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Determination of Some Heavy Metals in Soils and Vegetables Samples from Kericho West Sub-county, Kenya

Leonard Bett[1*], Ongera Gilbert[1], Wangila Phanice[1] and Shadrack Mule[1]

[1]*Department of Physical Sciences, University of Kabianga, P.O.Box 2030- 20200, Kericho, Kenya.*

Authors' contributions

This work was carried out in collaboration among all authors. Author LB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OG and WP managed the analyses of the study. Author SM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The present study was carried out to investigated the presence of heavy metals (essential and non-essential); Pb, Fe, Cu, Mn and Cd in soils and vegetables such as *Brassica oleracea*, *Brassica oleracea Acephala* and *Amaranthus palmeri.* These soils and vegetables were collected randomly from local farms in Kericho West Sub-County. The samples were analysed for heavy metal by Inductively Coupled Plasma Emission Spectrophotometer (ICPE 9000) to determine the levels of the heavy metals. The mean concentrations of the heavy metals ranged in vegetables:- Manganese (86.33-113.00 mg/kg), Copper (15.67-36.00 mg/kg), Iron (319.33-977.67 mg/kg), Cadmium (10.33-29.00 mg/kg) and Lead (31.67-53.67 mg/kg) as well as in the soils; Mn (172.33-201.00 mg/kg), Cu (1.33-3.33 mg/kg), Fe (63.67-98.00 mg/kg), Cd (3.67-5.33 mg/kg) and Pb (5.00-5.67 mg/kg). The data obtained was analysed by using SPSS version 20.0 for descriptive statistics and one- way ANOVA. From the analysis of heavy metals in vegetables, from Sosiot the concentration of Manganese and copper were significantly different at p-value < 0.05, while Iron, Cadmium, Lead and Manganese were not significantly different at p-value > 0.05; from Kabianga Division,

**Corresponding author: E-mail: lnrdbett@gmail.com;*

Manganese and Iron were significantly different at p-value < 0.05. Copper, Lead and Cadmium were not significantly different at p-value > 0.05; from Kiptere Division, Manganese, Iron and Copper had no significant difference at p-value < 0.05. Cadmium and lead were significantly different at p-value > 0.05. Manganese had the lowest transfer factor between 0.42 and 1.15. The highest ratios were observed from copper ranging from 15.67 to 36.00 in all vegetables.

Keywords: Heavy metals; vegetables; soils; assessment.

1. INTRODUCTION

Food safety is a major public concern worldwide. Increasing demand of food safety has stimulated research regarding risks associated consumption of foodstuffs contaminated by pesticides, heavy metals and/or toxins [1]. Heavy metals are among the major contaminants of food supply and may be considered the most important problem to our environment. Such problems are getting more serious all over the world especially in the third world countries [2]. Heavy metals in general are not biodegradable, have long biological half-lives and potential accumulation in the different body organs leading to unwanted side effects. Heavy metals are divided into essential (e.g. Cu, Ni, Fe, and Zn) and non-essential (e.g Cd, Pb, Hg, Sn) for living organisms [3].

Human beings are encouraged to consume more vegetables and fruits which are good sources of vitamins, minerals, fibers and also beneficial to their health. However, these plants contain both essential and toxic metals over a wide range of concentrations [4]. It is well known that leafy vegetables such as *Amaranth palmeri*, *Brassica oleracea*, *spinacia oleracea* and *Brassica oleracea Acephala* are said to be good absorbers of heavy metals from soils [5]. Vegetables take up heavy metals by absorbing them from contaminated soils as well as from deposits on the parts of the plants exposed to air from the polluted environments [6]. Human exposure to heavy metals is a subject of public health concern that has attracted the attention of researchers, health and nutrition experts all over the world. The allowable limit of heavy metals, as safe values for copper, lead, and cadmium in vegetables recommended by WHO/FAO are 40, 0.3, and 0.2 mg/kg respectively [7]. Keeping in view the potential toxicity, persistent nature and cumulative behavior, as well as consumption of vegetables and fruits, there is necessity to test and analyse these food items to ensure that the levels of these contaminants meet the agreed international requirements [8].

