



Heavy Metal Levels in *Amaranthus* Species from Chang'ombe-Mchicha Area in Temeke District, Dar es Salaam, Tanzania

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This study focuses on the concentration levels of copper, zinc, lead, iron and cobalt in *Amaranthus* species grown in a local garden located at Chang'ombe–Mchicha area in Temeke District in Dar es Salaam region, Tanzania. The garden is irrigated by wastewater from a stream flowing nearby and which passes through the industrial areas before reaching the garden. The heavy metal levels in the vegetables were determined using atomic absorption spectrophotometer (AAS). The findings revealed that the leaves have higher heavy metal concentrations than stems and roots. The average concentration for copper ranged from 1.14 to 1.70 mg/100 g dry weight, zinc 6.87 to 11.59 mg/100 g, iron 13.40 to 33.65 mg/100 g, lead 0.49 to 2.27 mg/100 g and cobalt 0.14 to 0.27 mg/100 g. These values were higher than the provisional maximum tolerable daily intake standards recommended by FAO/WHO codex committee on contaminants in foods. The high observed values put consumers of the vegetable grown in the study area at health risk over time unless urgent and right steps are to be taken by the responsible authority to address this issue. Thus, the findings are important to consumers and policy makers.

Keywords: Contaminant, Daily intake, FAO/WHO, Lead, Vegetables.

INTRODUCTION

Green leafy vegetables are important food for people and animals. They are popular around the world and they form part of daily diets in many of the households as they are vital source of vitamins, minerals, fibres and antioxidants required for human health [1]. Due to increased anthropogenic activities, especially the application of modern technologies, environmental pollution and contamination of food chain has become unavoidable [2]. Vegetables grown in polluted areas contain both essential and toxic elements over a wide range of concentrations that enter human body through dietary intake of contaminated food. The consumption of heavy metal-contaminated foods pose risk to human health [3-5]. Although heavy metals like Cu, Zn, Mn and Fe play a significant role in plant physiology, heavy metals such as Pb, Cd and Hg are exceptionally toxic and are recognized as dangerous environmental pollutants [6-8]. Thus, heavy metal contamination of food items is one of the most important aspects of food quality assurance [9-11]. Various studies have shown that some common vegetables including *Amaranthus* species are capable of accumulating high levels of metals from polluted irrigating water or soil [3,7,12,13]. Although green leafy vegetables occupy a very important place in human diet, unfortunately

constitute a group of foods which contributes maximally to heavy metal consumption [8,14]. Therefore, heavy metal contamination of vegetables cannot be underestimated as these food stuffs are significant components of daily human diet.

Rapid urbanization, unorganized urban and industrial developments have contributed to the elevated levels of heavy metals in most urban areas in developing countries [14-16]. Heavy metals are non-biodegradable and persistent environmental contaminants, which may be deposited on the surface of vegetables and then absorbed into the tissues [17,18]. The uptake of heavy metals in vegetables can be influenced by factors such as climate, land pollution, atmospheric deposition and nature or type of soil (which includes soil pH, organic matter content, clay mineral and other soil chemical and biochemical properties) on which the vegetables are grown [19,20]. The air pollution/atmospheric deposition may pose a threat to post harvest vegetables during transportation and marketing causing elevated levels of heavy metals in vegetables [17,21,22]. The soil-plant-root microbes' interactions play an important role in regulating heavy metal movement from soil to the edible parts of plant. Also, different agronomic practices such as use of fertilizer, water management and crop rotation system can affect bioavailability and accumulation of heavy metals in crops, which can influence the threshold for assessing dietary toxicity in food chain [4,5].

About 4 % (*i.e.* 650 ha) of the urban area of Dar es Salaam is used for vegetable farming. The farming is taking place in open spaces, majority being situated between settlements, along river valleys, near industrial areas, road reserves and along railway lines. Most of these open spaces are private (12 %), public (40 %), or institutionally (48 %) owned [15]. The urban agriculture is the most important source of supply for leafy vegetables like African spinach (*Amaranthus* spp), Chinese cabbage (*Bressica chinensis*), cowpea leaves (*Vigna unguiculata*), lettuce (*Lettuca sativa*), cassava leaves (*Manihot esculentum*) and pumpkin leaves (*Moschata cucurbita*) to the urban population [15,23,24]. Factors such as persistence of the peasant agriculture, political pressure to increase food production and the declining incomes of the urban workers as a result of declining value of the Tanzanian Shilling have contributed towards emergence and persistence of urban agriculture in Tanzania [23,25]. Also, the urban agriculture in Dar es Salaam has been reported to offer employment to over 4,000 people residing in the city who cannot secure well paid jobs due to lack of sufficient skills and it offers income and food security for farmers and their families [15].

