ASSESSMENT OF CONCENTRATIONS OF TRACE AND TOXIC HEAVY METALS IN SOIL AND VEGETABLES GROWN IN THE VICINITY OF MANYONI URANIUM DEPOSITIN TANZANIA

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ABSTRACT

This study reports on determination of concentrations of trace and toxic heavy metals in soil and vegetables grown near of Manyoni uranium deposit. Soil and vegetable samples were collected from five sites namely Mitoo Mbuga, farming area, Miyomboni, Tambukareli and near water pump. The concentrations of heavy metals in soil and edible vegetables samples were analyzed using Energy Dispersive X-ray Fluorescence Spectrometry (EDXRF).All vegetable samples were found to have higher concentrations (in µg/g) of trace elements such as Ni (67.3) in pea leaves, Cu (14.9) in pumpkin leaves, Fe (478.6), (200.5) and (337.1) in pea, pumpkin and spinach leaves respectively, than the maximum tolerable limits recommended by WHO/FAO. Mean concentration of Pb (1.6 µg/g) in pumpkin leaves collected from Miyomboni (area D) were observed to be higher than the safe limit of (0.3µg/g) set by Codex 2006. Toxic elements concentrations (in µg/g) such as Cd (10.4), Pb (23.2),Hg (4.1), Th (31.5) and U (23.9) were observed to be high in soil collected from Mitoo Mbuga and farming area. Therefore, vegetables in the vicinity of Manyoni uranium deposit can expose people to toxic elements which are detrimental to their health. A more detailed study involving other foodstuffs is needed to establish conclusive results.

Keywords: Soil, Vegetables, Manyoni Uranium Deposit, Toxic Elements, EDXRF.

INTRODUCTION

Uranium deposits are associated with heavy metals such as Cd, Cr, Pb, Mn, Ni, Zn, Sr and Cu (Brennan et al. 1992). However, diet is the main route of exposure to high concentrations of heavy metals to the consumers. Vegetable plants take up heavy metals by absorbing them from the air, polluted environments and contaminated soils (Kachenko and Singh 2006). Generally, plant uptake of Cu and Zn as essential micronutrients is higher than that of toxic elements such as Cd and Pb (Bowie and Thornton 1984). Ability of heavy metals to be distributed in different parts of the plant depends on the chemical characteristics and several parameters of the plants and soil (Shanthiet al. 2009).

Normally, in the uranium mining and milling, tons of radioactive rocks are crushed to produce dust and leave behind fine radioactive particles prone to wind and water erosion (Koziowska et al. 2008). Drilling and blasting may disrupt and contaminate local surface and ground water which may be used by humans for domestic purposes, wild animals and irrigation. The mining tailings dams may leak, leach or fail, hence releasing radioactive material into the local soil and waterways (IAEA 1999). The waste rocks produced by these operations normally contain both radionuclides such as Radium (^{226}Ra), Radon (^{222}Rn),Thorium (^{232}Th and ^{228}Th) and Pb are toxicand may pose threat to the ecosystem (WHO 1998).

Heavy metals generally exert an inhibitory action on microorganisms by blocking essential functional groups, displacing essential metal ions and they can modify the active conformations of biological molecules (Wood and Wang 1983). However, trace elements such as Co, Cu, Zn, Fe and Ni are essential for microorganisms since they provide vital cofactors for metallo-proteins and enzymes (Doelman et al. 1994) but at high concentrations they become toxic to microbes, humans and animals. Deficiency of trace elements produces physiological or structural abnormalities regardless of the species (Freiden 1985).

In the near future, mining process will start in these areas. It is therefore, important to have a pre-mining data of heavy metals in the villages near the uranium deposits so as to have reference information to assess any changes in background level during and after uranium extraction. Therefore, the current study aimed to assess the concentration levels of trace and toxic heavy metals in soil and edible vegetables namely spinach, pumpkin and pea leaves grown in Mitoo village which is very close to Manyoni uranium deposit in Singida.

MATERIALS AND METHODS

Description of Study Area

Manyoni uranium deposit is located at latitude $5^o 45^{'}$ S and longitude $34^o 50^{'}$ E in central part of Tanzania.It has a population of about 200,000 people (URT 2002).Mitoo village is located about 1.5 km northern of Manyoni town. Mitoo village has a flat landscape covered with dark soil within Mbuga area. The people living in this area are mainly farmers cultivating maize, millet, beans and variety of vegetables and others are herders and hunters.

