International Journal of Advanced Multidisciplinary Research
ISSN: 2393-8870
www.ijarm.com
(A Peer Reviewed, Referred, Indexed and Open Access Journal)
DOI: 10.22192/ijamr Volume 12, Issue 6 -2025

Research Article

DOI: http://dx.doi.org/10.22192/ijamr.2025.12.06.005

Toxic Heavy Metals Accumulated In Green Leafy Vegetables Cultivated Around Uranium Project Site In Bahi Wetland, Dodoma, Tanzania

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Keywords

uranium mine, heavy metal pollution, health risk assessment, Daily Intake, Health Risk Index.

Abstract

This study determined concentrations of heavy metals (Pb, Cu, Zn, Cr and Fe) in soil and vegetables (Ipomoea sp, Brassica L, Amaranthus sp, Cucurbita sp, and Spinacia sp) from Uranium exploration site at Bahi District, Dododma Region central Tanzania, using Atomic Absorption Spectrophotometry (AAS). The heavy metal concentrations in the soil decreased in the sequence Fe > Pb > Cu > Zn> Cr with highest concentration of Fe detected at Chipanga (B) village 811.64 ± 16.43 mg/kg and Lead (Pb) highest concentration detected 51.24 ± 2.48 mg/kg at Chimendeli village. The bioaccumulation factor was increased in the order of Cr < Pb < Fe < Cu < Zn. This is a clear indication that the bioaccumulation factors of Cu and Zn in vegetable samples were higher compared with other metals. The mean daily intake for Pb was higher than the RDI for adult's person. This has lead to high health risk index (HRI) for adult's ranges from 1.0571 to 2.0286 in Brassica L. sp and Cucurbita sp respectively. This may pose future health risks such as cancer. Based on the findings of this study, vegetable intake is just a small proportion of food consumed, complementary food that may include fish, meat, rice, beans and maize that are consumed in the study area need to be studies because they can also contribute and/increase amounts of heavy metals hence more health risks to the consumers.

Introduction

Uranium mining brings significant economic and social benefits to society but, at the same time, brings inevitable pollution to the surrounding natural environment (Galhardi, *et al.,* 2020). With the rapid development of nuclear technology, uranium mining, and smelting activities have increased. Uranium mining often releases used large volumes of groundwater into nearby rivers and lakes. This water often contains high levels of uranium and other dissolved chemical species that can be detrimental to the wider environment to compromise human health. Uranium, which is radioactive and chemically toxic, is one of the most critical pollutants from uranium mining and it is accompanied by heavy metal pollution, such as Cd, Cu, Pb, Mn and Zn, which are often reflected in the soil, sediment and water medium (Carvalho, *et al.,* 2022). Studies show strong positive correlations between the amount of radionuclides and heavy metals in the soil (WHO, 1992; Mohammed and Haule, 2018).

With global socioeconomic development, heavy metal pollution has gradually become a key factor that threatens the soil ecological environment and endangers human health (Ghanavati, *et al.,* 2019). Both natural processes and anthropogenic activities are the main sources of surface and groundwater contaminations by heavy metals (Horai *et al.,* 2022). Regardless of origin, increase of toxic heavy metal concentration in water and soil and hence to green leafy vegetables is becoming a serious threat to human health and aquatic ecosystems and human via the food chain (Naveedullah, *et al.,* 2014).

The increased mining activities in developing nations like Tanzania water and soil and hence food web contamination by heavy metal is likely to increase rapidly beyond these tolerance limits if best practices in mineral extraction and processing are not in place (IAEA 2010). Green leafy vegetables demand and consumption is remarkably growing in every parts of the globe as it institutes a vital part of the human diet and nutrition (Sachdeva *et al.,* 2013, Shaheen *et al.,* 2016). However, it has been documented that most of the vegetables commercially available, especially in developing nations, are often grown in urban and suburban areas of big cities (Sangster *et al.,* 2012). As a result, these vegetable are exposed to anthropogenic pollution instigated from sources including but not limited to urban and industrial wastes, mining and smelting and metallurgical industries (Kachenko and Singh, 2006). This evidently signifies that problems related to food safety and associated potential danger to the public has been a major apprehension all over the world (Mekonnen *et al.,* 2014).

Viable uranium deposits have been discovered in Bahi wetlands in Bahi District, Dodoma Region. The uranium deposit is reported to be shallow causing the radioactivity levels in the surface soil to be high (Mbogoro and Mwakipesile, 2010). Hence, this study was intended to evaluate heavy metal concentrations in green leafy vegetables commonly consumed at Bahi wetland area from central Tanzania. In addition, the probable health hazard related with the consumption of these vegetables have also been appraised through the determination of Bioaccumulation Factor (BAF), Estimated Daily Intake (EDI) for children and adults, Hazard Quotient (HQ) for children and adults, Hazard Index (HI) for selected heavy metals.

