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Research Article

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A study of bioaccumulation of heavy metals on selected vegetables grown in keteren-gwari mechanic village, minna metropolis, Nigeria

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Abstract The concentration of some heavy metals were determined in farm soil and vegetable samples of spinach (Amaranthu sspinosus) and water leaf (Talinum triangulare) collected around the mechanic village at Keteren-Gwari, Minna metropolis, Niger State Nigeria during the dry season. Metal concentration in both soil and vegetable samples were determined using Atomic Absorption Spectroscopy (AAS) (Buck Scientific 210VGB). Results from soil analysis showed mean values of 3661.5±16.25 for Fe, 13.75±0.03 Cu; 41.25±2.48 Zn; 6.25±0.71 Cr. The results for vegetable samples showed that spinach accumulated metals more in the leaves while waterleaf accumulated highest in the roots. Concentration for Fe ranged from 138±11.31-532±16.97; 6.00±1.41-13.25±1.06 Cu; 50.50±3.54-133.0±4.24 Zn; 1.5±0.71-6.0±0.71 Cr. Both vegetables are however good for studying heavy metal uptake and accumulation by plants. The high levels of some of these heavy metals place the consumers of these vegetable crops grown within the study area at health risk with time unless an urgent step is taken by relevant agencies in address this issue.

Keywords Heavy Metals, Vegetables, Mechanic Village, Bioaccumulation

Introduction

Heavy metals no doubt are important constituents for plants and humans but only in small amount. Some micronutrient elements may also be toxic to both animals and plants at high concentrations; for example copper (Cu), chromium (Cr), fluorine (F), molybdenum (Mo), nickel (Ni), selenium (Se) or zinc (Zn). Other trace elements such as arsenic (As), cadmium (Cd), mercury (Hg) and lead (Pb) are toxic even at small concentrations [1]. They are persistent and non-biodegradable as they are neither removed by normal cropping nor are they easily leached by rain water [2].

Since heavy metals tend to bio accumulate in the human body, they are dangerous and thereby pose great health and environmental risks. Over the last decades, there has been growing interest in determining heavy metal levels in public food supplied [3]. The concentration of metals in bio-available form is not necessarily proportional to the total concentration of the metal [4].

Foremost amongst the modes of ecosystem contamination in urban areas according to Adewole and Uchegbu (2005) [5] is the prevalence of automobile workshops and service stations. Automobile wastes include solvents, paints, hydraulic fluids, lubricants and stripped oil sludge; all results of activities such as battery charging, welding and soldering, automobile body works engine servicing and combustion processes [6]. All these find their way somehow into the ecosystem. The significant contamination of seeds, plants and plant products with toxic chemical elements due to contaminated soil and water has been observed as a result of these toxicants into the sea, rivers and even irrigation channels. Afterwards, the consumption of contaminated vegetables constitutes an important route of animal and human exposure [7-8].

Data on the heavy metal levels of vegetables grown around mechanic Villages especially in Niger State, Nigeria is scarce in literature. Adverse effects are supposed, when the concentration of heavy metals exceed the permissible limits in vegetables. This study therefore, is to assess the levels of Fe, Cu, Zn, Cr, Pb, Ni and Cd in Soils and Vegetables (Spinach and Water-leaf) around the study area.

Materials and Methods

Sampling

Sampling was done during the dry season in the month of February, 2014. Vegetable samples which included Spinach (Amaranthus spinosus) and Water-leaf (Talinum triangulare) were collected randomly from the farms along the banks of the Keteren Gwari stream bordering the mechanic village; and which are irrigated with its water. The vegetable samples were divided into leaf, stem and roots (to be analysed independently). The samples were then washed with tap water and distilled water to remove air pollutants. This was then followed by oven drying to remove moisture [9]. Dried samples were then pulverized using agate pestle and mortar and finally sieved through a 0.5mm mesh size sieve.

Two composite Soil samples were collected at depths of 0-15cm and 15-30cm from randomly selected points from farmlands around the mechanic village where vegetable samples were collected into clean polythene bags and labelled F1 and F2. Samples were then air dried for 48 hours, ground and sieved using 0.5mm mesh size sieve to have uniform particles. Control sample was also collected at a neutral location about 5 km away from the site.