Sample Collection and preparation

Five (5) soil samples and three (3) vegetable samples namely spinach, pea and pumpkin leaves were each collected randomly from ten different sampling locations in the Mitoo village making a total of 50 soil samples and 24 vegetable samples. Soil samples were collected in Mitoo Mbuga (area A), area B (Farming area), C (Tambukareli), area D (Miyomboni) and E (Near water pump) at depth between0 – 10 cm. Vegetable samples were collected from local farms in area C, D and E. To serve as future surveillance points, coordinates of these points were recorded using global positioning system (Garmin, GPS72H) as presented in Table 1. Then collected samples were taken to University of Dar es Salaam at Physics Laboratory for sample preparation.

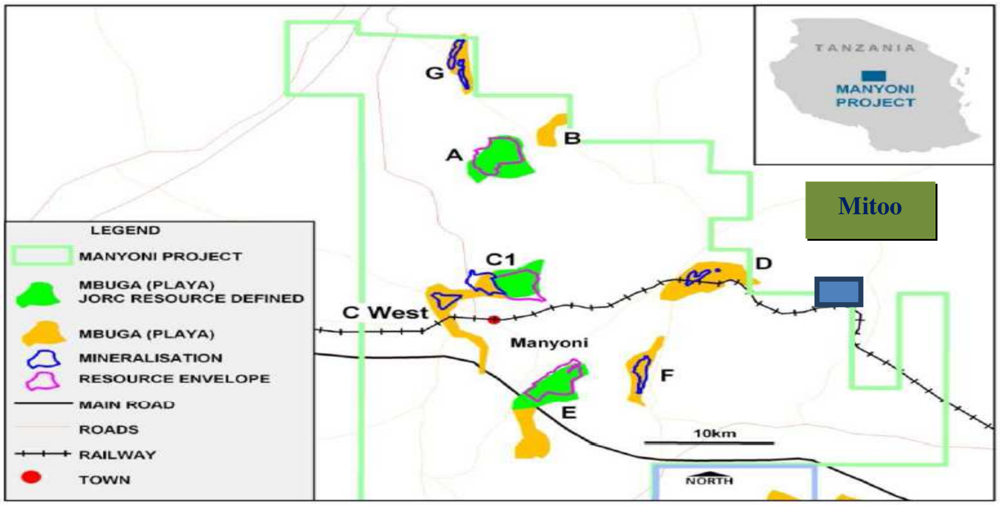

Figure 1: Map Showing the Location of Mitoo Village. (A, B, C, D, E and F are Mbuga / Playa Lakes (URANEX 2010).

Table 1: Type of Sample with Corresponding Sampling Points Coordinates

Type of Sample	Sampling Points	Location	Coordinates: Latitudes (South)	Coordinates: Longitudes (East)
Soil	A	Mbuga area (Deposit site)	$05^{o}\ 10'58''$	$034^{o}07'46''$
	B	Mbuga (Farming area)	$05^{o}15'23''$	$034^{o}33'07''$
	C	Near Tambukareli	$05^{o}\ 30'32''$	$034^{o}\ 43'06''$
	D	Near Miyomboni	$05^{o}41'07''$	$034^{o}48'35''$
	E	Near water pump	$05^{o}44'53''$	$034^{o}44'00''$
Vegetables	C	Pea leaves (Tambukareli)	$05^{o}37'04''$	$034^{o}03'40''$
	D	Pumpkin leaves (Miyomboni)	$05^{o}19'74''$	$034^{o}22'38''$
	E	Spinach leaves (near water pump)	$05^{o}36'10''$	$034^{o}40'00''$

The vegetables samples were cut into pieces and air-dried then placed in an electric oven at 65°C to remove all the moisture. The dried vegetables samples were homogenized by grinding using an electric blender to obtain a fine powder and then sieved to reduce particle size of < 50 µm. Soil samples were dried at room temperature then kept in an oven at 65ºC for 24h and ground by using electric grinder.

