

## Assessment of Heavy Metals in Guinea Sorrel (*Hibiscus Sabdariffa*) Cultivated on Fadama Soils in Maiduguri, Nigeria.

### Abstract:

River Ngadda is one of the main sources of water used by the resident of Maiduguri Metropolis. The proximity of the people to the river encourages a lot of irrigation farming along the river bank during the dry season especially vegetables therefore concentration values of heavy metals namely Aluminum, Cobalt, Iron, Lanthanum, Manganese, Chromium, Rubidium, Scandium, Samarium, Thorium, Vanadium and Zinc were determined in Guinea Sorrel (*Hibiscus sabdariffa*) vegetable samples obtained at six different locations on different dry season farming (Fadama) sites along the bank of river Ngadda and Alau dam in Maiduguri, Nigeria. Instrumental neutron activation analysis (INAA) technique which is a sensitive method for determination of major, minor and trace element in a matrix was used to assess the heavy metal accumulation levels in Guinea Sorrel with the aim to establish the food safety status from heavy metals concentration levels for guinea sorrel cultivated along the bank of river Ngadda and Alau dam and consumed on a daily basis as compared to WHO/FAO recommended maximum permissible limit (MPL) for edible vegetables. The result obtained showed that the concentration values of Al ranged from  $932 \pm 18$  to  $3369 \pm 54$  ppm, Co  $0.12 \pm 0.03$  to  $40 \pm 4$  ppm, La  $1.00 \pm 0.03$  ppm to  $38 \pm 4$  ppm, Manganese  $112 \pm 0.4$  to  $176 \pm 1$  ppm, Rubidium  $4 \pm 0.5$  to  $21 \pm 1$  ppm, Sc  $0.10 \pm 0.007$  to  $27 \pm 1$  ppm, Sm  $0.106 \pm 0.004$  to  $17.2 \pm 0.4$  ppm, V  $1.10 \pm 0.3$  to  $4 \pm 1$  ppm and Zn  $17 \pm 3$  to  $63 \pm 4$  ppm, and Fe  $379 \pm 33$  ppm to  $2316 \pm 65$  ppm. This result indicates that the maximum concentrations of Fe, Cr, Mn, and Co, in guinea sorrel from most of the sites were above the acceptable limits given by FAO/WHO for edible vegetables. Therefore, it is certain that there is the health risk associated with the continuous consumption of guinea sorrel vegetables cultivated from the study site and authors of this work hereby recommends that investigation of this kind should be carried out from time to time so as to know the buildup or otherwise of heavy metals in guinea sorrel cultivated in the study sites.

**Key Words:** Assessment, Guinea Sorrel, Metal Pollutants, Permissible Limit, Fadama soils

### Introduction

Recently, heavy metal concentration has received much attention with regard to accumulation in soils, uptake by plants and contamination of water. Pollution of plants is of concern for two major reasons, firstly pollutants may have direct or indirect phytotoxic impact on the plants themselves, leading to a decline in crop yield and threatening our food supplies and secondly, the plants may act as vehicle for transferring metal pollutant into the food chain.

This increasing trend in concentration of heavy metals in the environment has attracted considerable attention amongst ecologists globally during the last decades and has also begun to cause concern in most of the major metropolitan cities. The Excessive accumulation of heavy metals in agricultural soils through the use of agrochemicals and by other sources may not only result in soil contamination but also lead to elevated heavy metal up-take by vegetables and thus affect food quality and safety [1].

In many developing countries it is a common practice to grow vegetables along banks of rivers passing through urban Centre of which waters of such rivers have often been reported to be polluted by heavy metals [2].