Sample Preparation and Analysis

Vegetable samples were digested using a method described by Awofolu (2005) [10] and modified by Abdullahi et al,. (2008) [9]. 0.5g of ground sample was measured into an acid washed 100cm^3 beaker. 5cm^{3}of concentrated nitric acid (HNO_3) and 2cm^{3}of concentrated Percloric acid ($HClO_4$), together with few boiling chips were added. The mixture was then heated at 70ºC for 15mins until a light coloured solution was obtained. The sample solution was then filtered into a 50cm^3 standard flask and two 5cm^{3}portions of distilled water used to rinse the beaker and its contents filtered into the 50cm^3 flask. The filtrate was left to cool at room temperature before dilution was made to mark and taken for instrumental analysis.

Soil samples were digested as described by Sonawaneet al,. (2013) [11]. Homogenized samples of 2.0g were each measured into 250cm^3 glass beakers and 8cm^3 of freshly-prepared aqua-regia (3:1 HCl and HNO_3) added. The mixture was then heated at 200ºC on a hot plate for 2hrs. After evaporation to near dryness, the sample was then dissolved with 10cm^{3}of 2% nitric acid and filtered through Whatman filter paper before being diluted with deionised water to mark.

Aliquots of the diluted solution were analysed for heavy metals, using Atomic Absorption Spectrophotometer (AAS) (Buck Scientific model 210VGP). All analysis was performed in triplicates.

Results and Discussion

Table 1: Heavy metal Levels in Surrounding Farm Soils of Keteren-Gwari mechanic Village (mg/Kg)

Sample	Fe	Cu	Zn	Cr	Pb	Ni	Cd
F1	4265±21.21	16.25±0.04	40.00±2.83	7.50±0.71	BDL	BDL	BDL
F2	3058±11.30	11.25±0.03	42.50±2.12	5.00±0.71	BDL	BDL	BDL
Mean	3661.5±16.25	13.75±0.03	41.25±2.48	6.25±0.71	BDL	BDL	BDL
Control	32±1.41	17.50±2.12^c	26.00±2.83	31.50±4.95	BDL	BDL	BDL

From table 1 it is seen that the concentration of Fe ranged from 3058±11.30 - 4265±21.21µg/g with a mean concentration of 3661.5±16.25µg/g. Concentrations for Cu ranged from 11.25±0.03 – 16.25±0.04µg/g, Zn concentration ranged from 40.00±2.83 – 42.50±2.12µg/g while concentrations for Cr ranged from 5.00±0.71 – 7.50±0.71µg/g. Pb, Ni and Cd were below detection limit. The levels of heavy metals concentration in decreasing order is Fe > Zn > Cu > Cr. The High amounts of Fe and Zn as compared with those collected from control sites suggest anthropogenic sources of pollution. The similarity in pattern of distribution with those of vegetable samples indicates a transfer of heavy metals from the soils to plants as shown in table 2.

Table 2: Heavy Metals in Spinach and Waterleaf grown around Keteren Gwari Mechanic Village (µg/g)

Sample	Fe	Cu	Zn	Cr	Pb	Ni	Cd
Sroot	350±6.36	8.50±1.41	60.0±2.828	1.5±0.71	BDL	BDL	BDL
Sstem	355±4.24	6.00±1.41	50.50±3.54	6.0±1.41	BDL	BDL	BDL
Sleaf	380±6.36	13.25±1.06	78.50±6.36	5.25±0.35	BDL	BDL	BDL
Mean	361±5.65	9.25±1.29	63.0±4.23	4.25±0.82	BDL	BDL	BDL
Wroot	532±16.97	7.00±1.41	133.0±4.24	4.25±0.35	BDL	BDL	BDL
Wstem	138±11.31	5.00±0.00	61.50±2.12	6.00±0.71	BDL	BDL	BDL
Wleaf	314±18.38	8.00±1.41	81.0±7.07	3.00±1.41	BDL	BDL	BDL
Mean	328±15.55	6.67±0.94	91.83±4.47	4.42±0.82	BDL	BDL	BDL

Spinach (Amaranthus spinosus)

Heavy metal concentrations in spinach samples in decreasing order from table 2 show mean values of 361±5.65µg/g for Fe followed by 63.0±4.23µg/g for Zn, 9.25±1.29µg/g for Cu and 4.25±0.82µg/g for Cr. Pb, Ni, and Cd were below detectable limits. Mean concentrations of Fe was found to be highest in leaves (380±6.36µg/g) followed by the stem (355±4.24µg/g) and least in the root (350±6.36µg/g); although there was no significant variation between them at $P \leq 0.05$. Zn concentrations also showed highest concentrations in spinach leaves (78.50±6.36µg/g) followed by the roots (60±2.8µg/g) with least concentrations in the stem (50.5±3.54µg/g). Results for Fe and Zn were far greater than those reported by Khadeeja R et al., (2013) [2] for vegetables irrigated with both fresh and wastewater in Pakistan; however, present study compares with available literature [8, 12] that Fe and Zn showed more accumulation in the leaves of plants as shown in figure 1 and were also usually found in higher concentrations than other metals. In general, permissible limits for Cu which is 10mg/Kg [12] as well as Fe (300µg/g) and Cr (2.3µg/g) (WHO/FAO, 2011) were exceeded in the edible part of the spinach sample. However, samples were below maximum allowable limits for Zn given as 150mg/Kg [13].