The soil samples were sieved to 1 mm size. About 6.00 g of powder from each sample were mixed with 1.35 g of starch binder and then placed into a polished lapped thrust piece with smooth surface and fixed into hydraulic press machine. The pellets in pressed tablets were obtained by applying an average pressure of 20 bars. The pellets were of intermediate thickness ($m_{thin} < m < m_{thick}$) with the outer diameter of 32 mm. The pellets were finally placed in sample holders and inserted in EDXRF spectrometer for elemental analysis installed at Tanzania Atomic Commission (TAEC). The model of the system is Xepos with serial No.4R0138 and is operated by x-lab Pro^{TM} software. In this model, X–rays are generated by the X–ray tube and excitation of elements in the sample is carried out using three different secondary targets depending on the atomic number of the element. Samples were analyzed at the anode current of about 30 mA and tube voltage of about 35 kV. Light elements, from Na-V are excited using HOPG target (intense monochromatic polarized X-rays). Elements from Cr-Zr and Pr-U are excited using Mo secondary target (intense monochromatic non-polarized X-rays). High Z- elements (Y-Ce) are excited using Barkla target (Al_2O_3) (intense polychromatic polarized X-rays) as summarized by Table 2. The spectra running time was 30 minutes per sample.

Table 2: Targets and Corresponding Elements for Excitation Using Turboquant^{TM}Methods

Target	**Type of Target**	**Excited Elements**
Mo	Secondary	Cr Y(K), Hf - U(L)
Al_2O_3	Barkla	Zr - Ce
HOPG	Bragg	Na – V

(i) Calibration of EDXRF System

To verify the validity of manufacturer calibration, routine multichannel analyzer (MCA) recalibration was performed once a week. The system then uses the stored calibration algorithm in XlabPro^{TM} operating software to internally relate the radiation intensity of each element signal to the concentration of the element in the sample. The software corrects also for various effects such as the matrix effects basing on fundamental parameter methodology (Spectro 2005). However, in order to ensure consistence of the calibration process, the performance of the EDXRF system was verified using recommended reference materials with known elemental concentration as described in the next section. A typical X- ray spectrum used for determination of elemental composition from a sample is shown in Figure 3.For spectral line intensity (I_i) given as area under the curve divided by the live time (counts/second), the software of the EDXRF corrects for a background and converts the results to concentration (C_i) of the elements present in the sample after making interference (K_i) and matrix effects corrections as follows (Rousseau 1996).

$$C_i = K_i I_i M_a$$

where; C_i is the concentration of a given element i.

K_i is the constant of proportionality.
I_i is the intensity of the fluorescent radiation from the element i.
M_α is the correction factor for matrix effects.

(ii) Accuracy and Precision

In this work the accuracy and precision of the system to determine concentrations of elements in soil were checked using Standard Reference Material (SRM 2711a Montana 11 (IAEA Supplier)) for Soil samples and Certified values for Standard Reference Material (SRM Spinach (IAEA Supplier) leaves) for vegetable samples. Each ten (10) samples of Montana II and Spinach were analyzed and the data were used to produce statistical report on the overall accuracy of the system per element. The report is based on calculations suggested by (US. EPA 2006) whereby, relative percentage difference (RPD) for each element is obtained as follows;

$$RPD_n = \frac{C - M_n}{Average(C, M_n)}$$

Where; C is the concentration in the reference material sheet.
M is the XRF measured concentration.
n is an integer (1 – 10).

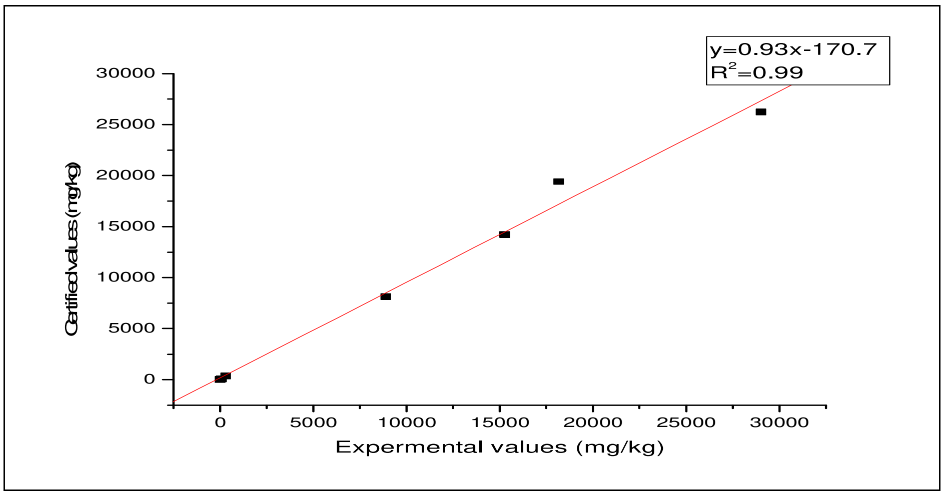

Figure 2: EDXRF experimental and recommended certified values in leaves (SRM 1570a).

