, 3,4, 5,6 and 7 and in farms 1, 2, 3 and 6 for A. *viridis*, respectively (Akande & Ajayi, 2017).

This finding is similar to the results obtained by Nataša et al. (2015). A similar trend was also observed in the findings of Akande and Ajayi (2017), as well as the findings of Zhou et al. (2016) and Hasan et al. (2020) but deviated from the report of Hussain and Qureshi (2020).

The high TF values found for Cd in some of the locations can be attributed to the excessive use of chemical fertilizers and fertilizers management on the farm. The present observation agrees with the results from an investigation made by Nataša et al. (2015), where Cd was also found to have elevated TF in plant studies. The HRI for *C. trigyna* and *A. viridis* was higher than 1 in farms 1, 2 and 3. This exposes people who consume such vegetables to a high risk of metal exposure.

5. CONCLUSIONS AND RECOMMENDATIONS

The pH of the soil was slightly acidic. The concentration of heavy metals in the soils was all within the acceptable limit of WHO/FAO. However, the level of Pb and Cd in vegetables was above the acceptable level set by WHO/FAO at locations 1, 2, 3, 4, 5 and 6. The health risk index for Pb and Cd was higher when compared with other toxic elements in the study. The concentration of the heavy metals in *Celosia trigyna* and *Amaranthus viridis* in this study is a function of the contaminated soil and the deposition of toxic elements from passing vehicles. Following the hazard index result of this study, the vegetables in locations 1–6 are not safe for human consumption.

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