Waterleaf (Talinum triangulare)

From table 2, mean concentrations of Fe in waterleaf samples was 328±15.55µg/g with concentration of 532±16.97µg/g in the roots; which was the highest followed by 314±18.38µg/g in the leaves and 135±11.31µg/g in the stem with significant variation in the values at $P \leq 0.05$. Zn was the next higher metal with a mean concentration of 91.5±4.49µg/g; having a concentration of 133±4.24µg/g in the roots, 81±2.0µg/g in the leaves and 61.5±2.12µg/g in the stem. Both Fe and Zn showed higher accumulation for these metals in the roots and least in the stem. Cu showed the highest concentration in the leaf (8.0±1.41µg/g) and least in the stem (5.0±0.00µg/g); its concentration in the leaves was 7.0±1.41µg/g with an overall mean concentration of 6.67±0.94µg/g. Whereas, Cr concentration in the leaves was 3.0±1.41µg/g which was the least while concentration in the stem (6.0±0.71µg/g) was the highest followed by 4.25±0.35µg/g in the root. Results obtained by Hart et al., (2005), were lower than the present study showing values for Fe which ranged from 67µg/g to 275µg/g. Cu was recorded to range from 4.7µg/g to 14.5µg/g while Zn ranged from 151µg/g to 216µg/g in the edible parts of the leaf; which are both closely related but a little higher than the present study. Higher concentrations of Fe in the vegetable might be due to the participation of green vegetables in the synthesis of ferrodoxin, which makes them useful sources of Fe. Results obtained by Ebunget al., (2007) [14] recorded a mean range of 223.43-260mg/Kg for Fe and 2.20-29.95mg/Kg for Zn and concentrations of Zn ranging from 50.67-102.98mg/Kg and a low Cr range of 0.64-4.54mg/Kg respectively in edible parts of samples analysed.

Concentrations for Pb, Ni and Cd were below detectable limits as shown in Fig. 2 unlike reports; a mean range of 2.27-7.20mg/Kg for Pb and 0.62- 2.74mg/Kg for Cd and Oluyemiet al., (2008) [15] who recorded mean values in edible parts of waterleaf to be 14.50±0.01µg/g for Cd, 5.0±0.06µg/g for Pb while Ni was not detected. These values except Ni show very high variations with respect to the present study; both carried out in the dry season.