Vegetables grown in heavy metals contaminated soils, accumulate higher amounts of metals than those grown in uncontaminated soils since they absorb these metals through their leaves [9]. Leafy vegetables are also said to be good absorbers of heavy metals when exposed to them e.g through exhaust fumes from vehicles and industries. It has been reported that nearly half of the mean ingestion of lead, mercury and cadmium through food is due to plant origin i.e. fruits and vegetables [10]. These metals enter human body through inhalation or ingestion and with ingestion being the main route. Some studies have shown that the levels of heavy metals (lead, cadmium, copper and zinc) were examined in selected fruits and vegetables sold in local markets in Egypt with levels ranging from 1.47 to 2.51 mg/kg [4].

Manganese forms soluble salts and complexes which are readily taken up by plants and this lead to elevated levels of Manganese in the vegetables [11]. Lead is toxic element that can be harmful to plants although plants usually show ability to accumulate large amounts of lead without visible changes in their appearance or yield [12]. Tolerance of heavy metals in plants is either by detoxification mechanisms or accumulation in different plant parts or cell organelles or in vacuoles or in cell wall. These heavy metals are some of the contaminants that can be found in tissues of fresh vegetables and leads to food chain contamination as crops and vegetables absorb them from polluted air or soil. Prolonged exposures to heavy metals can cause deleterious health effects in humans [13]. The heavy metals not only affect the nutritive values of vegetables but also affect the health of human beings and therefore, the safe limits of these heavy metals are lowered regularly in vegetables [14].

When plants decay, heavy metals that had been taken into the plants are redistributed so the soil is again enriched with the pollutants [15]. It has been established that heavy metals in soil are associated with various chemical forms that relate to their solubility which directly bear on their mobility and biological availability. Heavy metals in soluble form have high relation to their uptake by plants [16]. Apart from the source of heavy metal, the physical and chemical properties of the soil also affect the concentration of heavy metals in soils. The uptake and bioaccumulation of heavy metals in vegetables is influenced by many factors such as climate, atmospheric depositions, the concentrations of heavy metals in soils, the nature of soil and the degree of maturity of the plants at the time of the harvest [17].

The objective of the present research was to assess the levels of heavy metals in the vegetables and soils collected from Kericho west sub-county. The results can be useful for selecting appropriate clean-up measures for the deteriorated environment, and the protection of the local community from potential health hazards.

2. MATERIALS AND METHODS

2.1 Study Area

The research was carried in the admistrative divisions of Kabianga, Sosiot and Kiptere found in Kericho West Sub-County, Kericho County where the selected vegetables are commonly grown. It covers an area of 516.6 km^2 with a population of 202, 591 as per Kenya Population and Census report of 2009 as shown in Fig. 1 [18].

2.2 Soil and Vegetable Sampling

Soil samples were randomly collected using soil auger at a depth of 15 cm in triplicate from each of the three study sites. The sampling took place at the location where the selected vegetables were grown. The composite mixture from each of the three study sites were packed in well labeled polythene bags and transported to University of Kabianga chemistry laboratory. The soil samples were air dried, ground into powder using grinding miller (Black and Decker model CBM3 Type 02, 2012), labeled and kept in plastic containers for further analysis. The vegetable samples were randomly collected in triplicates from three study sites located in Kericho West Sub-County. Vegetable roots, leaves and stems of *Brassica oleracea, Brassica oleracea Acephala*, *Amaranthus palmeri* were collected, packed in well labeled plastic bags and transported to University of Kabianga chemistry laboratory. The samples were washed with distilled water, chopped into small pieces and air dried at room temperature for 6 days. The samples were finally ground, labeled and stored awaiting digestion.

2.3 Sample Analysis

The total concentrations of metals were determined by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-ES 9000 model, Shimadzu) after strong acid digestion (1:1 concentrated HNO_3 and HCl (v/v)) of about 200 mg of ground plant and soil samples.

Soil samples were digested using aqua regia as recommended by Golia et al. [19]. In this procedure, 1.0 g of the soil sample was placed in a Kjeldahl flask and 6 mL of concentrated nitric (V) acid was added first before adding 18 mL of concentrated hydrochloric acid. The mixture was heated until a clear digest was obtained. The digest was cooled and few drops of water were added before filtering using a Whatman No.42 filter paper. The filtrate was diluted with distilled water to 100 mL ready for analysis.