The heavy metal contamination from wastewater irrigation is of serious concern due to its implications to human health [6,7,13,18]. Thus, the present study aimed at assessing the levels of copper, zinc, iron, lead and cobalt in the popularly consumed leafy green vegetable, the African spinach (*Amaranthus* species) commonly known as “Mchicha”, which is irrigated using wastewaters at Chang’ombe Mchicha area, Temeke District in Dar es Salaam. The African spinach is a vegetable that is present almost in everyday meal of most Tanzanians living in urban areas. Additionally, this study compares amount of fresh *Amaranthus* consumed per day with the provisional maximum tolerable daily intake and maximum level of food contaminant by WHO/FAO.

EXPERIMENTAL

The *Amaranthus* species were randomly collected from a vegetable garden located at Chang’ombe-Mchicha area, Temeke District in Dar es Salaam region. Collected samples were kept in pre-distilled water rinsed polythene bags and pinned up to avoid the excess deposition. Then the samples were brought to the laboratory for preparation. The roots, stems and leaves were separated and then washed with distilled water to remove dust and dirt or any air-borne pollutant. They were then placed on sheets of paper and left to drain dry at room temperature to remove excess moisture. Different parts of the sample were then sliced, weighed and oven dried at 80 °C for 72 h to a constant weight. The oven dried samples were powdered with a mortar and passed through a 2 mm size sieve. Then, the samples were kept at room temperature in clean, dry stoppered glass containers for further analysis.

Analytical procedure for heavy metal analysis: Destruction of organic matter for each sample was done by a dry ashing method (Perkin-Elmer 1982). A powdered sample (1 g each) with three replicates was transferred to an acid washed porcelain crucible and was placed in muffle furnace for 4 h at 500 °C. The crucibles were then removed from furnace and cooled. 10 mL of 6 M HCl was added to each crucible and then heated

on a steam bath for 15 min. Then 1 mL of HNO₃ was added and the composition was evaporated to dryness by continuous heating for 1 h to completely digest organic compounds. 5 mL of 6 M HCl followed by 10 mL of water was added and the mixture was re-heated on a steam bath to complete dissolution. Thereafter, the mixture was cooled down and filtered through a Whatman filter paper No. 41 into a 50 mL volumetric flask and the solution was made to the mark with deionized water. Then, the atomic absorption spectrophotometer (AAS) was used to determine the heavy metal concentration. Each sample was run twice to ensure repeatability of the obtained results. The same modus operandi was followed for each sample and appropriate dilution factors were used in the calculations.

Atomic absorption spectrophotometric analysis: Atomic absorption spectrophotometry (AAS) on a model Perkin-Elmer 2380 was used for the measurement of concentration of heavy metals in the digested sample at the Department of Chemistry, University of Dar-es-Salaam. For analytical quality assurance, the result of each metal was corrected by subtracting the value from the blank. A 10 cm long slot-burner head, a lamp and a standard air-acetylene flame were used. Other AAS used conditions were same as those explained by Welz and Sperling [26].

Average daily intake of heavy metals: According to Lukwanjo and Tanner [27] the average consumption of fresh green leafy vegetables per person per day in Tanzania is 108 g. Heavy metal concentration in leaves and stem were considered in calculating the average daily intake as both are edible parts of the plant. Thus, the daily average intake of heavy metals from *Amaranthus* species per person was calculated using the formula below:

$$ADI = A_{v\text{Consumption}} \times \% DW_{\text{Vegetable}} \times M_{\text{Heavy metal}}$$

whereby: ADI = Average daily intake of a metal by a person (mg); $A_{v\text{Consumption}}$ = Average daily consumption of vegetable per person (108 g); $\% DW_{\text{Vegetable}}$ = Percent dry weight of vegetable; $M_{\text{Heavy metal}}$ = Mean heavy metal content/g of dry vegetable (mg/g).