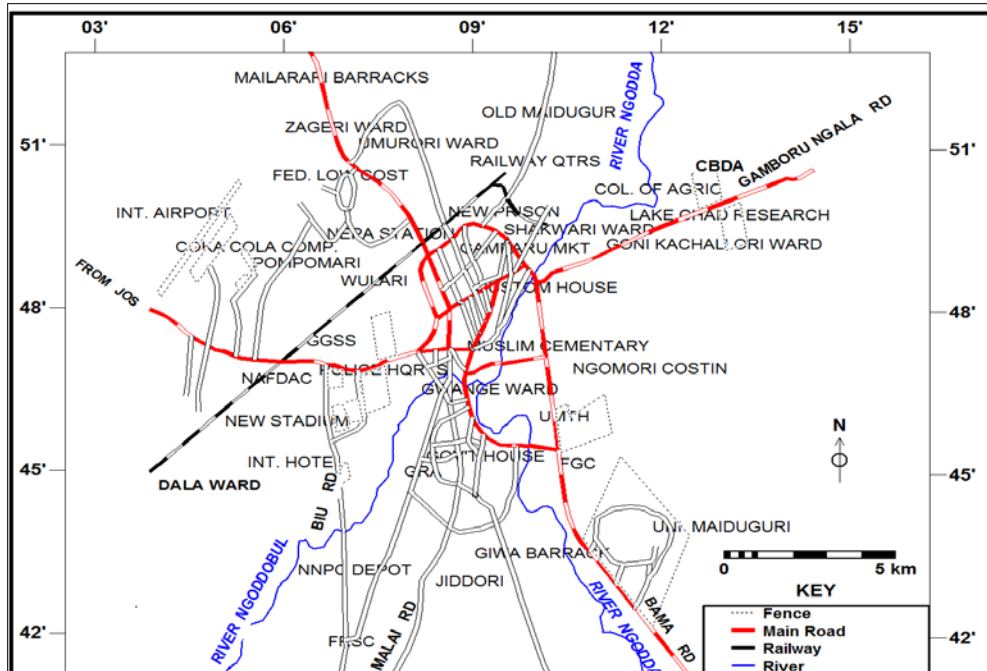
It is a known fact that Vegetables are important edible crops and are an essential part of the human diet and generally consumed because of their nutrition value [3], [4], [5] but take up heavy metals and accumulate them in their edible parts [6]).and studies have shown that the heavy metals are easily accumulated in the edible parts of leafy vegetables, as compared to grain or fruit crops [7], [8] and also the quantities accumulated can be high enough to cause clinical problems both to animals and human beings when they consume these metal-rich vegetable/plants [9]. The extent of absorption of the elements by the plant depends on among other things, the nature of the plant, and chemical constitution of the pollutant, concentration of the element in the soil, pH and the interaction with other metals [10].

The dumping of solid waste generated from domestic and cottage industries on farmlands along channels or streams that transcend urban Centre usually contaminates the soils and if plants are cultivated thereon can be a primary route of human exposure to metal toxicants [11] hence heavy metals in soils used for cultivation is viewed as an international problem because of the effects on ecosystem in most countries [12]. According to [13] the situation of heavy metal pollution is more worrisome in the developing countries where research efforts towards monitoring the environment has not been given the desired attention by the stakeholders.

Many studies have shown that municipal refuse may increase heavy metal contamination in soil and underground water [14], [15] which may have effects on the host soils, crops and human health [16]. Thus the environmental impacts of municipal refuse are greatly influenced by their heavy metal contents. In Nigeria the situation is no better by the activities of most industries and populace towards waste disposal and management which usually lead to increasing levels of pollution of the environments. [Hence this work intends to assess the level of bio-accumulation of heavy metals in Guinea Sorrel cultivated during dry season along the bank of river Ngadda and Alau dam and establish the consumption safety with respect to the FAO/WHO standard for heavy metals in vegetables.](#)

### **Materials and Methods**

This work covers a study area that lies between latitude  $11^{\circ} 48' N$  to  $11^{\circ} 52' N$  and longitude  $13^{\circ} 06' E$  to  $13^{\circ} 14' E$  at an altitude of 345m above sea level Figure 1. The area of study is known for its long period of dryness, with Sudan type of climate, Savanna or Tropical grassland vegetation and light annual rainfall.