The ground vegetable samples were sieved using 2 mm sieve. 0.25 g of finely ground samples were weighed using electronic analytical balance (AAA Model from Adam Equipment Company limited). The weighed samples were transferred to ashing tubes. The samples were ashed using Fisher Scientific Isotemp Programmable Muffle Furnace for four and half hours at 450°C and allowed to cool. The acid mixture of concentrated HCl and HNO_3 in the ratio 1:1 and 20% H_2O_2 were added. The mixture was heated gently on a hot mantle at 70°C until brown fumes disappeared and re - dissolved using 0.5 N of HCl, cocked in the specimen tube and was allowed to stand for at least 5 hours to re – extract. This was done in a fume chamber. The contents were transferred into a 50 mL volumetric flask and made up to the mark with deionized water. The calibration standards were run followed by the sample for quantification of the analyte of interest. The samples were aspirated to the instrument for analysis.

2.4 Statistical Analysis

The significance of differences between the concentrations of heavy metals in soil and vegetables were shown by using Student's t-test. The data of heavy metal concentrations in the plants at different sites were subjected to two way analysis of variance (ANOVA) test for

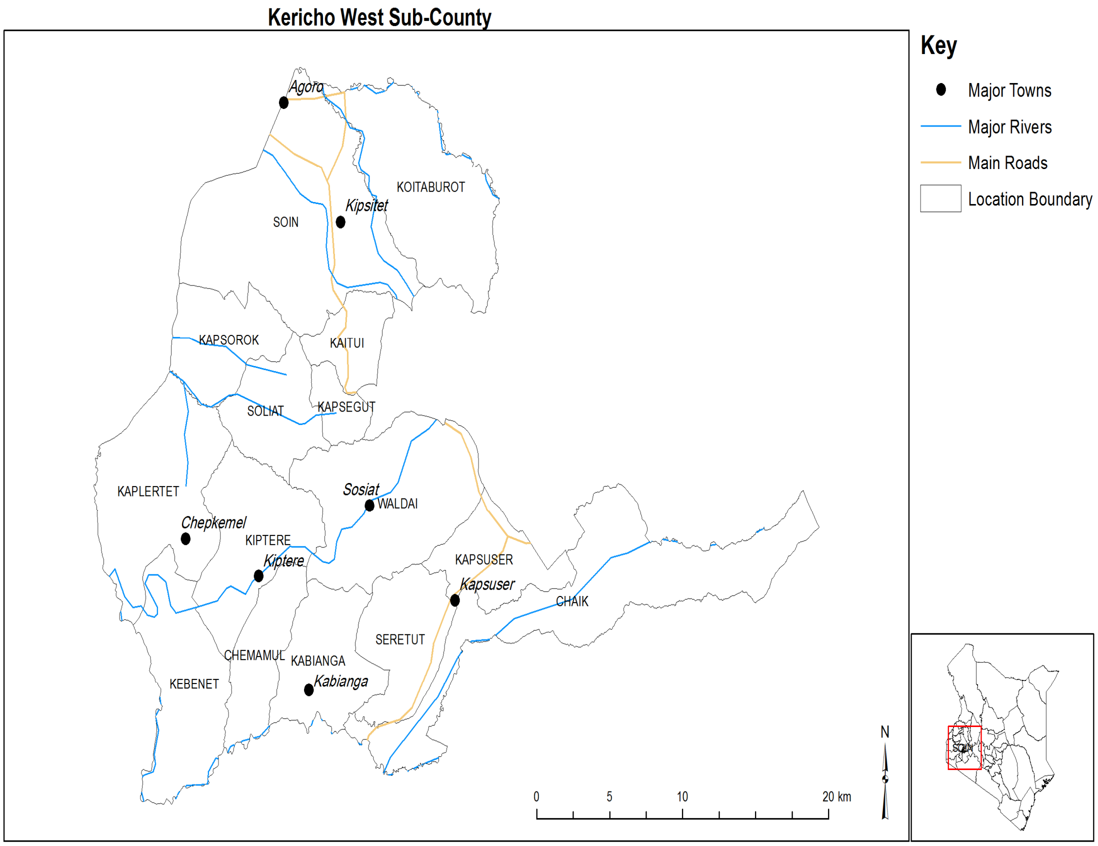

Fig. 1. Kericho West Sub-County

assessing the significance of differences in heavy metal concentrations due to different irrigation practices. All the statistical tests were performed using SPSS software (SPSS Ins., version 20).

