

HEAVY METAL (CU, ZN, CD AND PB) CONTAMINATION OF INDIGENOUS GREEN VEGETABLES IN ELDORET TOWN AND THEIR HEALTH IMPLICATIONS TO CONSUMERS

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Abstract

The crops that are grown and sold could be exposed to toxic substances due to wide spread contamination of water, air and soils by environmental pollutants. A single source of contamination can have serious effects on human health. This study assessed the levels of selected heavy metals; Lead (Pb), Cadmium (Cd), Copper (Cu), and Zinc (Zn) in indigenous green vegetables *Solanum nigrum*, *Cleome gynandra* and *Amaranthus blitum* sold in Eldoret municipality. Samples were collected from sampling stations, Eldoret municipal market, estates and supermarkets in polythene bags twice a month for three months. Analysis of heavy metals was determined in the laboratory using atomic absorption spectrophotometer (AAS-Varian 200 model). The Provisional Tolerable Daily Intake (PTDI) values were calculated to assess health risk implications. The results show high concentration levels of Pb and Cd in the indigenous vegetables in all the sampling sites. Concentrations of heavy metals in studied markets within Eldoret showed that, mean Zn concentration ranged from 0.16 $\mu\text{g}/\text{kg}$ at municipal market to 3.99 $\mu\text{g}/\text{kg}$ DW at Langas, mean Pb concentration ranged from of 0.00 $\mu\text{g}/\text{kg}$ DW at municipal market to 1.23 $\mu\text{g}/\text{kg}$ dw at supermarket. Copper ranged from 0.01 $\mu\text{g}/\text{kg}$ at Langas to 1.20 $\mu\text{g}/\text{kg}$ DW at Huruma while Cd ranged between 0.05 $\mu\text{g}/\text{kg}$ at supermarket to 1.70 $\mu\text{g}/\text{kg}$ DW at Huruma. A single washing of the samples showed decline of heavy metals concentrations up to 30%. The calculated Pb and Cd PTDI values for unwashed vegetables in the range of the FAO/WHO recommended values (214 μg and 60 μg respectively) indicating a potential health risk to consumers. The study concludes that atmospheric depositions can elevate the levels of heavy metals in vegetables during marketing having potential health hazards to consumers. Washing of vegetables with clean water was a very effective and easy way of decontaminating the metal pollution as it reduced the contamination levels. Consumption rates of the indigenous vegetables sold in Eldoret should fall within the recommended limits to minimize health risks.

Keywords: Heavy metals; Indigenous green vegetables; Health risk; Bio-accumulate; Bio-concentrate

Introduction

Food safety is major public concern worldwide. During the last decades, the increasing demand for food safety has stimulated research regarding the risk associated with consumption of food stuffs contaminated by pesticides, heavy metals and/or toxins (D'mello, 2003). With the increasing contamination of the environment by toxic substances, food has become a possible source of exposure of pollutants to humans.

The public health sector for many years has become concerned with the transfer of food contaminants through the food chain to human. The study

provides baseline information by assessing the levels of Cu, Pb, Cd and Zn in indigenous green vegetables which are largely consumed by human.

A heavy metal is a general term applying to the group of metals and metalloids with the atomic density greater than 5g/cm³. Although it is only a loosely defined term, it is widely recognized and usually applied to the elements such as Cd, Cr, Cu, Hg, Ni, Pb and Zn, which are commonly associated with pollution and toxic problems (Alloway & Ayres, 1997).

The continuous uptake of heavy metals could bio-concentrate and bio-magnify to toxic levels resulting in malfunction of certain organs of the body. With global heavy metal concentration increasing through



out the world due to various human and natural activities, ecosystems have been and are being contaminated with heavy metals (Beavington, 1975).

Copper enters the air, mainly through release during the combustion of fossil fuels (Lokeshwari & Chandrappa, 2006). Copper in air will remain there for a long period of time, before wet deposited by precipitation. Copper accumulates in plants and animals when found in soils at high concentrations.