Most of the elements were within the accuracy of ± 10 %. Plot of experiment concentration against the reference values is also presented in Figure2. Standard deviations evaluated for each concentration did not exceed 20%. For samples which were below the minimum detection limit (MDL), a mean value equal to one half of MDL for each element was used to avoid missing data points (Davis 2001).

Correlation analysis of the samples were also performed using multivariate statistical analysis (correlation coefficient matrices) indicated by correlation coefficient (r^2). Statistical analyses in this work were performed by using Statistical Packages for Social Sciences (SPSS) software version 16, Origin software version 6.1 and an Excel Software. These analyses included testing for normality of data distributions, calculating measures of central tendency, standard error of the mean (SEM) and measures of variability, constructing tables of descriptive statistics as well as making comparisons of mean elemental concentrations of soil and vegetable in each sampling area.

RESULTS AND DISCUSSIONS

Elemental Concentrations in Soil Samples

As shown in Table 3concentrations of elements can be discussed in two groups. The first group consists of elements Cu, As, Hg, Mg in area C and Cd in area E whose concentrations were insignificant because they were below the detection limit of the analytical technique. The second group includes Na, K, Al, Ca, V, Mn, Cr, Fe, Ni, Co, Zn, Cu, Sr, Ba, Th, Pb and U elements with concentrations above MDL.