Transfer factor (TF) was used to determine the mobility of Mn^{2+}, Fe^{3+}, Cu^{2+}, Cd^{2+}, and Pb^{2+} ions from the soil to the plant and calculated by dividing the concentration of heavy metals in the vegetables by the total heavy metal concentration in the soil.

$$TF = \frac{Metal\ Concentration\ of\ plant}{Metal\ concentration\ in\ the\ soil}, \quad (1)$$

The mean concentration of metals was calculated using the following formula;

$$\bar{x} = \frac{1}{n}\sum_{i=0}^{n} x_i \quad (2)$$

Where,

x_i = individual result
$\bar{x}$ = mean
n = total number of samples

3. RESULTS AND DISCUSSION

3.1 Levels of Heavy Metals in Soil

The mean concentrations of heavy metals in the soil collected from the production sites of Kericho West Sub-County are summarised in the Table 1.

Table 1. Concentrations of heavy metals (mg/kg) in the soil from the production sites

Area	Mn	Cu	Fe	Cd	Pb
Sosiot	199.7 ± 0.88	1.3±0.33	63.7 ± 2.19	5.3 ± 1.20	5.3 ± 0.33
Kabianga	172.3 ± 4.84	2.0 ± 0.58	79.7 ± 1.20	4.7 ± 0.33	5.0 ± 0.58
Kiptere	201.0 ± 2.52	3.3 ± 1.20	98.0 ± 1.53	3.7 ± 0.33	5.7 ± 0.88

It was observed that the concentration of Mn^{2+} ions varied from 172.3 ± 4.84 to 201.0± 2.52 mg/kg in all areas studied. The values are higher than the permissible levels in soils as indicated by EU and Indian standards. These results agreed with the reports from other researchers; in the study of Callistus et al. (2012) the concentration of Mn^{2+} ions in the soil ranges from 377.61 to 499.68 mg/kg which were also below the FAO/WHO (Codex Alimentarius Commission, 2001) permissible limits. The concentration of Cu^{2+} ions ranged from 1.3 ± 0.33 to 3.3 ± 1.20 mg/kg in all areas whose values are lower than the permissible limits in soils indicated by EU, FAO and Indian standards. These results can be compared with that reported by Callistus *et al*., (2012) which were also below the FAO/WHO (Codex Alimentarius Commission, 2001) permissible limits (4.95 to 7.66 mg/kg). The concentration Fe^{3+} ions varied from 63.67 ± 2.19 to 98.00 ± 1.53 mg/kg. The concentration of Cd^{2+} ions varied from 3.67 ± 0.33 to5.33 ± 1.20 mg/kg in all areas whose values are higher than the permissible levels set by EU, FAO and Indian standards. The concentration of Pb^{2+} ions ranged from 5.00 ± 0.58 to 5.67 ± 0.88 mg/kg and these concentrations are lower than permissible levels indicated by EU, FAO and Indian standards. Similar results within the range in soils were reported by Callistus et al. (2012) in which the Pb^{2+} ions levels were 5.15 to 14.01 mg/kg. Kiptere had the highest concentration of Mn^{2+}, Cu^{2+}, Fe^{3+} and Pb^{2+} with Cd^{2+} the lowest amongst other areas. Sosiot had the highest concentration of Cd^{2+} ions.

3.2 Levels of Heavy Metals in the Plants

Heavy metal concentrations in different parts of vegetable samples collected from Kericho West Sub-county showed different variations as shown below.