**Figure1: Maiduguri Township Map Showing River Ngadda.**  
**Source: Ministry of Land and Survey.**

### Sample Collection

Fresh Guinea Sorrel (*Hibiscus sabdariffa*) vegetable samples were collected directly on six different farmlands at different sites within the dry season period between the month of January to May along the bank of river Ngadda and Alau dam and labeled with the identification codes (D1, D2, D3, D4, D5, D6) Figure 2. The locations points for the collection of samples were obtained using Global Positioning System (GPS) by taking the ordinates. Samples from the study area were collected in a pre-designed manner such that on each farmland in the specified area, samples were collected at different locations of the farm and homogenized to constitute a sample site.



**Figure 2: Guinea Sorrel Sampled Sites Along River Ngadda and Alau dam**

### Sample Preparation

The fresh vegetable samples collected were put in a clean black polyethylene bags and adequately labeled for easy identification during the laboratory analysis. The samples were taken to The Herbarium laboratory in Biology Department at Ahmadu Bello University, Zaria for identification. After the identification, the samples were taken to laboratory where they were thoroughly washed with running tap water and properly rinsed with double distilled water to remove any airborne particulates. The vegetables were then air dried and oven dried at 60°C temperature for not less than eight hours and then grounded and sieved to required particle size using a sieve that was pre-cleaned. The sample was put in a sample bottle, labeled, capped and taken to Centre for Energy Research and Training (CERT) Ahmadu Bello University, Zaria for further preparation and analysis.

### Sample Preparation for Neutron Activation Analysis

Instrumental Neutron Activation Analysis (INAA) techniques which is a sensitive method for accurate determination of elemental concentration in materials was used in this study employing Nigeria Research Reactor-1 (NIRR-1) facility located at Center for Energy Research, Ahmadu Bello University Zaria, Kaduna State of Nigeria. The detail working principle and function of NIRR-1 was obtained in the work of [17], [18].

Conventional method of sample preparation of vegetable samples for irradiation was used as provided by [17] was adopted after which the samples were then put in an irradiation vial. The vial was then capped and sealed. Standard Reference Material (SRM) NIST 1573a which is a direct representative of the vegetable sample was prepared in the same way as that of the sample and put in the same type of vial as that of the sample.

### Sample Analysis

The samples and standard of known quantities of the elements in question were irradiated simultaneously in identical positions, followed by measuring the induced intensities of both the standard and the sample in a well-known geometrical position. For data processing, the gamma-ray spectrum analysis software WINSPAN, 2004 used by [19] based on the practice of using the activity induced at time after irradiation for time  $t$  and given by Equation (1)

$$A_t = \frac{\varepsilon \sigma_Q \rho W_Q \varphi}{M_Q} = N_A (1 - e^{-\lambda t_i}) d s^{-1} \quad (1)$$

$A_t$  is activity of element Q at the end of radiation ( $ds^{-1}$ ),  $\sigma_Q$  is neutron capture cross section of element ( $cm^2$ ),  $\rho$  is fractional abundance of particular isotope of element Q,  $M_Q$  is atomic weight of element Q to be measured,  $N_A$  is Avogadro's number ( $mol^{-1}$ ),  $\lambda$  is decay constant of induced radionuclide ( $s^{-1}$ ),  $t_i$  is irradiation time (s),  $\varphi$  is the flux of neutron used in irradiation ( $m^{-2}s^{-1}$ ) and  $W_Q$  is weight of element Q irradiated.

The sample and standard parameters were then related as in Equation (2)

$$\frac{A_{\text{sam}}}{A_{\text{std}}} = \frac{\phi\omega\epsilon I N_A (1 - e^{-\lambda t_{\text{irr}}})_{\text{sam}} (e^{-\lambda t_d})_{\text{sam}} (1 - e^{-\lambda t_c})_{\text{sam}}}{\phi\omega\epsilon I N_A (1 - e^{-\lambda t_{\text{irr}}})_{\text{std}} (e^{-\lambda t_d})_{\text{std}} (1 - e^{-\lambda t_c})_{\text{std}}} \quad (2)$$

where  $A_{\text{sam}}$  is activity of the unknown sample,  $A_{\text{std}}$  is activity of the standard. The standard is irradiated and counted under similar conditions as the sample, therefore common parameters in equation (2) cancelled out and the mass of the element in the sample relative to the standard comparator is calculated using Equation (3)

$$\frac{A_{\text{sam}}}{A_{\text{std}}} = \frac{m_{\text{sam}} (e^{-\lambda t_d})_{\text{sam}}}{m_{\text{std}} (e^{-\lambda t_d})_{\text{std}}} \quad (3)$$

$m_{\text{sam}}$  = mass of element in the sample,  $m_{\text{std}}$  = mass of element in standard,  $\lambda$  = decay constant for the isotope.