Materials and Methods

Study Area

This study was conducted at Bahi wetland located within the Bahi depression, a down warped section of the Eastern Rift Valley, between latitudes 05°51' and 06°20'S and longitudes 34°59' and 35°21'E, the wetland has a surface area of approximately 974 km^2 (Figure 1). The climate condition of the area, is semi-arid tropical condition with rainfall averaged from 500 mm to 700 mm commencing between November to April yearly and the temperature of the area ranges from 18ºC to 31ºC.

Bahi swamp area being seasonal plays a vital role in the lives of people in adjacent villages by creating an enabling environment to achieve food security during periods of food insecurity caused by weather/climatic variability. Household food security is enhanced through crop production and fishing being done in the swamp. The main economic activities from the study area include vegetable and crop cultivation, fishing, livestock grazing, salt harvesting and collection of thatching grasses.

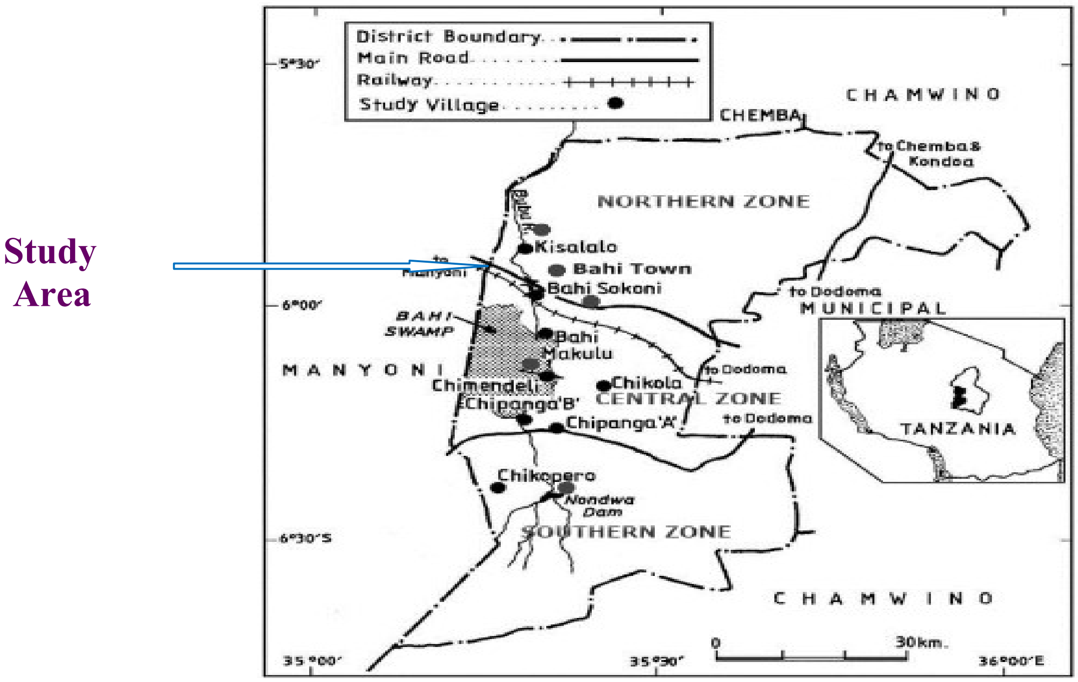

Figure 1: Map of District Showing Sampling Sites

Sampling of Green leafy Vegetables

Three sampling villages around Bahi wetland were identified (Chipanga, Chimendeli and Makulu villages). Triplicate samples of five GLV (1 kg each) of green leaf vegetable from five different types of vegetables namely *Ipomoea sp, Brassica L, Amaranthus sp, Cucurbita sp, and Spinacia sp* were collected. The collected samples were wrapped in aluminium foils and stored in polythene bags according to their type and brought to Geological Survey of Tanzania Laboratory for preparation and analysis. Each sample had their stalks removed, rinsed with de-ionized water and the residual moisture evaporated at room temperature before sun-drying for 2 -3 days on a clean paper with constant turning over to avert fungal growth.