3.3 The Concentration of Manganese in Vegetables

The mean concentrations and range of manganese in the vegetables grown in the study sites are as shown in Table 2. From the results in Table 2, the mean concentration of Mn^{2+} ions ranges from 21.3 ± 1.33 mg/kg to 95.0 ± 2.89 mg/kg in the roots. In the stems, the mean concentrations of Mn^{2+} ions spread from 20.7 ± 0.67 mg/kg to 123.0 ± 3.51 mg/kg. In the leaves, the mean concentration of Mn^{2+} ions ranges from 122.0 ± 4.16 to 442.0 ± 14.05 mg/kg. The highest concentration of Mn^{2+} ions was found in *B. oleracea Acephala* leaves from Kabianga, *A. palmeri* leaves from Kabianga, whereas the lowest concentration was in *B. oleracea Acephala* roots from Kiptere.the concentration of Mn^{2+} ions was lower in the roots as compare the leaves. These results were the same as that obtained by Sharma et al. 2009, Sinha et al. 2006 and Anita et al. [8]. The variation in the conc. Of Mn^{2+} ions in the roots stem and leaves may be ascribed to be the variability in the absorption of Mn^{2+} ions in the plant and its further translocation within the plant (Vousta et al. 1996, Anita et al. [8]). The mean concentration of Mn^{2+} ions in all the vegetables were below the permissible levels (500.00 mg/kg) set by FAO/WHO (Codex Alimentarius Commission, 2001). The results also showed that all the vegetables had the highest concentration of Mn^{2+} ions in the leaves. This can be attributed to higher accumulation of Mn^{2+} ions in the leaves than in other parts of the vegetables.

3.4 The Concentration of Copper in Vegetables

The results for copper concentration in the vegetables are shown in Table 3.

Table 3, the mean concentration of Cu^{2+} ions in *Brassica oleracea, Amaranthus palmeri*, and *Brassica oleracea Acephala* at the three selected study sites. According to the results the concentration of copper in roots ranges from 5.3 ± 0.67 mg/kg to 26.33 ± 0.88 mg/kg. The *Amaranthus palmeri* roots from Kiptere had the highest concentration while *Brassica oleracea Acephala* roots from Kiptere had the lowest concentration. In the stems, the concentration of Cu^{2+} ions ranges from 11.0 ± 0.57 mg/kg to 28.00 ± 1.15 mg/kg. The *Amaranthus palmeri* stem from Sosiot had the highest concentration of Cu^{2+} ions while *Brassica oleracea Acephala* stem from Kiptere had the lowest concentration of Copper. In the leaves, the mean concentration ranges from 14.0 ±0.57 to 62.7 ± 1.67 mg/kg. *Amaranthus palmeri* leaves had the highest concentration of Cu^{2+} ions while *Brassica oleracea* leaves from Kabianga had the lowest concentration. The results were comparable with those obtained by R. Subramanian, S. Gayathri, C. Rathnavel, V. Raj (2012) in which they reported high of Cu^{2+} in the leaves. In all the vegetables the mean concentration of Cu^{2+} ions was the highest in the leaves as compared to other parts of the vegetables except for *Brassica oleraceas* leaves from Kabianga and Kiptere which had the highest in the stems. The concentrations of Cu^{2+} ions were within the permissible limits (73.3 mg/kg) set by FAO/WHO (Codex Alimentarius Commission, 2001).

3.5 The Concentration of Iron in Vegetables

Table 4 shows the mean concentration of Fe^{3+} ions in the selected vegetables from the three study sites. The concentration of Fe^{3+} ions in roots, stem and leaves varied between 109.0 ± 3.06 to 792.0 ± 22.72 mg/kg, 175 .0 ± 3.79 mg/kg to 708.7 ± 19.80 mg/kg, 370.33 ± 16.7 mg/kg to 2096.7 ± 63.3 mg/kg respectively. The concentration of Fe^{3+} ions in *Amaranthus palmeri* leaves from Kabianga was the highest. Generally, the concentration of Fe^{3+} ions in vegetables were above the permissible levels (425.50 mg/kg) set by FAO/WHO (Codex Alimentarius Commission, 2001). These results are comparable with that obtained by Mohammed et al. (2012) who reported high levels of Fe in *Amaranth* collected in farms which ranges between 348.9 to 1186.5 mg/kg.