## Results

Table 1 present concentration values of the various elements determined in Guinea sorrel vegetables obtained from the different sites D1 – D6 using INAA technique. The concentration values were graphically represented in Figures 3-5 by grouping them according to their concentration magnitudes and this was done for convenience and clarity.

**Table 1: Concentrations of Elements determined in Guinea Sorrel Samples from Different sites by INAA technique.**

Sample Site	Al	Fe	Mn	Br	Co	Cr	La	Rb	Sc	Sm	Th	V	Zn
D1	3369±054	1027±53	176±1.0	21±2.0	29±4.00	2.6±0.3	2.5±0.10	21±1	27±1.00	0.36±0.01	1.04±0.06	4±1.00	36±3.0
D2	1851±20	2316±65	121.4±0.50	12.1±1,5	40±4.00	8.6±0.3	38±4.00	14±1	21±1.00	BDL	81±5.00	2.82±0.41	63±4
D3	932±018	707±47	6±1.00	10±1.0	0.15±0.03	BDL	1.24±0.03	6±1.00	0.15±0.01	0.149±0.00	BDL	1.5±0.4	26±3
D4	1068±16	395±40	161.9±0.3	10±1.0	0.12±0.03	11.3±0.4	1.1±0.03	4±1	0.1±0.01	BDL	0.133±0.005	0.24±0.04	27.7±2.3
D5	1293±14	14490±130	173±1.0	3.6±0.6	1.0±0.3	BDL	5241±267	BDL	17.2±0.400	36±5	2.0±0.3	21±3	21±3
D6	1057±62	379±33	112.2±0.40	13±1.0	BDL	3.9±0.3	1.00±0.03	5.4±0.6	0.099±0.006	0.106±0.004	BDL	BDL	17±3

**BDL: Below Detection Limit**

**All concentrations are in ppm**



### Daily Intake of Metals (DIM)

In order to quantify the level of exposure from consumption of the vegetable investigated, an index referred to as daily intake of metals (DIM) was calculated according to the expression:

$$DIM = \frac{M * C * I}{W} \quad (4)$$

where  $M$  is the metal concentration in the vegetable (mg/kg),  $C$  is the conversion factor,  $I$  was the estimated quantity of vegetable taken on daily basis, and  $W$  is the average weight of a human being. The conversion factor (from fresh to dry weight of vegetable) of 0.085 was adopted from [20]; the average weights of an adult and a child were approximated to be 55.9 and 32.7 kg respectively, while the average quantities of vegetable taken on daily basis by adults and children were 0.345 and 0.232 kg/person/day respectively based on reports of [21] and [22].

The best way to estimate the health risk of any pollutant is to determine the level of exposure to that pollutant and the route(s) of exposure to a particular tissue or organ. In this study, the daily intake of metals (DIM) was used as the exposure index. Evaluation of DIM based on the stated assumptions revealed a minimum of  $1.2 \times 10^{-3}$  mg and a maximum of  $836.7 \times 10^{-3}$  mg for adults, while the children had a minimum of  $1.4 \times 10^{-3}$  mg and a maximum of  $961.9 \times 10^{-3}$  mg. It is obvious from the results that all the daily intakes of metal in guinea sorrel for all the elements for children were higher than the corresponding values for adults. The implication of these results is that children tend to take in more metals than adults, and this could be due to tenderness of children's body tissues. Again, the metals with relatively high DIM values (eg: Al = 0.837 mg, Fe = 0.464 mg for adults and Al = 0.962 mg, Fe = 0.533 mg for children) are mainly major elements with high natural abundances.