Sample portions were dried in a drying oven, at 105°C, until constant weight was obtained then cooled to ambient temperature, crushed by means of a clean pestle and mortar to obtain homogenized samples. About 2.0 g of each of the processed samples was weighed and subjected to dry aching in a well-cleaned porcelain crucible at 550 ºC in a muffle furnace. The resultant ash was dissolved in 5.0 mL of $HNO_3/HCl/H_2O$ (1:2:3) and heated gently on a hot plate until brown fumes disappeared. To the remaining material in each crucible, 5.0 mL of de-ionized water was added and heated until a colourless solution was obtained. The mineral solution in each crucible was transferred into a 100.0 mL volumetric flask by filtration through Whatman No.42 filter paper and the volume was made to the mark with de-ionized water. This prepared solution was used for elemental analysis AAS.

Sampling and Preparation of Soil Samples

Soil samples were collected at the garden where the GLV were collected. The sample were taken at depth of about 15cm using hand auger, stored in polyethylene bags and oven dried at 60°C for 2 days, followed by grinding with mortar and pestle and sieved using a 2 mm sieve. About 1.0 g of the oven dried ground sample was weighed into a 250 mL beaker which has been previously washed with nitric acid and distilled water. The mixture of 5 mL of HNO_3, 15 mL of concentrated H_2SO_4 and 0.3 mL of $HClO_4$ were added to the sample using pipette.

The mixture was digested in a fume cupboard, heating continued until a dense white fume appeared which was then digested for 15 minutes, set aside to cool and diluted with distilled water. The mixture was filtered through acid washed Whatman No.44 filter paper into a 50 mL volumetric flask and diluted to mark material in each crucible; 5.0 mL of de-ionized water was added and heated until a colorless solution was obtained. The mineral solution in each crucible was transferred into a 100.0 mL volumetric flask by filtration through Whatman No.42 filter paper and the volume was made to the mark with de-ionized water. This prepared solution was used for elemental analysis AAS. Table 1 indicates the AAS conditions for heavy metals analyzed by Perkin-Elmer, 1996.

Table 1: Standard Atomic Absorption Condition for Elemental Analysis

Element	Wavelength (nm)	Spectra width (nm)	Std solution range (mg/L)	Flame
Fe	248.3	0.2	0.22, 0.34, 0.78	Air-Acetylene
Cu	324.7	0.7	0.14, 0.43,0.85	Nitrous oxide-acetylene
Pb	283.3	0.7	0.24, 0.43, 0.83	Nitrous oxide-acetylene
Zn	213.9	0.7	0.11, 0.27, 0.57	Nitrous oxide-acetylene
Cr	357.9	0.2	0.06 to 15	Air - Acetylene

Human Health Risk Assessment

Risk assessment is function of hazard which defined as the process of estimating the probability of occurrence of an event and the probable magnitude of adverse health effects on human exposures to environmental hazards over a specified time period (WHO, 2008). The risk assessment includes hazard identification, exposure assessment, dose response of the toxicity and risk characterization (Adamu, *et al.,* 2015) and it is expressed in carcinogenic or a non-carcinogenic health risk such as slope factor represent carcinogen risk characterization and reference dose (RfD) for non-carcinogen characterization (Lee, *et al.,* 2005).

Bioaccumulation Factors (BAFs) of Heavy Metals in Vegetable

Bioaccumulation factors (BAFs), defined as the ratio of the metal concentrations in the edible parts of the vegetable to the metal concentrations in the soil as indicated in equation 1.

$$BAF = \frac{C_{veg}}{C_{Soil}} \quad (1)$$

Where: BAF = Bioaccumulation factor; C_{veg} = Detected concentration of heavy metal in vegetable; C_{soil} = Detected concentration in soil

The BAF can be used to estimate the ability of vegetables to accumulate metals in their edible parts. Significant differences were found in the BAFs of heavy metals in the edible parts of the vegetable.

Estimation of Daily Intake Rate (DIR)

The Daily Intake Rate (DIR) is the average metal content in each vegetable was calculated and multiplied by the respective consumption rate. The DIR was determined by the following equation (2) (Sajjad *et al.,* 2009; Arora *et al.*, 2008):

$$DMI = \frac{C_{veg}(mg/kg) x C_f x M_{\text{int}}(kg/day)}{BM(kg)} \tag{2}$$

Where, C_{veg} = Heavy metal concentration in vegetables (mg/kg); C_f = Conversion factor (0.085); M_{int} = Heavy metal Daily Intake of Vegetable (kg $person^{-1}day^{-1}$). The conversion factor of 0.085 is set to convert fresh vegetable weight to dry weight based on calculation in literatures (Rattan *et al.,* 2005; USDA 2007).