RESULTS AND DISCUSSION

The observed mean concentration of the studied heavy metals in *Amaranthus* species are summarized in Table-1. The heavy metal concentration levels determined were based on 100 g of dried sample of *Amaranthus* species. The observed heavy metal content ranged from 0.40 to 2.35 mg/100 g for Cu, 1.96 to 18.21 mg/100 g Zn, 3.71 to 40.99 mg/100 g Fe, 0.04 to 7.79 mg/100 g Pb and 0.14 to 0.27 mg/100 g for Co in the investigated parts. The iron concentration level was high than other heavy metals in the vegetable. The order of mean concentration levels in the species was Fe > Zn > Pb > Cu > Co. The general findings revealed the heavy metals content (mg/100 g) to increase polynomially in the order of roots < stems < leaves (Fig. 1). The observation concurs with the findings of Santamaria *et al.* [28] and Akan *et al.* [14]. The higher concentration levels in leaves may be attributed by the reason that leaves are entry point of heavy metals from air [29] and they are the last organ to receive whatever is absorbed by plant root from soil. For lead, roots had higher concentration levels followed by leaves and then stem. Cobalt was only

TABLE-1
HEAVY METAL LEVELS (mg/100 g) IN ROOTS, STEMS AND LEAVES OF *Amaranthus* SPECIES

Part of plant		Cu	Zn	Fe	Pb	Co
Root	Mean	1.14	6.87	13.40	2.27	0.14
	Range	(0.40-1.54)	(1.96-9.53)	(3.71-20.37)	(0.04-7.79)	(0.14-0.27)
Stem	Mean	1.17	7.26	14.01	0.49	BDL
	Range	(0.94-1.29)	(6.59-8.34)	(8.23-24.01)	(0.32-0.76)	
Leave	Mean	1.70	11.59	33.65	1.10	BDL
	Range	(1.35-2.35)	(8.48-18.21)	(28.58-40.99)	(0.95-1.23)	

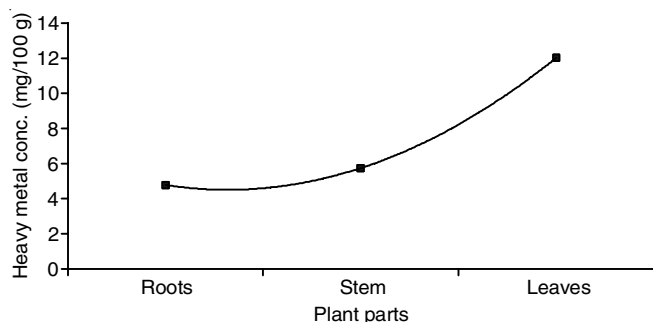


Fig. 1. Overall trend of heavy metals content (mg/100 g) in *Amaranthus* plant parts

detected in the roots of *Amaranthus* species. The variation in the heavy metal contents in the studied species is most likely due to absorption of the metals from the soil, which is influenced by factors such as soil pH, organic matter content, concentration of the metals in the soil and interaction of the other metals (*e.g.* selenium) in the growing area [5]. The form in which the metal is present in the soil may also affect the absorption capacity of the *Amaranthus*, hence causes differences in the content.

The observed mean copper concentration levels of 1.14 to 1.70 mg/100 g dry weight *Amaranthus* (Table-1) were higher than the maximum levels of copper as food contaminant of 0.5 mg/100 g food produce recommended by WHO/FAO. Copper is an essential trace element to human health as it maintains health of the central nervous system, proper functioning of metabolic processes, pigmentation and prevention of anaemia [30] but when its level exceeds the recommended safe limits it poses health hazards to human. Some of the health hazards associated with high copper levels in human include hypertension, sporadic fever, coma, anaemia, liver and kidney damage, as well as stomach and intestine irritation [31,32]. Moreover, people with the Wilson's disease are at greater risk for health effects from over exposure to copper [33]. Moreover, the observed average daily intake for copper exceeds the provisional maximum tolerable daily intake (PMTDI) of 0.05-0.5 mg/kg recommended by WHO/FAO. Hence, high levels of copper in the *Amaranthus* species from the studied area pose a significant health hazard to human consuming them.

The mean zinc concentration levels of 6.87 to 11.59 mg/100 g dry weight *Amaranthus* were higher than the maximum level of contaminant of 0.5 mg/100 g for food produce recommended by WHO/FAO. Zinc is an essential element for human healthy body as it plays role as an antioxidant, wound healer and co-factor for several enzymes in energy metabolism. Excess zinc can be harmful to human health as it suppresses copper and iron absorption, gastrointestinal irritation and may

cause interference with physiological processes. The clinical signs of zinc include vomiting, diarrhea, cramps, bloody urine, icterus (yellow mucus membrane), liver failure, kidney failure and anaemia [34]. The average daily intake for zinc (Table-2) exceeds provisional maximum tolerable daily intake (PMTDI) of 0.03 to 0.1 mg/100 g recommended by WHO/FAO. This signifies that the population consuming *Amaranthus* from the study area are subjected to health effects related to increased zinc in their body.