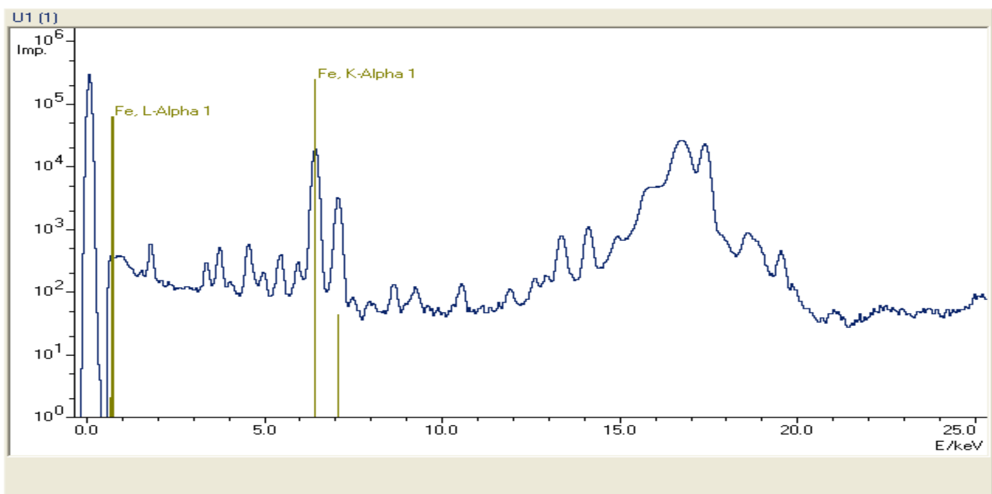

Figure 3: Typical Spectrum of Soil Sample Collected in MitooMbuga area

Soil samples in area A had significantly ($p \leq 0.05$) higher concentrations of Na, Ca, Mn, As, Pb, Hg, Ba and U as compared to other areas. The concentration of U was 43 times higher than the lowest concentration in area D. Concentrations of Na, Ca, Mn and Ba were about 4, 22, 3 and 2 times higher than their lowest concentrations of soil in area C. However, Pb and Hg were about 14 and 2 times higher than their lowest concentrations in area E. Area B had significantly ($p \leq 0.05$) higher concentration of Al as compared to other sampling areas. The concentration of Al was 15 times higher than the lowest concentration in area A while concentration of As was found to be below minimum detection limit and therefore lower than the concentration of 3.9 µg/g obtained in area A. Area C had significantly ($p \leq 0.05$) higher concentration of K, V and Cd and lowest concentrations of Na, Ca, Mn and Ba. Concentrations of V and Cd were 1.3 and 11times higher than the lowest concentration in area E while K is 5 times higher than in area D. Furthermore, the highest concentrations of Mg, Fe, Co, Ni, Cu, Sr and Th were observed in area D and the lowest concentrations were for K and U. Concentrations of Mg, Fe, Co, Ni, Cu, Sr and Th were about 3, 3, 7, 4, 2, 6 and 4 times higher than in area E while that of Cr in area E was 4 times higher than its lowest concentration in area D. Figure 4 shows variation of concentrations of Sr, Cd and Pb in different sampling areas.

Table 3: The elemental concentrations (µg/g) in soil in different areas (A. mean ± SEM)

Elements	AreaA(n=10)	Area B(n=10)	Area C(n=10)	Area D(n=10)	Area E(n=10)
Mg	3012 ± 38.57	1328.4± 16.2	MDL	4357.9 ± 444	126.5 ± 18.2
Al	3388 ± 34.01	52216± 78.93	26136±163	51858 ±32.84	21124 ± 388.1
K	6265 ±10.5	3628.5±37.4	8659 ± 40.1	1923.9± 106.7	8470.6 ± 18.9
Ca	14243±22.10	3456.5±132.2	650.7 ± 14	12002 ±21.15	2415.6 ± 21.65
V	153 ± 9.2	144 ± 14.9	175.2± 10.6	145.7± 10.5	124.3 ± 44.02
Cr	54.5 ± 7	59.3 ± 8	108.4 ± 2.8	27 ± 2.87	119.6 ±42.03
Mn	328.8 ± 28.3	133.2 ± 2.9	106.6±1.9	182.2 ± 7.1	109.2 ± 2.76
Fe	13727 ± 82.82	13582 ± 22.85	7503.2±116	19081± 33.4	5808.3 ± 723.2
Co	24.9 ± 3.1	35.6 ± 1.9	17.8± 2.5	53.1 ± 1.9	7.3 ± 3.96
Ni	14.9± 0.99	11.5 ± 0.4	4.9 ± 0.3	17.2 ± 0.42	4.3 ± 0.51
Cu	5.7± 0.5	4.8 ± 0.3	4.7± 0.3	6.1± 0.47	3.3 ± 0.63
Zn	39.8± 2.1	16.8 ± 0.4	9.9 ± 0.3	34.9 ± 0.9	17.1 ± 3.45
As	3.9 ± 0.6	MDL	MDL	MDL	MDL
Sr	104.3 ± 14.2	39.9 ± 1.0	22.4 ± 0.2	118.3 ± 1.4	20.7 ± 0.92
Cd	5.1 ± 1.4	10.4 ± 1.05	12 ± 0.6	11.6 ± 1.01	MDL
Pb	23.2 ± 3.0	15.1± 0.4	10.2 ± 0.2	22.4 ± 0.55	7.37 ± 0.21
Hg	4.1 ± 0.6	MDL	MDL	0.6 ± 0.15	MDL
Ba	319.7 ± 3.65	201.3 ±1.57	136.6 ± 6.5	216.9 ±16.4	159.6 ± 1.09
Th	31.5 ± 3.4	29.6 ± 1.5	12.4 ± 0.5	34.4 ±1.04	8.0 ± 0.66
U	23.9 ± 1.5	2.9 ± 0.2	1.4 ± 0.9	0.56 ± 0.1	4.2 ± 0.2

The concentrations of Th and U were found to be significantly high in area A. This concentration of U is higher than the world wide reported range (0.3 – 11.7 µg/g) set by UNSCEAR (2000). The lowest concentration of Th was found in area E and that of U was detected in D. However, both Th and U are natural radioactive materials and their concentrations in all soil samples collected in area A were above the permissible limit of 2 µg/g set by NCRP (1984).