3.6 The Concentration of Cadmium in the Vegetables

Table 5 shows the concentration of Cd^{2+} in the vegetables from the three study sites. From the results, the concentration of Cd^{2+} ions ranges from 0.9 ± 0.04 mg/kg to 71.7 ± 7.16 mg/kg. The order of concentration of Cd^{2+} ions in the vegetables was leaves > stem > roots. The results are comparable with those obtained by Mohammed et al. (2012) who reported high values of Cd^{2+} ions 41.5 ± 6.61 mg/kg in cabbages which were also above permissible levels. In this study, the concentration of Cd^{2+} ions was found to be above the permissible limits of 0.2 mg/kg set by FAO/WHO (2006) and thus might be a threat to the consumers. Reports have suggested that cadmium uptake by plants is determined by the total available cadmium concentration, soil pH and organic matter content [14]. These results on cadmium is also comparable with that reported by Iqrar et al. (2006) which found out that maximum Cd^{2+} ions concentration was found highest in spinach leaves.

3.7 The Concentration of Lead in the Vegetables

Table 6 shows the mean concentration of Pb^{2+} ions in the selected vegetables from the three study sites. The concentration of Pb^{2+} ions ranges from 13.0 ± 2.00 mg/kg to 52 ± 1.76 mg/kg in the roots, 12.3 ± 1.80 mg/kg to 49.3 ± 1.22 mg/kg in the stem and 45.3 ± 1.76 mg/kg to 71.7 ± 1.86 mg/kg in the leaves. All the samples vegetables had high concentration of Pb as compared to threshold limits (0.3 mg/kg) set by Codex Alimentarius Commission, 2001. This is an indication that none of the selected vegetable was safe for consumption because the concentration of Pb^{2+} ions were beyond the safe limits. In all the vegetables the concentration of Pb^{2+} was found to be high in the leaves which is an indication that there is an uptake of Pb^{2+} ions from the soil which can promoted by the pH and levels of organic matter [14]. Cadmium and lead were significantly different at p-value > 0.05.

3.8 Transfer Factors of Heavy Metals from Soils to Vegetables

Transfer factor is the ratio of concentration of heavy metals in plant to the concentration of heavy metals in the soil. It signifies the amount of heavy metals in the soil that ended up in the vegetable crop site [20]. Transfer factor was calculated to understand the extent of risk and associated hazard due to the ingestion consequent upon heavy metal accumulation in edible portion of vegetables. The transfer factor was calculated by dividing the concentration of heavy metals in vegetables by the total heavy metal concentration in the soil [19,21]. Table 7 shows the transfer factors of heavy metals in selected vegetables and regions of Kericho West Sub-County.

From the Table 7, manganese has the lowest transfer factor between 0.42 and 1.15. The highest Transfer factor was observed from copper ranging from 15.67 to 36.00 in all vegetables. In vegetables, Fe found to have highest concentrations. Manganese had the lowest transfer factor between 0.42 and 1.15. The highest ratios were observed from copper ranging from 15.67 to 36.00 in all vegetables. It is also evident that vegetables absorb heavy metals from the atmosphere and there is high mobility of metal ions from the soil to the plants. This is because leaves have the highest concentrations of heavy metals as compared to soils where the plants are grown and stem and roots of the respective plants. The concentrations of Lead and Cadmium from the soils are above the safe limits while for Manganese, Copper and Iron are below the safe limits. This shows that there is high mobility of copper from the

Table 2. The concentration of manganese in the vegetables

	Mean Concentration of Mn (mg/kg) n=3, ($\bar{x}$ ± S.E)								
	Kabianga			Sosiot			Kiptere		
	Roots	Stem	Leaves	Roots	Stem	Leaves	Roots	Stem	Leaves
B. oleracea	75.0±2.88	43.3±3.33	152.0±4.16	95.0±2.89	49.3±0.67	122.0±4.16	95.0±2.89	20.7±0.67	147.7±6.63
A. palmeri	39.0±1.00	69.0±1.00	238.3±6.01	74.7±2.91	58.0±2.00	186.7±6.67	37.7±2.33	64.3±2.96	171.0±4.93
B. o. Acephala	39.0±1.00	123.0±3.51	442.0±14.05	38.3±1.67	37.7±2.00	207.0±6.51	21.3±1.33	122.0±4.16	152.7±3.71