### Discussion

Guinea sorrel is one of the most utilized vegetables by the people in the northern part of Nigeria due to the fact that, the leaf, flower (calyx) and the seeds are all edible. The leaf is use in preparing soup, the calyx in making a local drink called zobo and the seed for preparing local spice. Therefore, the study on the accumulation of heavy metal in Guinea sorrel is very paramount so as to ascertain the safety of continuous consumption. Figure 3 presents the graph of the concentrations of Aluminium, Iron and manganese determined in Guinea sorrel samples obtained at six different sites along the bank of river Ngadda and Alau dam. It can be observed from the graph that the concentrations of Aluminium in Guinea Sorrel were higer than iron and Manganese in all the six different sites. The high concentration of Aluminium in guinea sorrel collected from the various sites could be attributed to the fact that the element has high natural abundance and occurance which might have aid in having a high cncentrations value in the soil used for the cultivation of the vegetable which were absorbed during growth together with nutrients . Secondly the study environment was mostly within and at the outskirts of maiduguri town hence anthropogenic activities would have deposited the element on the cultivation soil

through erosion, wind or town storm and absorbed by by the vegetable during growth. The concentratrion value of iron in Guinea Sorrel was above MPL given by FAO/WHO.

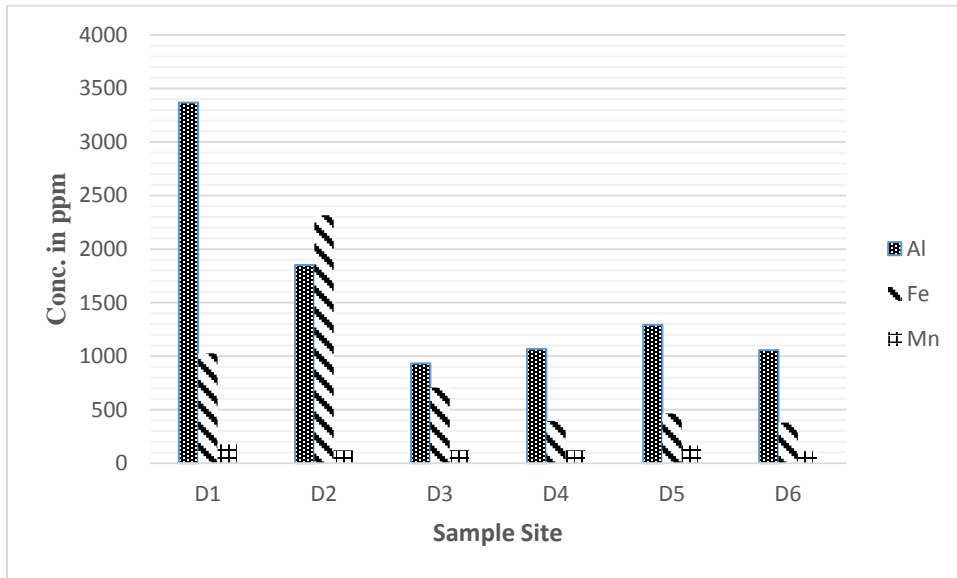


Figure 3: Concentrations of Elements Determined in Guinea Sorrel

Figure 4 showed the graph of the concentrations of Bromine, Lanthanum, Rubidium, Cobalt, Chromium and Zinc. It can be observed that at site D1, Zn>Co>Rb>Br>La, at site D2, Zn>Co>La>Rb>Br>Cr while at site D3, D4, D5 and D6 Zn> Br>Rb >Cr> Br> la except at D5 where Co was higher than all the other elements. It is obvious therefore that that basically Zn > Co > La > Br > Rb > Cr in most of the sites. The maximum concentrations of all the elements were found to be at sampled site D2 which represent a location area around Custom Bridge adjacent to Custom area market which was a hub of activities on a daily basis.