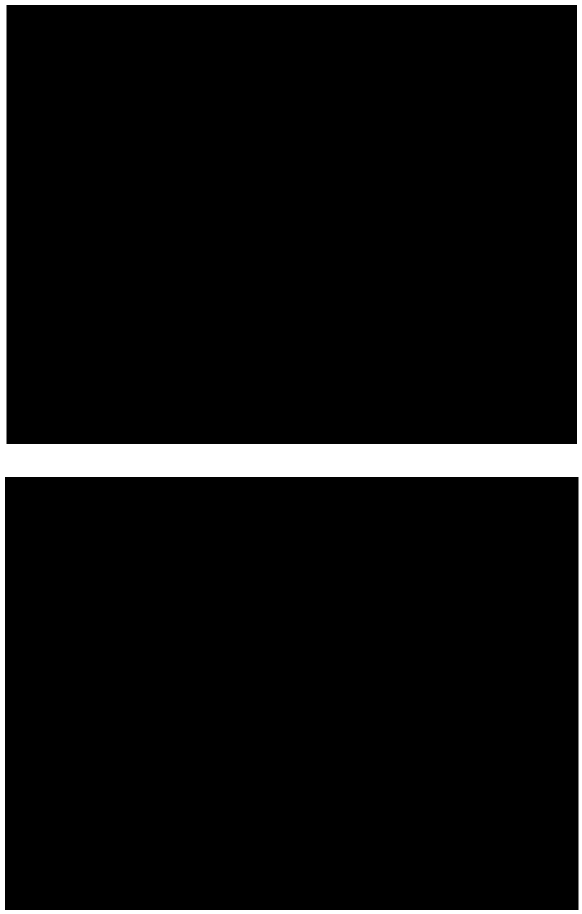

Figure 4: Histograms Showing the Mean Concentrations of Th, U, Cd, Sr and Pb in Soil Collected in Different Sampling Areas.

Studies have reported both chemical toxicity and radiation exposure in the body upon ingestion of either Th or U (Sztajnkrycer and Otten 2004). Since As, Cd, Pb, Hg, Co, Ba are toxic to human being, there is a possibility that people living in area A (Mitoo Mbuga) are exposed to the toxicity of these elements. Therefore, further study using analytical tool with lower MDLs for As and Hg is proposed to confirm this hypothesis.

Elemental Concentrations in Vegetable Samples

Table 4 shows the mean concentrations of heavy and toxic elements in all vegetables from different sampling locations. However, It can be noted that, the concentrations of V, Co, As, Cd, Pb, Hg, Th and U in all vegetables were found to be below their minimum detection limits of (0.91, 0.28, 0.31, 1.73, 0.86,0.57, 0.55 and 1.28 µg/g) respectively) for the EDXRF system used in this study. The maximum tolerable limit for concentration of Cd and Pb in vegetable sample is 0.2 and 0.3 µg/g which are 9 and 3 times less than their MDLs for the respective elements. Since both Cd and Pb are toxic to human being, there is a possibility that consumers of pumpkin leaves in area D are exposed to the toxicity of Pb associated with uranium decay.

Table 4: Elemental Concentrations (µg/g) in Vegetable Samples (A. Mean ± SEM;n=8 each)

Elements	Pea (Area C)	Pumpkin (Area D)	Spinach (Area E)
Na	1218.9 ± 162.8	2707.7 ± 76.17	2968.5 ± 10.07
Mg	5957.5 ± 60.65	5949.1 ± 43.71	7726.8 ± 75.25
Al	451.7 ± 9.6	239.2 ±10.19	951.9 ± 4.53
K	37146 ± 38.52	46440.3 ±15.6	51878 ± 20.85
Ca	36592 ± 70.19	24614 ± 18.60	28612 ± 17.86
Cr	28.6 ± 2.9	19.6 ± 2.6	24.9 ± 2.4
Mn	115.7 ± 22	65 ± 3.9	221.2 ± 5.1
Fe	478.6 ± 5.7	200.5 ± 11.2	337.1 ± 4.1
Ni	67.3 ± 4.7	7.6 ± 0.7	2.6 ± 1.15
Cu	8.08 ± 1.1	14.9 ± 0.6	8.3 ± 1.99
Zn	56.3 ± 8.1	52.4 ± 2.8	79.8 ± 9.4
Sr	258.5 ± 33.1	186.8 ± 8.0	244.6 ± 23.5
Pb	MDL	1.6 ± 1.0	MDL
Ba	222.8 ± 2.5	177.5 ± 15.3	162.7 ± 3.0
U	MDL	MDL	MDL

Note: V, Co, Cd, As, Hg, Th and U were not detected.SEM= Standard Error of the Mean.