For daily vegetable consumption was obtained through a formal survey conducted in the Bahi district in three villages (Chipanga B, Chinendeli and Makulu). An interview of 160 adults were having 50-77 kg body weight (average 63 kg) was conducted about their daily consumption rate of vegetables investigated. An average consumption rate of each vegetable per person per day was calculated. The average daily intake was set to be 0.150 kg/person/day (Child) and 0.346 kg/person/day (Adult) (expressed as fresh weight). According to WHO (1989) guidelines, the required amount of vegetables in our daily diet must be 0.300 to 0.350 Kg per adult person.

Non-Carcinogenic Risk Assessment

Hazard quotient is ratio of the potential exposure to a substance and the level at which no adverse effects are expected (calculated as the exposure divided by the appropriate chronic or acute value) (equation 3) (Custodio, *et al.,* 2020).

$$HQ_{ing} = \frac{D_{ing}}{RfD_{ing}} \quad \text{B} \tag{3}$$

Where HQ_{ing} is the hazard quotient of the single element for ingested, D_{ing} is daily intake ingestion and R_fD are standard values for ingestion (Custodio, *et al.,* 2020). A value of HQ ≤ 1 indicates that adverse health effects are unlikely.

Hazard Index (HI) is sum of hazard quotients for toxic elements that affect the same target organ or organ system. Because different elements can cause similar adverse health effects, combining hazard quotients from different toxic substances is often appropriate (Taghizadeh *et al.,* 2017).

While Hazard Quotient (HQ) is used for assessing the health risks due to any single contaminant, Hazard Index (HI) is used to evaluate the potential health risks when a person is exposed to multiple contaminants at the same time. This is mainly because exposure to more than one contaminant has additive effects. Therefore, HI can be an effective tool to understand the potential health risks that are associated with human exposure to multiple contaminants simultaneously. Same as hazard quotient, an HI value of greater than 1 signifies potential health risks.

The HI is the sum of the hazard quotients for each pollutant, as shown in the following equation (4) (Kacholi and Sahu, 2018).

$$HI = \sum_{i=1}^{n} HQ_{ing} = HQ_{Pb} + HQ_{Zn} + HQ_{Cu} + HQ_{Fe} + HQ_{Cr} \tag{4}$$

Where HI_{ing} is the hazard index for ingestion, n is the total number of chemical elements considered. If HI < 1, the non-carcinogenic adverse effect due to a particular route of exposure or chemical is assumed to be insignificant. When HQ > 1, reveals probable adverse health effects, when HQ > 10 indicates high chronic risk. The general potential for non-carcinogenic effects has been assessed by integrating the HQs calculated for each element and expressed as a hazard index.

Dietary Survey

Due to the geographical habits between different regions, dietary preferences, physical conditions and other differences, it is not appropriate to use the national or international exposure parameters directly. Thus, the questionnaire on the exposure parameters of the Bahi area was designed, which mainly covered the problems related to the calculation of dietary route exposure, including gender, age, height, weight and other individual characteristics and vegetable types, consumption weight, frequency, time and other dietary exposure parameters.

The investigation area was concentrated in Chipanga B, Chimendeli and Makulu Villages, which were randomly selected from the study area. A serial of interviews with local residents of these three villages was conducted in December 2022. A total of 200 questionnaires were issued and 198 valid 99% returned questionnaires were obtained. After data input, SPSS software Version 20 & Microsoft Excel 2010 software were used for statistical analysis.

Quality Assurance

Strict quality assurance/quality control measures were taken to ensure reliability of the study results. All reagents and chemicals used were of good and high purity. Thoroughly glassware was cleaned with detergent and rinsed several times using de-ionized water before use. For quantification and detection limits of the Atomic Absorption Spectrophotometer purposes, a blank solution was read twenty five times, and the standard deviations were considered for the noise generation levels for each of the heavy metals.

The reproducibility and accuracy of the analytical procedure was done by spiking and homogenizing three replicates of each of three samples selected. The triplicate of each sample was spiked with three diverse concentrations of the metal of interest and preserved in a manner similar as the samples as per literature (Scott and Nancy, 2000). The absorbance measured by the atomic absorption spectrophotometer was converted to concentrations using standard calibration curves. A 1000 mg/l single element standard of the metals of interest, found from Fluka Analytical (Sigma Aldrich Chemie GmbH, Switzerland), was diluted using 10% HNO_3 and used to generate the calibration curves for the atomic absorption spectrophotometer analysis. After each batch of five samples, the control sample was analyzed to check the accuracy of the analysis. Recovery rates for each element were in acceptable ranges (85.7–115%). Accepted recovery ranged from 80 to 120%.