Zinc is a very common substance that occurs naturally in air, water and soil. Many food stuffs contain certain concentrations of Zn. Some soils are heavily contaminated with Zn, particularly in areas where Zn is being mined or refined, or where sewage sludge from industrial areas has been used as fertilizer.

The content of heavy metals in vegetables may be increased by various contamination routes. Most of the Cd found in plants originates from the soil, while Pb contamination is usually air borne. A part of heavy metal precipitated on plants remains on the surfaces of leaves and can be easily removed by washing. However, a part of the precipitate migrates into the plant tissue through the pores and cannot be removed by washing (Gonzalez et al., 1986). Thus vegetables grown in polluted areas can take up considerably large amounts of heavy metals exceeding the tolerable limits.

Airborne heavy metals such as Pb can contaminate foodstuffs before and after harvesting and even during preparation at meal times at home (Jones & Stephen, 1983). Deposits of heavy metals in fruits and vegetables can be due to accumulation of dust on their surfaces. Vegetables which have a high area to mass ratio such as sukumawiki and spinach have been shown to contain elevated concentration of heavy metals (Thornton & Culbard, 1987). A study by Onyari et al. (1991) indicated that Pb concentration in soils within Nairobi city vary from 137-2196 mg/kg while that of industrial area ranged from 148-4088 mg/kg which is high compared with regions far from the city.

Indigenous vegetables include *A. blitum* commonly known as 'mchicha'. The African nightshades, *Solanum nigrum* (suja) is another common indigenous vegetable that is popular both in rural and urban centers (Chweya & Nameus, 1997). *Cleome gynandra* is also a common indigenous vegetable (Schippers, 2000).

Based on these nutrition values, indigenous

vegetables are usually recommended for the HIV/AIDS patients as part of the health care supplement program (Cheya & Mnzanva, 1997). Whether the heavy metal content of these vegetables is safe, is a concern that this study aimed at addressing. Prolonged human consumption of unsafe concentration of heavy metals in foodstuffs may lead to the disruption of numerous biological and biochemical processes in the human body (Gatubu, 1999).

There is tremendous variability in the ability of crops to take up heavy metal through their roots and transport them to the edible portions of the plant. This depends, not only on the type of heavy metal but also the crop species being grown and the prevailing soil and other growing conditions. For example, Pb is not readily taken up by many plants and even if it is taken up by plant roots; it is often not transported to this edible portion of the plant (Bahemuka & Mubofu, 1999). Heavy metals may accumulate preferentially in leaves, stalks, roots and less commonly in grains (Maina, 1984). Heavy metal contents of different vegetables types have been shown to follow the order leafy vegetable > root tubers > fruit vegetables (Feng et al., 1995).

Objectives of the Research

1. To determine Pb, Cd, Cu and Zn concentration levels in *Solanum nigrum*, *Cleome gynandra* and *Amaranthus blitum* sold in Eldoret municipality.
2. To assess impact of washing on the heavy metals concentrations in the vegetables.
3. Estimate potential health risks due to heavy metals in the indigenous vegetable samples from Eldoret municipality.

Study Area

The study was carried out in Eldoret municipality which is located in Uasin Gishu district of the Rift Valley province in Kenya. It is situated in the highlands of Rift Valley at latitude 00311N and longitude 350171E of the Greenwich (Figure 1), at an altitude of 2085 meters above sea level (Republic of Kenya, 1988). The municipality has rapidly grown and expanded both physically and in terms of population.