Pea leaves collected in area C had significantly higher concentrations of Ca, Cr, Fe, Ni, Sr and Ba. The concentration of Ca in pea leaves(36592µg/g) was about 2 times higher than its lowest mean concentration in pumpkin leaves in D. The concentration of Cr in pea leaves (28.6µg/g) was about 2 times higher than its lowest concentration in pumpkin leaves sampled in area D. The same to Ba and Ni levels that were found higher in pea leaves than 3 and 1.4 times its lowest concentration in spinach leaves collected in area E respectively. The concentrations of Cu and Pb in pumpkin leaves collected in area D were 6 times higher than the lowest concentration in pea leaves. This implies that pumpkin plants have greater absorptive capacity of Pb than pea plants.

Lastly, the levels of Na and K in spinach leaves were found to be 2 times and 1.4 times higher than lowest value in pea leaves. It was noted also that, higher concentrations of Al, Mn, Zn and Mg at 4, 3, 2 and 1times than in pumpkin leaves respectively. However, it is interesting to note that, the mean concentration values of Hg, Pb, Th and U in vegetable samples was less than their Minimum Detection Limits (0.57, 0.86, 0.55 and 1.28 μg/g) respectively. This implies that, mean concentrations of these elements were lower than the world wide permissible limits Hg (0.03 μg/g) and Pb (0.2 μg/g) recommended by (WHO 2004).

The Spearman correlation test was carried out to examine the variation of mean concentrations of elements in the soil with the distance from the deposit site. Several elements including Fe, Cd, Pb, Hg, Th and U showed a strong positive correlation as follows, Fe (r = 0.88) Pb (r = 0.73). U (r = 0.57) Hg (r = 0.76), Th (r = 0.91)and Cd (r = 0.73). However, Ni (r = -0.57) and Zn (r = -0.39) show negative correlation. These results imply that, the concentrations ofFe, U, Pb, Hg, Cd and Th increase as one move toward the deposit site whereas the concentrations of Zn and Ni decrease as the distance increases.

Comparison of Elemental Concentrations in the Soil with Elemental Concentrations in Soil as Reported in the Literature

As shown in Table 6 the mean concentrations of the Pb, Cd and Cr in soil from this study were lower than the mean values in three studies reported in the literature and concentration of Cd were about 6, 10 and 3 times higher than the mean concentration found in Romania, Nigeria and England respectively.

Table 6: Comparison of the Mean Concentrations of Heavy Metals (μg/g) in Soil Samples with Literature Values from elsewhere

LITERATURE	Cu	Zn	As	Pb	Cd	Cr
Area A	5.7	39.8	3.9	23.2	5.1	54.5
Area B	4.8	16.8	ND	15.1	10.4	59.3
Area C	4.7	9.9	ND	10.2	12	108.4
Area D	6.1	34.9	ND	22.4	11.6	27
Area E	3.3	17.1	ND	7.4	ND	119.6
Romania (Miclean 2008)	104	359	ND	248	1.63	-
Nigeria (Tsafe 2012)	1.13	68.9	-	29.7	0.97	16.7
England (Davies 1980)	15	267	ND	183	3.2	-
Maximum Tolerable Limit	30	60	-	100	3	400

ND = Not Detected, - = Not Reported Source (NCRP 1984, WHO/FAO 1999)

Toxicity of Heavy Metals to the Public in the Vicinity of Manyoni Uranium Deposits

Most of the people are not aware of the potential hazards of uranium deposit and they may be easy victims of the negative impacts. Therefore, effective toxicity of heavy metals to the public can be investigated by referring the Daily Intake Rate (DIR) of toxic elements by adult consumers. This is computed by the following assumption;

$$\text{DIR (mg/day)} = C \times D_{\text{food intake}}$$

where; C = Concentration of heavy metal in plants (mg/g)

$D_{\text{food intake}}$ = daily intake of vegetable (g/day)