Results

Levels of Heavy Metals in the Garden Soils

The mean concentrations of the five heavy metals (Cu, Pb, Zn, Cr and Fe), in the soil samples within farm lands where the green leafy vegetable is grown is presented in Table 2. The highest concentration of Fe was detected at Chipanga (B) village 785.08±16.43 mg/kg while the lowest was 459.64±13.54 detected at Chimendeli village

Table 2 Mean Heavy Metal Concentrations (mg/kg) in the Garden Soil

Sampling garden soil	Cu	Pb	Zn	Fe	Cr
Chipanga B. Village	4.23 ± 0.21	17.67 ± 0.35	1.67 ± 0.22	811.64 ± 16.43	ND
Chimendeli village	1.46 ± 0.32	27.66 ± 2.48	2.96 ± 0.43	459.64 ± 13.54	ND
Makulu Village	2.89 ± 0.58	16.78 ± 0.76	3.84 ± 0.36	594.83 ± 23.44	ND
FAO/WHO (2002)	100	50	300	150	50

Concentration of heavy Metals in Different Types of Green Leafy Vegetables

Heavy metal concentrations in green leafy vegetable samples collected from Bahi wetland area farmlands were examined and the data obtained is presented in Table 3. From the data obtained, it revealed that all the investigated vegetable samples tested positive to the heavy metals measured

Table 3 Mean Concentration of heavy metals in selected green leafy vegetables (mg/kg)

Vegetables	Site	Cr	Cu	Pb	Zn	Fe
Amaranthus sp	Chipanga(B) Village	ND	21.23± 22.39	11.39±8.46	70.09±1.13	785.08±37.56
Ipomoea sp	Chipanga(B) Village	ND	27.55±8.74	13.18±0.2	55.49±1.27	1,001.77±123.58
Spinacia sp	Chimendeli	ND	2.79 ±3.28	11.98±6.54	22.87±2.78	328.42±58.11
Brassica L. sp	Chimendeli Village	ND	12.09±8.31	9.46 ±0.23	49.26 ±2.72	1.246.47±426.65
Cucurbita sp	Makulu Village	ND	13.17± 10.41	17.95±0.10	51.52 ±6.23	608.25±12.95
FAO/WHO, (2007)		2.3	40	0.3	60	450

Bioaccumulation Factor (BAF)

The transferability of heavy metals from soil to the plant species this study considered vegetables commonly consumed in study area and data for Bioconcentration factor (BFC) of the heavy metals analyzed has been given in Table 4.

Table 4 Bioaccumulation factor (BAF) of Heavy Metals Analyzed for Vegetable Samples

Vegetable	Cu	Pb	Zn	Fe	Cr
Amaranthus sp	5.0189	0.6446	41.9701	0.9673	ND
Ipomoea sp	6.5130	0.7459	33.2275	1.2343	ND
Spinacia sp	1.9110	0.4331	7.7264	0.7145	ND
Brassica L. sp	8.2808	0.3420	16.6419	2.7118	ND
Cucurbita sp	4.5571	1.0691	13.4167	1.0226	ND

Health Risk Assessment

To assess human the health risk of the inhabitants of Bahi and the environs due to heavy metal intake from vegetables consumption, the daily intake of metals (DIM), health risk index (HQ), and target hazard quotient (THQ) were calculated from equations 1, 2, and 3 respectively and the results are presented in Tables 5 and 6.

Estimation of Daily Intake Rate (DIR)

The DIR of heavy metals was calculated according to the concentration of each metal in the vegetable samples (eq 1). The mean DIR values for adults and children were compared with recommended daily intake (RDI) of the studied metals via dietary intake of the leafy vegetables are represented in Table 5.

Table 5Mean Daily Intake (DIR) for the Analyzed GLV

Vegetable type		Cu	Pb	Zn	Fe	Cr
Amaranthus sp	Adults	0.0099	0.0053	0.0327	0.3665	ND
	Child	0.2286	0.1227	0.7549	8.4553	ND
Ipomoea sp	Adults	0.0129	0.0062	0.0259	0.4676	ND
	Child	0.2968	0.1419	0.5976	10.7891	ND
Spinacia sp	Adults	0.0013	0.0056	0.0107	0.1533	ND
	Child	0.0301	0.1290	0.2463	3.5371	ND
Brassica L. sp	Adults	0.0013	0.0044	0.0230	0.5819	ND
	Child	0.0301	0.1019	0.5305	13.4245	ND
Cucurbita sp	Adults	0.0061	0.0084	0.0241	0.2839	ND
	Child	0.1418	0.1933	0.5549	6.5509	ND
RDI mg/kg	Adults	0.90	0.0036	13.0	19.0	2.3
	Child	10.00	0.008	10.1	16.0	

RDI =Recommended daily intake (RDI) (FDA, 2001; Horiguch, 1978, WHO, 1993)

Estimation of Hazardous Quotient (HQ) and Hazard Index (HI)

Table 6 summarizes the hazardous quotient and hazard index (HI) for residents of ingesting these metals by consuming vegetables grown around Bahi wetland area (eqn 4).