TABLE-2
AVERAGE DAILY INTAKE OF HEAVY METALS (mg)
FROM EATING 108 g *Amaranthus*

Part of plant	Cu	Zn	Fe	Pb
Stem	0.120	0.745	1.438	0.050
Leaves	0.174	1.189	3.453	0.113
Average	0.147	0.967	2.445	0.081

The observed iron concentration levels and its average daily intake in *Amaranthus* were higher than the PMTDI of 0.08 mg/100 g recommended by the WHO/FAO. The iron concentration levels were higher in leaves than other parts of the plant. In this study, the iron had much higher concentration than the rest of the heavy metals. The higher iron content could be due to iron-rich soil in the area. In human, acute toxicity of iron ingested from normal dietary sources has not been reported; the amount of iron absorbed in normal subjects is subjected to mucosal regulation so that excessive iron is not stored in the body. However, subjects with impaired ability to regulate iron absorption (*i.e.* suffering from idiopathic haemochromatosis), will be at risk from excessive exposure to iron. Excess iron intake may result in siderosis (deposition of iron in tissue) in liver, pancreas, adrenals, thyroid, pituitary and heart depending on the chemical form. Haemochromatosis patients suffer from liver cirrhosis, adrenal insufficiency, heart failure or diabetes. It is unknown whether excessive iron in the diet of individuals with impaired ability to regulate iron absorption will accelerate the clinical symptoms of the disease or increase the incidence of preclinical haemochromatosis.

Both the observed concentration levels of lead (Table-1) and the calculated average daily intake of lead were higher than the maximum level of contaminant for food produce and PMTDI of 0.03 mg/100 g dry weight of leafy vegetables recommended by WHO/FAO, respectively and are likely to be a health hazard to human consumers. The findings concurs with Othman (2001) who observed higher lead concentration levels in the vegetables of Tabata, Makongo, Buguruni and Sinza in the Dar es Salaam City, Tanzania. Plants do not readily absorb large amounts of lead and the amount they do absorb

depends on the species and variety of plants, the chemical composition of soil, the amount of lead in the soil and the soil temperature. However, lead is generally slow to move within the plant (from roots to leaves) and most of the Pb that does enter a plant accumulates in the fine roots and secondarily in the leaves. Therefore, this observation is evident from the present study where the concentration of Pb in roots (2.27 mg/100 g), leaves (1.1 mg/100 g) and stem (0.49 mg/100 g) confirms the order roots > leaves > stems (Table-1).

The possible source of lead to the area could be industrial effluents from the nearby industry and indiscriminate disposal of domestic and sewage to the stream untreated or partially treated. Sewage and industrial wastes are likely to find their way to the water course, which subsequently is used for irrigation in the studied vegetable garden. Also, high lead concentration in the *Amaranthus* may be attributed by heavy traffic passing near the garden. In human, lead can result into a wide range of biological effects depending upon the level and duration of exposure. Some effects that have been observed include haematological effects, neurological and behavioural effects, renal effects, cardiovascular and reproductive effects. Moreover, lead has shown to have effects on the bones and immune systems. Children are reported to be more vulnerable to the effects of lead than adults.

The mean concentration of cobalt of 0.14 mg/100 g was found only in the roots of *Amaranthus* while no trace of this metal was obtained in stems and leaves (Table-1). The safety limit for human consumption of cobalt is 0.05 to 1 mg/day [35]. Usually, the concentration of cobalt in different plant parts follow the order, root > stem > leaves [36] due to the transfer and translocation factor. The translocation factor nearer to zero indicate increased retention of metals in plant roots with very less movement to above soil plant parts as seen in red *Amaranthus* [37]. Therefore, in the present study, the observed cobalt concentration (Table-1) could have influenced by translocation factor of *Amaranthus sp.* Absence of cobalt in edible parts increase risk of its deficiency outcomes in the human health, especially to the consumers [31].

Generally, the study findings reveal that the concentration levels of the studied heavy metals are higher than the tolerable daily intake recommended by the WHO/FAO. This means that, the consumers of the vegetables grown in the studied area are exposed to health risk of heavy metals. The degree of toxicity of heavy metals to human depends on the daily intake over time. Though Fe, Cu and Zn are recognized to be very useful elements in human health, their presence in vegetables above PMTDI pose threats too as we know that anything in excess is harmful. The sources of heavy metals to the study area could be effluents from the nearby industries, heavy traffic that pass close to the garden and domestic effluents. Moreover, the study has shown that the heavy metal concentration levels are higher in leaves than stems and roots. It also tells us that consumers of *Amaranthus* species grown within the study area are at high health risk with time unless urgent steps are to be taken by the relevant authorities in addressing this issue. Thus, this information is very useful to both consumers and policy makers.

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