An average daily vegetable intake for adults is considered to be 0.345 kg/person/day (Wang et al. 2005). The percentage contribution of vegetable samples to the Upper Tolerable Intake Level (UL) for particular elements was then calculated and presented in Table 7.The vegetables contribution to the daily intake of most of the essential element is above the Tolerable Upper Intake Levels (ULs) for the respective elements except Na which is lower than MTL proposed by EFSA (2006). Trace elements (K, Mg, Ca, Zn and Fe) were observed to be higher than 100 percent of the maximum tolerable limits set byWHO2004, EFSA 2006 and US. EPA 2006

Table 7: Estimation of the Percentage Contribution of the Leafy Vegetables to the DailyIntake of Elements (mg/day) using the Maximum Daily Intake of 0.345kg/person/day

			Pea leaves contribution		**Pumpkin leaves contribution**		**Spinach leaves contribution**	
Elem	**UL (mg/day)**	**ORG**	**(mg/day)**	**%**	**(mg/day)**	**%**	**(mg/day)**	**%**
Na	1600	EFSA	421	26	934	58.4	1024	64
Mg	375	EFSA	2055	548	22052	547	2666	711
K	3700	EFSA	12815	333	16022	433	17898	484
Ca	2500	EFSA	12624	505	8492	340	9871	395
Cu	5	EFSA	2.8	55.8	5.14	103	2.9	57.3
Cr	10	EFSA	10	100	7.1	70	8.5	85
Mn	10	USEPA	39.9	399	22.4	224	76.3	763
Fe	18	WHO	165.1	917	69.2	384	116.3	646
Zn	15	WHO	19.4	129	18.1	121	27.5	183.3

Excessive intake of Cr contributed in Pea leaves are toxics and a known human carcinogens. Presence of higher contribution of Cu in pumpkin leaves and K, Mg, Ca, Mn, Fe and Zn in all vegetable samples than their essential values can cause anemia, acne, adrenal hyperactivity, allergies, hair loss, arthritis, autism, cancer, depression and elevated cholesterol (Kabata and Pendias 1993).

CONCLUSIONS

This study has identified the presence of both trace and toxic elements in soil and vegetables grown in the vicinity of Manyoni uranium deposit. This datawill be valuable in monitoring concentration of heavy and toxic metals pollution in soil and vegetables when uranium mining starts. Since the results have shown high concentrations of toxic elements in the soil,it is advised that soil from Mitoo Mbuga should undergo thorough purification or phytoremediation before being used for crops cultivation. This will minimize the concentration of elements to safe levels as recommended by WHO/FAO.Soil samples analyzed showed elevated concentrations (in µg/g) for Mn (328.8), Fe (13727), As (3.9), Cd(5.1), Pb (23.2), Hg (4.1), Th (31.5) and U (23.9) especially in Mitoo Mbuga (area A). Despite that, the concentrations of Cu. Cr, Zn and Ni were lower than the world average. Other elements (Mg, As, Hg and Cd) analyzed were not detected in some samples of soils. These elements in soil are reported in literature to exist in concentrations which were below the MDL of the EDXRF techniques used in this study. Therefore, people living in Mitoo Mbuga are potentially subjected to toxic elements such as Hg (4.1µg/g), Cd (5.1µg/g), Th (31.5µg/g) and U (23.9 µg/g) which were found in soil samples. The concentration of mercury exceeding the maximum permissible limit (0.03µg/g) can cause serious health problems such as loss of vision, hearing and mental retardation and finally death. Phytoremediation of heavy metals in this area is encouraged.

This study also observed that all vegetable samples analyzed were contaminated with toxic elements namely Cr, Sr and Ba. The concentration of Pb (1.6 µg/g) in pumpkin leaves which were collected in area D was higher than the safe limit of 0.2 µg/g set by WHO/FAO while the concentration of Ni (67.3 µg/g) in pea leaves collected from area C was higher than safe limit (12 µg/g) recommended by WHO/FAO. Generally, the pumpkin leaves were found to have high absorptive capacity for Cu (14.9µg/g) and Pb (1.6 µg/g) while spinach plants have high absorptive of Na (2968.5),Mg (7729.8), Al (951.9µg/g),K (51878µg/g),Mn (221.2µg/g) and Zn (79.8 µg/g) and pea leaves collected near Tambukareli show great uptake of Ca (36592µg/g), Ni (67.3µg/g), Sr (258.5µg/g) and Ba (222.8 µg/g).

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