Table 6 Estimation of Hazardous Quotient (HQ) from Green Leafy Vegetables

Vegetable	Human Category	Cu	Pb	Zn	Fe	HI
		Human Health Risk Index (HQ)				
Amaranthus sp	Adults	0.2475	1.5143	0.1090	0.5237	2.3945
	Child	0.3400	2.0857	0.1497	0.7179	3.2932
Ipomoea sp	Adults	0.3225	1.7714	0.0863	0.6683	2.8485
	Child	0.0450	2.4000	0.1183	0.9159	3.4792
Spinacia sp	Adults	0.0325	1.6000	0.0357	0.9159	2.5840
	Child	0.0450	2.2000	0.0487	0.8316	3.1252
Brassica L. sp	Adults	0.1400	1.2571	0.0767	0.8316	2.3054
	Child	0.1925	1.7429	0.1050	0.9293	2.9697
Cucurbita sp	Adults	0.1550	2.4000	0.0803	0.4059	3.0412
	Child	0.2100	3.2857	0.1100	0.5561	4.1619

Discussion

The heavy metal concentrations in the soil decreased in the sequence Fe > Pb > Cu > Zn > Cr. These mean value detected in all three sampling sites is higher than FAO/WHO, (2002) permissible limit of 150, 50, 100, 300 and 50 mg/kg for the metals respectively. The highest concentration of Fe detected at Chipanga B village (785.08 ± 16.43) was also higher than values detected earlier (Nwadinigwe *et al*., 2014) where the concentrations of Fe during dry season was 15.15 ± 5.01mg/kg and during wet season was 12.09 ± 4.99 mg/kg.

Lead (Pb) concentration ranges from 16.78 ± 0.76 mg/kg at Makulu Village to 27.66 ± 2.48 mg/kg detected at Chimendeli village. Similar study in the area with high natural background radiation detected Pb concentration from soil samples ranged from 109 to 744 mg/kg, exceeding the average of 27 mg/kg (Nugraha *et al.,* 2022) which might pose human health risks.

The highest concentration of Cu was detected at Chipanga B village with 4.23 ± 0.21 mg/kg while the minimum was detected at Chimendeli village with average of 1.46 ± 0.32 mg/kg. Zinc (Zn) concentration ranges from 1.67 ± 0.22 to 3.84 ± 0.36 mg/kg. Similar study in Tanzania (Banzi *et al.,* 2015) detected the concentrations of heavy metal in soil samples varied from Cu (2 to 17) and Zn (2 to 62.94) mg/kg.

The concentration of copper from the five vegetable samples range 2.79 mg/kg (*spinacia sp*) to 27.55 +8.74 mg/kg (*ipomoea sp*). The highest concentration is almost half the standard FAO/WHO, (2007) permissible limit. In earlier study in Uranium mining in Ethiopia (Bayissa and Gebeyehu, 2021) reported Cu ranges from 56.06 to 455.6 mg/kg.

Copper (Cu) is among of essential micronutrients in plants and animals (Khan *et al*., 2011) normally human body contains Cu level of about (1.4- 2.1 mg/kg) of body mass. Also, Cu is essential to human being as metalloproteins and function as enzymes, however critical doses causes health risks such as anemia, diabetes, inflammation, kidney and liver dysfunction and vitamin C deficiency (Lokeshappa *et al*., 2012). Normally copper is absorbed in the intestine and facilitate Iron uptake. The Cu deficiency promotes anemia like symptoms, abnormalities in glucose and cholesterol metabolism and skeletal abnormalities (ATSDR, 1994).

The level of lead (Pb) detected in this study was highest in *Cucurbita sp* (17.95+0.10 mg/kg) followed by 11.39±8.46 mg/kg, 13.18±0.2 mg/kg, 11.98±6.54mg/kg and 9.46 ±0.23 mg/kg for *Amaranthus sp*, *Ipomoea sp spinacia sp* and *Brassica L* respectively (Table 3). These values are higher permissible level set by FAO/WHO (2002) in vegetables. These may pose high human health risks and bioaccumulation in the environment that might also pollute water sources from humus.