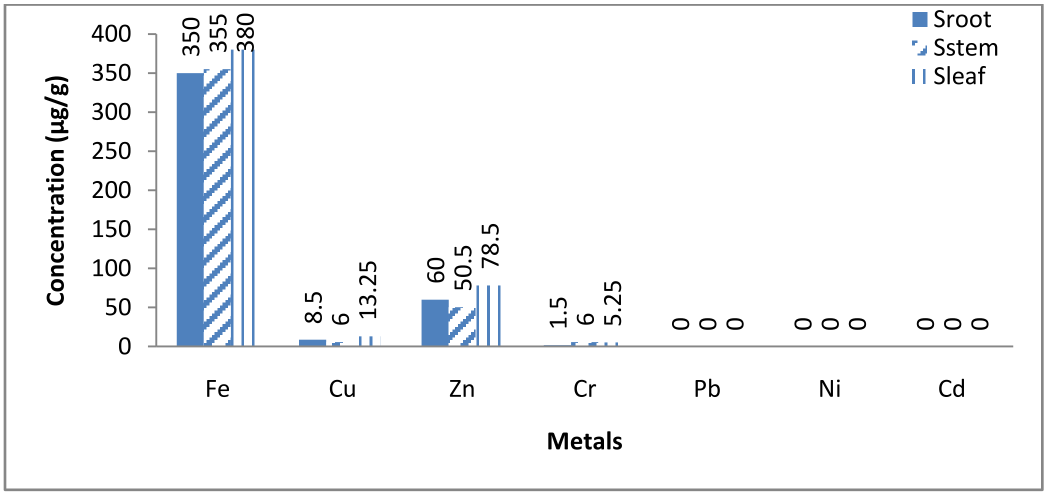

Figure 1: Levels of Heavy Metals in Spinach (Amaranthus spinosus) sample

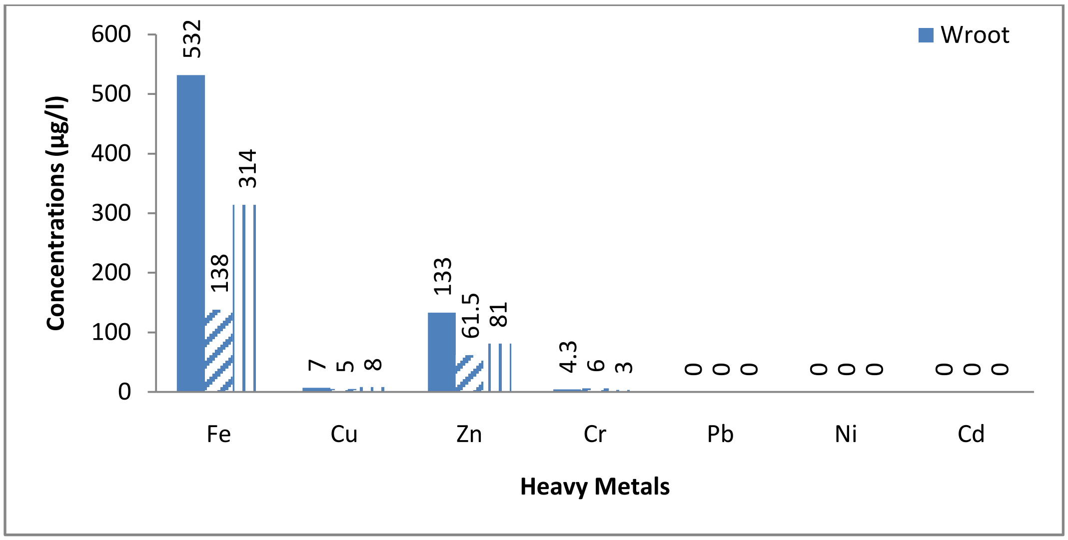

Figure 2: Levels of Heavy Metals in Waterleaf (Talinum triangulare) sample

Transfer Factor (TF)

The Transfer factor (TF), also called bio-accumulation factor (BCF) is calculated as the ratio of element concentration in plant tissues to the element concentration in soil. Anappropriate measure for the assessment is obtained when there is a linear relationship observed between the concentration of vegetables and soil for a given element [16]. TF is calculated with the relationship given below on the basis of dry weight as follows;

$$\text{Transfer Factor (TF)} = \frac{\text{Cveg}}{\text{Csoil}} - - - - - - - - - - - - - - - (\text{eqn. } 4.1)$$

Where Cveg = concentration of metals in vegetable

Csoil = concentration of metals in soil

Table 3: Transfer Factor (TF) of Heavy Metals from Farm Soils to Vegetables

Sample	Fe	Cu	Zn	Cr	Pb	Cd	Zn
Spinach	0.104	0.960	1.900	0.840	-	-	-
Waterleaf	0.086	0.580	1.960	0.480	-	-	-

Transfer factor for Zn was seen to be highest than other metals with mean values of 1.90 in spinach and 1.96 in waterleaf while Fe had the lowest transfer factor with a mean value of 0.104 in spinach and 0.086 in waterleaf. Cu had a transfer value of 0.960 in spinach and 0.580 in waterleaf while values for Cr showed 0.840 in spinach and 0.48

for waterleaf. On an average, spinach showed more absorption of heavy metals in its edible parts than waterleaf for the metals tested. The sequence for transfer factor in the metals present followed the decreasing order Zn > Cu > Cr > Fe. Leafy vegetables are reported to show higher transfer factors than non-leafy vegetables [17].

Conclusion

In this study, vegetables were seen to bio accumulate heavy metals in their various parts differently and in varying concentrations. While spinach accumulates the highest in its leaves, waterleaf accumulates heavy metals highest in its roots with the stems of both vegetables accumulating the least. Nonetheless, patterns are irregular in terms of distribution in all parts. Waterleaf was also noticed to absorb more heavy metals on an average compared to spinach which could be due to it having more moisture than spinach. Both vegetables are however good for studying heavy metal uptake and accumulation by plants. The high levels of some of these heavy metals place the consumers of these vegetable crops grown within the study area at health risk with time unless an urgent step is taken by relevant agencies in address this issue.

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