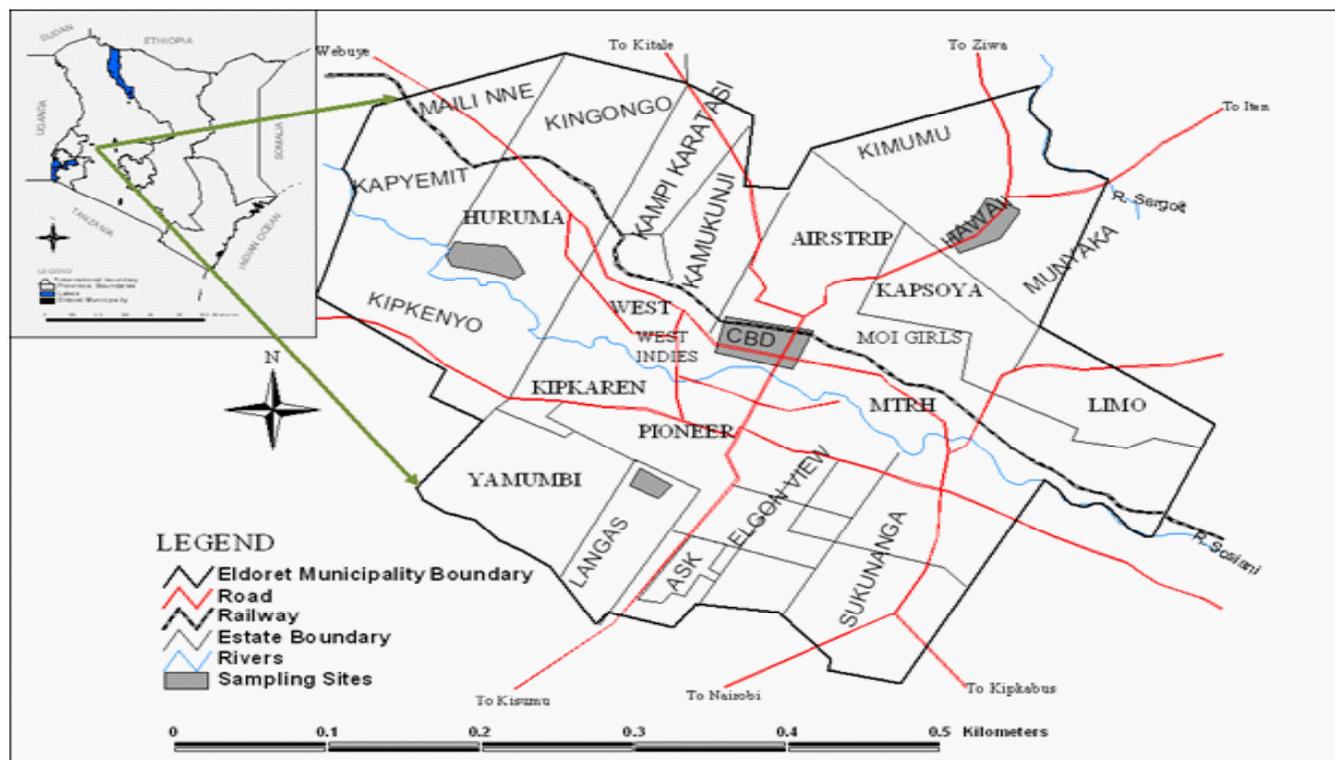


Figure 1. Map showing the location of Eldoret Town in Kenya Map and Eldoret Municipality

Housing Estates and the CBD Area.

Methodology

Materials consisted of glassware including pipettes, filter funnels, weighing bottles, measuring cylinders, volumetric flasks and conical flasks. All glassware was thoroughly washed with detergents and tap water and soaked overnight in 1:1 nitric acid solution rinsed several times with deionized water and left to dry overnight in the oven at 80°C.

Preliminary study involved a reconnaissance of the study area to identify sampling sites, vegetable suppliers and the vendors of the vegetables within the municipality. The number of sites that sell indigenous vegetables were identified, which included open municipal market, supermarkets, and residential estates.

Approximately 0.5kg of each vegetable samples were collected from each side in polythene bags and transported to the laboratory for preparation and analysis. Sampling was conducted bimonthly for three months beginning from January 2009 to March 2009.

The procedures used in the analysis of vegetable samples were adopted from analytical chemistry (Brodie, 1985). For each of the vegetable samples, a portion of the sample was oven dried unwashed while

the other portion washed before oven drying at 80°C for 48 hours before they were removed for grinding to a fine powder and sieved through plastic sieve of 60µm aperture. One gram of the fine sieved powder of each sample was accurately weighed into a conical flask. The powder was digested using a tri-acid mixture of 5ml of concentrated H₂SO₄, 2ml of concentrated HNO₃ and of 5ml of 30% H₂O₂. The mixture was heated on a hot plate at 100°C for two hours in a fume cupboard. The resulting solution was left to cool over night and filtered into 100ml conical flask and the filtrate was made to the mark using de-ionized distilled water. The filtrate was analyzed for concentrations of Pb, Cd, Zn, and Cu using Atomic Absorption spectrophotometer (AAS-Varian 200).