Permissible levels set by FAO/WHO (Codex Alimentarius Commission, 2001), (500 mg/kg) Source: Source: Mathenge (2013)

Table 3. The concentration of copper in the vegetables

	Mean concentration of copper (mg/kg, DWB) n= 3, ($\bar{x}$ ±S.E)								
	Kabianga			Sosiot			Kiptere		
	Roots	Stem	Leaves	Roots	Stem	Leaves	Roots	Stem	Leaves
B. oleracea	17.3±0.88	17.6±0.33	14.0±0.90	17.0±0.58	12.0±0.67	21.3±0.86	5.3±0.67	11.0±0.57	27.0±1.53
A. palmeri	13.0±0.60	24.0±1.54	29.7±1.21	19.3±0.91	28.0±1.15	62.7±1.67	26.3±0.88	27.0±1.54	35.7±4.91
B. oleracea Acephala	7.7±0.80	14.0±0.57	44.0±1.52	9.7±0.87	18.3±0.81	25.3±0.92	17.0±1.33	19.7±0.82	45.7±1.20
Conc. mg/kg		73.3			30.0			40.0	

Safe limit (mg/kg)

Source: FAO/WHO (Codex Alimentarius Commission, 2001)} Indian Standard; Awashthi WHO/FAO (2006)

Table 4. The concentration of iron in the vegetables

	Mean concentration of Iron (mg/kg, DWB) n= 3, ($\bar{x}$ ±S.E)								
	Kabianga			Sosiot			Kiptere		
	Roots	Stem	Leaves	Roots	Stem	Leaves	Roots	Stem	Leaves
B.oleracea	792.0 ±22.72	274.0 ±26.03	492.7 ±11.57	757.0 ± 21.66	267.0 ±20.03	625.3 ±17.42	109.0 ± 3.06	175.0 ± 3.79	691.7 ± 19.27
A. palmeri	564.3 ±15.38	384.7 ± 9.68	2096.7 ±63.33	388.7 ± 9.68	274.7 ± 6.33	1040.0 ± 30.55	408.0 ±10.50	708.6± 19.80	1416.7 ± 42.56
B. oleracea Acephala	614.0 ±17.09	609.3 ±16.90	800.3 ± 23.05	251.3 ± 15.43	357.7 ± 9.68	632.0 ± 17.56	269.7 ± 6.33	509.7 ± 13.68	370.3 ± 16.76

Permissible levels set by FAO/WHO (Codex Alimentarius Commission, 2001) (425.50 mg/kg)

Table 5. The concentration of cadmium in the vegetables

	Concentration of cadmium (mg/kg,) n= 3, ($\bar{x}$ ±S.E)								
	Kabianga			Sosiot			Kiptere		
	Roots	Stem	Leaves	Roots	Stem	Leaves	Roots	Stem	Leaves
B.oleracea	0.93 ± 0.04	0.98 ± 0.01	32.33 ± 2.96	2.01±0.01	30.33±2.96	51.67 ± 4.98	1.06±0.06	0.94± 0.06	15.33± 1.45
A.palmeri	7.33 ±0.88	27.00 ± 2.65	43.67 ± 4.41	12.00± 0.58	23.67±2.33	58.33 ± 5.61	5.00±0.58	27.00 ±2.65	71.67 ± 7.06
B. oleracea Acephala	1.01±0.01	8.33 ±0.88	55.00 ± 5.29	1.11 ±0.11	15.33±1.45	65.00± 6.25	1.08±0.08	32.33± 2.96	47.67 ± 4.41
Conc. mg/kg		0.1			1.5			0.2	

Safe limit (mg/kg)

Source: FAO/WHO (Codex Alimentarius Commission, 2001) Indian Standard; Awashthi(2000) WHO/FAO (2006)