Kacholi and Sahu, (2016) reported highest concentration of lead about 22.7mg/kg in *Amaranthus species* from Chang'ombe which is about 1.3 times compared to our study. High concentration of Pb in *Cucurbita sp* leaves mainly attributed by contaminants contained in wetland water used for irrigation, contaminated soil, pollution from the highways traffic and dust materials transported from uranium mining activity (Rossi, 2008). Lead is among of non-essential metal in the human body which is reported to be more persistent in the environment and estimated to have soil retention time for a number of years. High level accumulation of lead in body tissues causes anemia, colic, headache, brain damage, cancer and central nervous system disorder (Wani *et al.,* 2015). The half-life of lead in blood and other soft tissues is about 28-36 days but it is much longer in various bone compartments and is mainly excreted through the kidney (WHO, 2000).

The concentration of Zinc ranges between 22.87±2.78 mg/kg in *spinacia sp* to 70.09 1.13 mg/kg in *amaranthus sp* leaves. The level of Zn obtained from this study is higher than that of Akinola and Adesuyi, (2016) where they reported Zn concentration ranges from 4.21 to 20.8mg/kg in Amaranths leafy samples collected from different markets in Lagos Metropolis, Nigeria.

Zinc is a crucial element for human development and normal growth, basically required for proper functioning of body immune system and also a natural constituent of soil in terrestrial ecosystem which is actively taken up by plant roots (Adesuyi *et al*., 2015), Zn deficiency results in a variety of immunological defects (ATSDR, 1994).

Iron (Fe) is an essential element in human and participates in formation of hemoglobin which is important for oxygen and electron transport from the lung to the tissues (Kalagbor and Barivule, 2014). In the present study mean concentration of Fe in the entire leafy vegetable samples analyzed (Table 3) ranges from 328.42 ± 58.11 mg/kg in *spinacia sp* to 1246.47 ± 426.65 mg/kg in *brassica L.* The detected values were above the acceptable limit (450mg/kg) (FAO/WHO, 2007) except in *spinacia* sp.

Iron is among of the abundant heavy metal found in the soil and highly absorbed actively by leafy vegetable roots and transported to different parts of vegetable plants organ. The highest concentration of Fe in leafy vegetables is attributed by weathering of sulfide ores, wastewater irrigation and atmospheric deposition (Singh *et al*., 2010). Disorders of Iron metabolism are among the most common disease of humans and encompass a broad spectrum of diseases with diverse clinical manifestations, ranging from anemia to iron overload (Andrews, 1999). Iron can be reduced and oxidized in various biochemical processes and also an important cofactor of many enzymes which involves in the respiration, photosynthesis and nitrogen assimilation (Hell and Stephan, 2003).

The passage and deposit of heavy metal from soil to edible part of plants act as the main route to the entry of potentially toxic metals into the food chain (Sharma *et al.,* 2018). The rates of transfer and accumulation of the heavy metals to plants vary depending upon certain factors including types of plant species, amount and types of heavy metals, physicochemical characteristics of the soil itself and other factors (Naser *et al.,* 2012).

From the data in Table 4, it can be seen that the transfer factors were increased in the order of Cr < Pb < Fe < Cu < Zn. This is a clear indication that the bioaccumulation factors of Cu and Zn in vegetable samples were higher compared with other metals. Similar study elsewhere indicated the bioaccumulation of metals in vegetables in the similar order of Zn > Cu > Pb > Cd (Oluwatosin *et al.,* 2008).

The large accumulation factor for Zn elucidate that Zn metal ion is more mobile than the other metals. This was reported earlier (Lokeshwari *et al*., 2006), that Zn was less retained by the soil and hence it is mobile than other metals. Higher transfer factors values for Cu, Fe and Pb vegetable varieties are due to the waste water irrigation, anthropogenic and geologic activities may be attributed to differences in the concentration of heavy metals in the soil and rate of metal uptake by vegetable plants (Singh *et al*., 2010).

The physical chemical parameter such as organic matter content, pH, cation exchange capacity, soil texture and clay contents (Mwegoha and Kihampa, 2010) also may influence the migration and transformation of metal ions. Plants have a key function in the biotransformation of chemical elements from soil, air and water. Soil contents of these metals may therefore be a significant source of entry into the food chain. The physical and chemical state of the metal is all important for transport mechanism, so also for bioaccumulation (Marr *et al.,* 1999).

It is worth noting that in all these cases the measured intakes were generally below or close to the corresponding RDI thresholds for Fe, Zn and Cu in a normal vegetable diet. Indeed, values higher than the RDI were found for Pb intake ranges between 0.0044 – 0.0084 mg/kg for adults and 0.1019 – 0.1933 mg/kg for children. These values exceeds the recommended DIM 0.0036 mg/kg for adults and 0.008 mg/kg for children and higher than the values detected earlier in Nigeria (Hannah *et al.,* 2016) which ranges between 0.046 – 0.182 mg/kg. This should raise serious concerns for human health since this nonessential element can be toxic even at trace levels and is very dangerous for nervous system (Zhao *et al.,* 2012).