Data analysis was done using STATISTICA program (StatSoft 2001). Means and standard deviations were carried out using univariate analysis. The relationship among heavy metals in the vegetables was determined using correlation coefficients. Duncan's Multiple Range Test (DMRT) was used for post-hoc discrimination between the means that were different from each other. The differences were significant at 95% confidence level.

Results

Comparison of Mean Values of Heavy Metal Concentrations in Washed and Unwashed Vegetables

Heavy metal concentrations in all the washed vegetables were lower than in unwashed vegetables except Cd. ANOVA statistical analysis showed that the difference in heavy metals concentrations was significantly ($P < 0.05$) for all metals except for Cd which showed no significant differences. *C. gynandra* exhibited the highest mean concentration of Zn of $2.25\mu\text{g}/$

kg. in the unwashed samples while the lowest Zn mean concentration was in the washed *S. nigrum* with the mean concentration of $1.18\mu\text{g}/\text{kg}$.

Lead mean concentration was highest in unwashed *S nigrum* sample with concentration of $0.64\mu\text{g}/\text{kg}$ and lowest $0.35\mu\text{g}/\text{kg}$ in the washed *C. gynandra*. On the other hand the mean concentration of Cu was highest in the unwashed *S nigrum* with a concentration of $0.54\mu\text{g}/\text{kg}$ and lowest $0.13\mu\text{g}/\text{kg}$ in washed *A. blitum*.