Table 6. The concentration of lead in the vegetables

	Concentration of Pb (mg/kg) n=3, ($\bar{x}$ ±SE)								
	Kabianga			Sosiot			Kiptere		
	Roots	Stem	Leaves	Roots	Stem	Leaves	Roots	Stem	Leaves
B. oleracea	13.00± 2.00	19.33±1.86	46.33± 1.80	25.67±1.76	36.33±2.03	60.67±1.90	9.33±2.33	12.33±1.80	45.33±1.76
A. palmeri	39.00 ± 1.53	32.67± 1.76	61.33±1.67	35.33±2.08	44.00±1.73	61.33±1.76	41.33±2.08	49.33±1.22	63.67±1.86
B. oleracea Acephala	15.33± 2.87	41.67± 1.03	66.67±1.96	20.33±1.86	30.67±1.76	71.67±1.83	52.33±1.76	40.00±1.73	56.67±1.86
Conc. mg/kg		0.3			5.0			0.3	

Safe limit (mg/kg)

Source: FAO/WHO (Codex Alimentarius Commission, 2001) Indian Standard; Awashthi WHO/FA(2007)

Table 7. Transfer factors of heavy metals from soils to vegetables

Vegetable	Site	Manganese	Copper	Iron	Cadmium	Lead
	Kabianga	0.67	22.00	12.38	6.25	7.89
A. palmeri	Sosiot	0.51	36.00	8.88	9.67	8.94
	Kiptere	0.42	27.67	8.40	11.11	9.06
	Kabianga	1.15	21.67	8.25	5.08	7.39
B. oleracea Acephala	Sosiot	0.45	17.67	6.45	6.89	6.28
	Kiptere	0.47	23.67	4.05	8.56	6.44
	Kabianga	0.52	16.67	6.61	2.58	5.28
B. oleracea	Sosiot	0.43	15.67	8.41	9.00	7.33
	Kiptere	0.48	19.67	3.30	9.22	7.67

soil to the vegetables, keeping in view the concentrations of copper in the soil was registered the lowest. Metals with high TF are more easily transferred from soil to the edible parts of plants than ones with low TF [20]. The transfer factor of the heavy metals are as follows, Fe^{3+} ions ranges from 3.30 to 12.38, Pb^{2+} ions (6.28 to 9.06), Cd^{2+} ion (5.08 to 11.11), Mn^{2+} ions (0.42 to 1.15) in all the vegetables collected from the three study sites. In this study the transfer factors of heavy metals in all the vegetables is quite high. As the three vegetables are widely consumed in the three study sites, through these plants toxic elements can be transferred to the human body creating disruption in various biological systems. The higher value of transfer factor indicates that more elements would be accumulated by the vegetables. This can be comparable with the similar results obtained by Dinelli and Lombini (1996).

4. CONCLUSION

Soils from the study site contain heavy metals and the order of concentration from the selected areas from the highest was as follows; Mn (172.33-201.00 mg/kg) > Fe (63.67-98.00 > Pb (5.00-5.67 mg/kg) > Cd (3.67-5.33 mg/kg) > Cu (1.33-3.33 mg/kg). The mean concentrations of the heavy metals in vegetables, the mean concentration of manganese and copper are below the permissible limits while for Lead, Cadmium and Iron are above the permissible limits set by FAO/WHO except the mean concentrations of Iron in *Brassica oleracea Acephala* in vegetables collected from Sosiot. In vegetables collected from Kiptere, the mean concentrations of iron in *Brassica oleraceas* and *Brassica oleracea Acephala* are below the permissible limits but for *Amaranthus palmeri* are above. The mean concentrations of cadmium and lead are above the permissible limits. This shows that there is high mobility of copper from the soil to the vegetables, even though the concentrations of copper in the soil were registered the lowest. Soil-to-plant transfer is one of the key components of human exposure to metals through food chain. In this study, the transfer factors for Mn^{2+}, Fe^{3+}, Cu^{2+}, Cd^{2+} and Pb^{2+} and *Brassica oleracea*, *Amaranthus palmeri* and *Brassica oleracea Acephala* consumed in the area were calculated and the data showed that the transfer factor values differed significantly between locations and vegetable species. The difference in TF values between locations may be related to soil nutrient management and soil properties.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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