With exception of Pb, the HQ values of all heavy metals in all vegetables were all below the one (1) for both adults and children. When HQ exceed one (1), there is concern for potential health effect (Huang *et al.,* 2008). In present study HQ for adult's ranges from 1.2571 to 2.4000 while for children ranges from 1.7429 to 2.4000 in *Brassica L. sp and Cucurbita sp* respectively.

Sridhara *et al.,* (2008) also found HQ of Pb in Spinach as high as 5.3. This high HQ for Pb observed in green leafy vegetables grown at Bahi wetland area had greatest potential to pose health risk to the consumer. The results indicated that those living around the Bahi wetland area were probably exposed to some potential health risk through the intake of Pb via consuming locally grown green leafy vegetables. Even though there was no apparent risk when each metal was analyzed individually, the potential risk could be multiplied when considering all heavy metals.

Higher HQ for Pb were also reported by Zheng *et al.,* (2007) in vegetables collected from waste water irrigated area of Huludao Zinc Plant in Huludao city, China. In the present study, all heavy metals except for Pb were least responsible for causing risk to the local population as the value of HQ was below 1 for all the vegetables.

The hazard index (HI) values of the heavy metals studied for adults ranged from 2.3054 to 3.0412 while for children ranged from 2.9697 to 4.1619 that were above 1, indicating non-acceptable level of non-carcinogenic adverse health effect. Hence, HI recorded in Bahi wetland area the contribution of heavy metals can lead to aggregate risk via consumption of vegetables.

Similar study in Ghana (Ametepey *et al.,* 2018) identified HI of heavy metals Cd, Cr, Pb, Mn, Fe, Zn and Cu in the various green leafy vegetables ranged from 6.51 to 29.30 that were above 1, indicating non-acceptable level of non-carcinogenic adverse health effect. In another study in Bangladesh (Sultana *et al.,* 2022) the detected hazard indices of turnip (1.541), mustard (1.663), spinach (2.113), coriander (1.925), and mint (2.834), exceeded unit value, signifying potential health hazard from the dietary intake of the studied vegetables.

This high HI values for all heavy metals observed in cabbage, green pepper, onion and tomato have great potential to pose health risk to the consumer. The difference in THQ values for adults and children are usually attributable to the differences in the ingestion of the heavy metals, body weight between adults and children, and exposure time. The consequence can be more severe for special populations that are people with weak constitution, sensitive, and pregnant women with the potential human health risks of heavy metal accumulation through vegetable consumption

Conclusion and Recommendations

The present study was performed to assess heavy metal levels of commonly consumed vegetables and their associated human health risks in Bahi wetland area. Generally, the heavy metals concentrations in the various vegetables were all below the permissible limit of WHO / FAO. The individual hazard quotient values were all below 1, except Pb in adult and children that suggest an acceptable level of non-carcinogenic adverse risk. The hazard index for both adult and children exceeded 1 which may pose future risk such as cancer. Based on the findings of this study; vegetable intake is just a proportion of food consumed, supplementary or complementary food that may include fish, meat, rice, beans and maize that are consumed in the Bahi District study area can also contribute and/increase amounts of heavy metals.

This study is preliminary in nature, similar research work should be carried out to study the levels of other heavy metals in vegetables and all other complementary food stuff in and around Bahi District Dodoma Region area so as to determine human health risks directly affected by ingestion of heavy metals through consumption of vegetables and other complementary food stuff.

Conflict of Interest Statement

The authors declares that there is no conflict of interest

Acknowledgments

The authors are so grateful to Geological Survey of Tanzania Laboratory for donating standards and providing a laboratory facility for this work. Thanks to the Management and all other authorities as well as the field work assistances.

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Access this Article in Online	
	Website: www.ijarm.com
Quick Response Code	Subject: Ecotoxicology
DOI:10.22192/ijamr.2025.12.06.005	

How to cite this article:

Calos Manda, Irene Tarimo and Josephat Saria. (2025). Toxic Heavy Metals Accumulated In Green Leafy Vegetables Cultivated Around Uranium Project Site In Bahi Wetland, Dodoma, Tanzania. Int. J. Adv. Multidiscip. Res. 12(6): 46-60.

DOI: http://dx.doi.org/10.22192/ijamr.2025.12.06.005