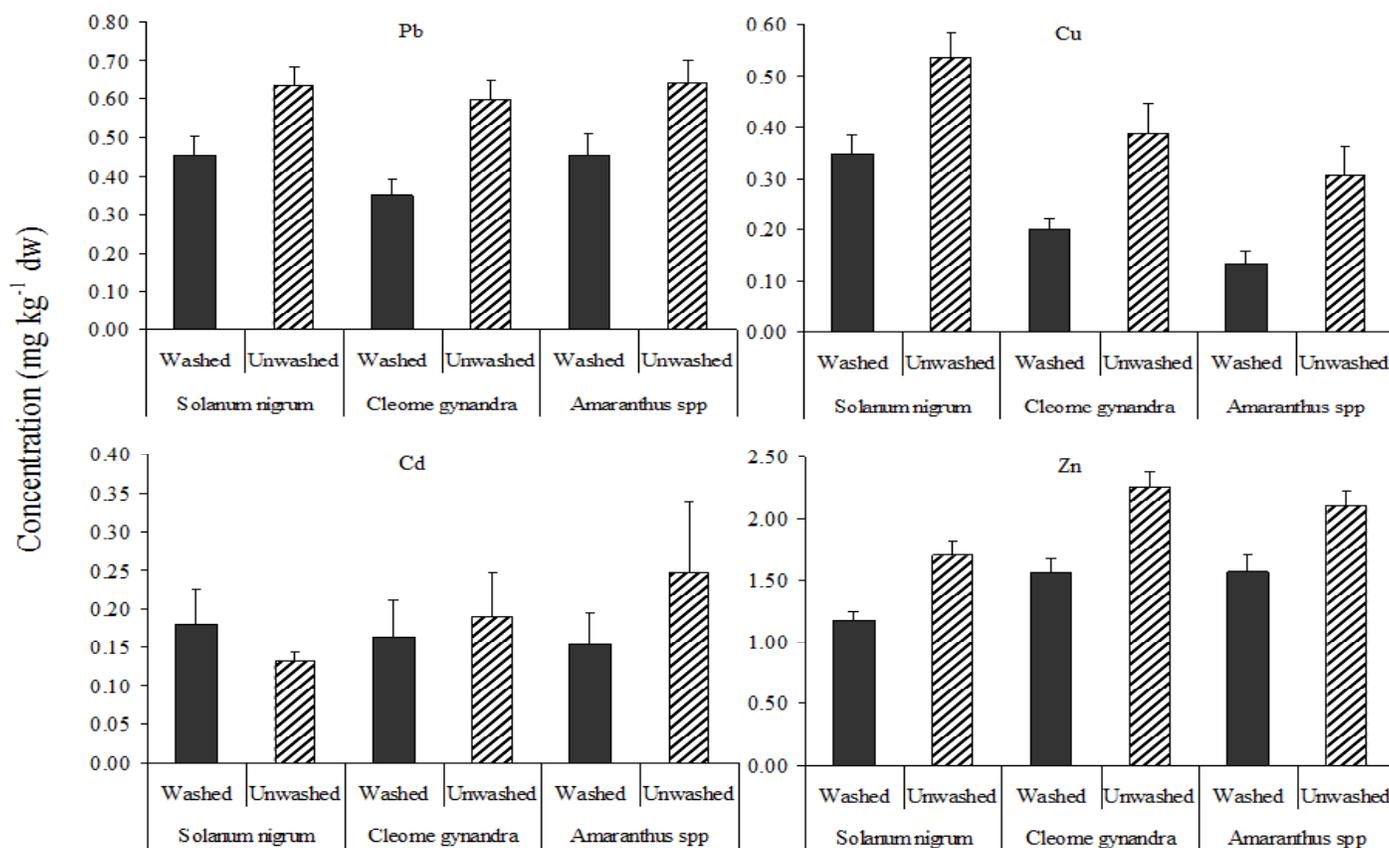


Figure 2. Heavy metal concentration in washed and unwashed indigenous vegetables

Mean Value of Heavy Metal Concentration in Studied Indigenous Vegetables

Since the unwashed vegetables had relatively elevated heavy metal concentrations, the worst scenario hazard of exposure to health risk was estimated. The calculated mean concentrations are shown in the table below. The mean values of the various vegetables were compared with the FAO/WHO (2001) recommended levels in food crops as shown in the table. Zinc and Cu

concentration were found to be below the maximum recommended levels. However Pb and Cd which are non essential and toxic exceeded the maximum recommended levels.

Mean concentrations of the heavy metals in the studied vegetables and maximum recommended concentration in food crops (FAO/WHO, 2001)

Vegetable species	Heavy metal concentrations in μg			
	Pb	Cu	Cd	Zn
<i>S. nigrum</i>	630	540	280	1710
<i>C. gynandra</i>	600	390	190	2250
<i>A. blitum</i>	640	310	250	2100
FAO/WHO (2001)	100	2000	30	3000

Estimated Potential Health Risk from Pb and Cd Due to Consumption of Indigenous Vegetables in Eldoret Municipality

Hazards of exposure to health risks of Pb and Cd were estimated using provisional tolerable daily intake (PTDI). The PTDI of Pb and Cd which had concentration mean above recommended FAO/WHO levels were calculated to estimate health risks to consumers for both the washed and unwashed vegetables.

The PTDI values were calculated based on the FAO/WHO (1999) estimates that a person consumes 218g of vegetables per day. The amount of heavy metals taken by a person per day was calculated according to the equation.

Amount of heavy metal taken by a person =

concentration of metal in vegetables ($\mu\text{g}/\text{kg}$) * Average consumption of vegetables per day (g).

The daily heavy metals intake for respective studied indigenous vegetables is summarized in the table below. The results were compared with the PTDI values provided by FAO/WHO (1999). In all studied vegetables the calculated PTDI of Pb and Cd are less than the WHO/FAO recommended values except for Cd concentration in *S. nigrum* where the calculated PTDI value was above the recommended value.