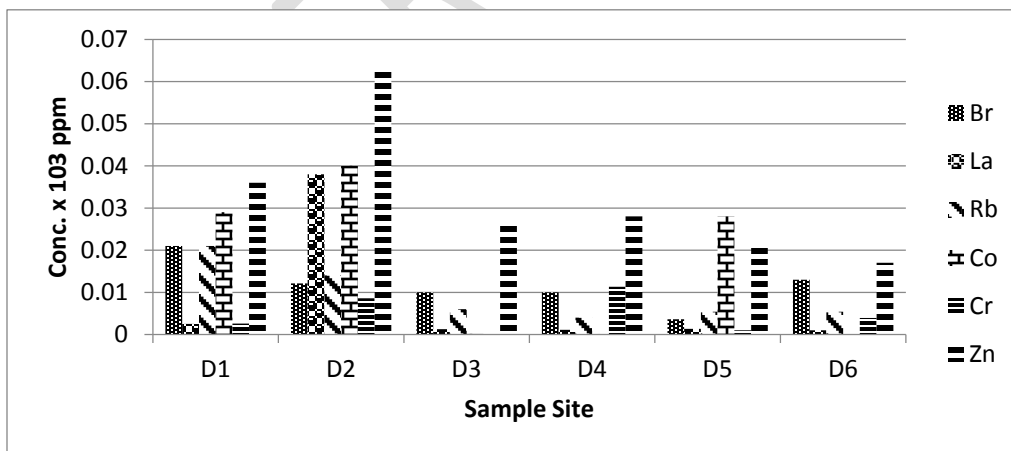


Figure 4: Concentrations of Elements Determined in Guinea Sorrel

Figure 5 showed the concentrations of Scandium, Samarium, Thorium, and Vanadium determined in the samples obtained at different sites of the study area. Scandium had a maximum concentration of at site D1, Samarium at site D5, Thorium at site D2 and Vanadium 4 ppm at site



D1, while Sites D3 and D4 showed insignificant concentration of these four elements. Those sites that have Thorium, Scandium and Samarium having high concentrations could be that there are rock underground having these elements in them.

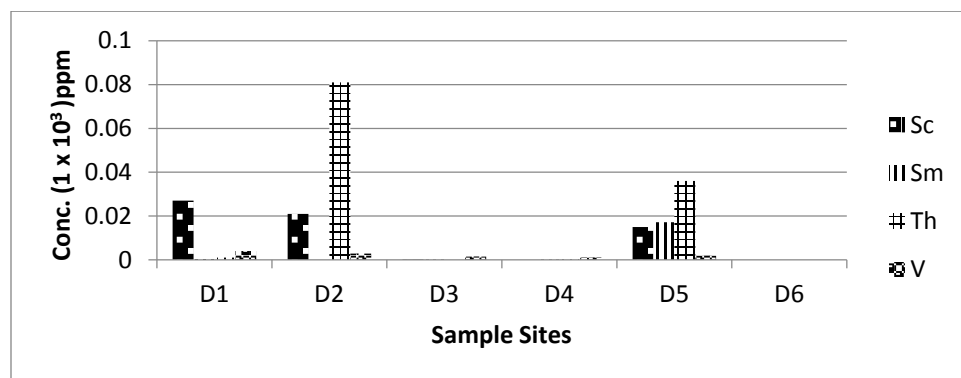


Figure 5: Concentrations of Elements Determined in Guinea Sorrel

## Conclusion

The variation in concentration values of the metals determined in Guinea Sorrel samples obtained at different locations suggests that there might be effects of anthropogenic and or natural processes that contributed to the abundance of the trace and heavy metals in the soils on which the guinea sorrel were cultivated. From the result of this work, the maximum concentrations of iron  $1027 \pm 65$ , cobalt  $29 \pm 4$  ppm, Chromium  $11.3 \pm 0.4$  ppm, and Manganese  $176 \pm 1$  ppm exceed the safe limit recommended by FAO/WHO (2005) of 425.5, 1.0 ppm, 1.3 ppm and 26 ppm respectively. Therefore, the implication is that continuous consumption of Guinea sorrel cultivated from the study sites pose health risk and also recommend that investigation of accumulation of heavy in Guinea sorrel cultivated along river Ngadda and Alau dam should be done from time to time to ascertain the buildup of the other heavy metals that are now within the recommended MPL limit.

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