Calculated PTDI of Pb and Cd intake in consumed indigenous vegetables and maximum recommended PTDI in food crops (WHO/FAO, 1999)

Vegetable species		Treatment		Heavy metal concentrations in μg	
		Unwashed	Washed	Pb	Cd
<i>S. nigrum</i>	Unwashed	137.34	60.84		
	Washed	117.7	39.24		
<i>C. gynandra</i>	Unwashed	130.8	41.42		
	Washed	76.3	34.88		
<i>A. blitum</i>	Unwashed	139.52	54.5		
	Washed	117.7	32.7		
FAO/WHO (1999)		214	60		

Student's t-test analysis shows significant difference ($P < 0.05$) between calculated PTDI values in *S. nigrum*, *C. gynandra* and recommended FAO/WHO (1999) values. Similarly there was significant difference between Cd PTDI values in *A. blitum* and the FAO/WHO recommended values. On the other hand there were no significant differences between Pb PTDI values in *A. blitum* and FAO/WHO recommended values, and Cd PTDI values in *S. nigrum* and *C. gynandra* respectively. Cadmium concentration in *S. nigrum* was more than the recommended PTDI values.

Discussion

Concentrations of heavy metals in the studied indigenous vegetables from Eldoret municipality show that Zn concentrations have a lower concentration than the WHO recommended levels of 3 mg/kg. That there was no significant difference in Zn concentrations among the studied indigenous vegetables indicates that there was non preferential vegetable species accumulation of Zn in leafy parts.

Copper concentrations in the studied indigenous vegetables were below the FAO/WHO (2004) recommended safe limits of 2mg/kg. Samples of *S. nigrum* from Langas and Huruma had Cu concentrations that were elevated. This result agrees with the generally established trend whereby vegetation in the rift valley tends to exhibit Cu deficiency. For example a similar study carried out in selected vegetable in Tanzania (Radwa and Salama, 2006) showed that Cu concentration in all samples were lower than the permissible value for food (4mg/100g) recommended by FAO/WHO (2001).

About 80% of the samples contained Pb concentrations that exceeded the WHO recommended safe limits of 0.1mg/kg. This could be attributed to ubiquitous nature of Pb in the environment and also vegetable handling from farm, transportation and storage, the farming mechanism employed and the environmental conditions at market sites. Gatubu (1999) in his study on assessing heavy metals in vegetables and fruits consumed in Nakuru Municipality established that the sources of food determines the levels of heavy metals in it after realizing that food grown and sold near roads and urban centers had high levels of Pb. This also depends on the ability of the crops to take up heavy metals through their roots and transport them to the edible portion of the plant.

That is the green leafy kales had relatively higher Pb concentration compared to tomatoes hence an indicator in species variability in Pb accumulation in leaves.

All of the vegetable samples had a Cd concentration higher than the WHO recommended safe limits of 0.03mg/kg. These results agree with other similar studies for example, Gatubu (1999) reported high Cd in kales sold in Nakuru. This study shows that Cd concentrations in studied vegetables did not vary significantly among the species hence indicating that there was no species preferential accumulation of Cd in the leafy parts.

Health Implications to Consumers

As is evidenced the calculated PTDI for Pb in all studied vegetable were below the FAO/WHO (1999) recommended limits. That there was significant difference with PTDI Pb value in *S. nigrum* and *C. gynandra* indicates consumption of these vegetables within recommended daily intakes of 218g (FAO/WHO, 1999) does not pose health risk from Pb. However, there is need for caution especially with regard to *A. blitum*, with Pb value of 198.05 was not statistically different from the recommended limit.

Conclusion

Results of the study, have established that Cu and Zn concentrations in studied indigenous vegetable were below FAO/WHO (2001) recommended level while Pb and Cd concentrations in the studied indigenous vegetable were above the FAO/WHO (2001) recommended level. The study also established that the calculated PTDI values for Pb and Cd were below the FAO/WHO recommended levels. However, there is need for caution especially with regard to *A. blitum*, with Pb value of 198.05 was not statistically different from the recommended limit.

Recommendations

Based on the study findings, it is recommended that:

1. There is need for further studies to establish sources of Cd in indigenous vegetables sold in Eldoret municipality.
2. There is need for further studies to do metal speciation to establish sources of

- contamination to various vegetable types.
3. There is need for awareness so that farmers and consumers are made aware of the hazards associated with heavy metal contamination on food crops.
 4. Vegetable vendors should be sensitized on proper vegetable handling methods during transportation and storage to reduce post-harvest contamination.

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