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Original Research Article

Assessment of metal pollutants in lettuce (*lactuca Sativa*) cultivated via irrigation in Maiduguri, Nigeria

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Vegetable cultivation along channels and rivers that transcend major cities have been a concern globally in the recent decades due to accumulation of heavy metals and introduction of heavy metals into the food chain. Lettuce samples cultivated along the bank of river Ngadda and Alau dam in Maiduguri were collected and analyzed for the accumulation of heavy metals namely Aluminum, Cobalt, Iron, Lanthanum, Manganese, Chromium, Rubidium, Antimony, Scandium, Thorium, Europium and Zinc (Zn) using instrumental neutron activation analysis (INAA). The aim of the study was to determine the levels of accumulation of heavy metals in lettuce cultivated during dry season along the bank of river Ngadda and Alau dam and to compare the values obtained with the maximum permissible limit (MPL) recommended for vegetables. The results obtained showed that the concentration level of Aluminum ranged from 1634 ± 05 to 6450 ± 213ppm, Cobalt from below detectable limit (BDL) to 72 ± 11ppm, Iron 379 ± 31 to 1087 ± 71 ppm Lanthanum 0.40±0.05 to 2.49±0.06 ppm, Manganese 11.3 ± 1 to 170 ± 1 ppm, Chromium 1.3 ± 0.2 to 5 ± 1 ppm, Rubidium 13 ± 1 to 57 ± 3 ppm, Antimony BDL to 4.2 ± 1.00 ppm, Scandium 0.07 ± 0.01 to 37.1 ± 1.40 ppm, Barium10 ± 2 to 135 ± 14 ppm, Thorium 0.15 ± 0.04 to 20.00 ± 3ppm., Europium 0.021 ± 0.004 to 32 ± 5.00 ppm and Zinc 25 ± 3 to 42 ± 4 ppm. The result indicates that the maximum concentration values of Fe and Co exceed the Maximum Permissible Limit (MPL) recommended by FAO/WHO while the other heavy metals concentration values were within the safe limit. However, the continuous consumption of lettuce obtained from the study area pose health risk therefore periodic investigation of the accumulation of heavy metals in lettuce should be done periodically as the built up of these metal pollutants could occur overtime unnoticed even with the heavy metals that were within the safe limit at the moment.

Keywords: Assessment, accumulation, metal pollutants, irrigation, lettuce.

INTRODUCTION

Heavy metal contamination is a globally recognized environmental issue, threatening human life very seriously (Khan et al., 2015). The increasing trend in concentration of heavy metals in crop cultivation soils and the environment generally has attracted considerable attention amongst ecologists globally during the last decades. This has also begun to cause concern in most of the major metropolitan cities as the increase in release of metal pollutants to the environment is linked to the population growth. Studies have shown that municipal refuse usually increases heavy metal contamination in soil and underground water (Okoronkwo et al., 2005;Okoronkwo et al.,2006) which may have effects on the host soils, crops and human health Reyes-Gutiérrez et al., 2007).

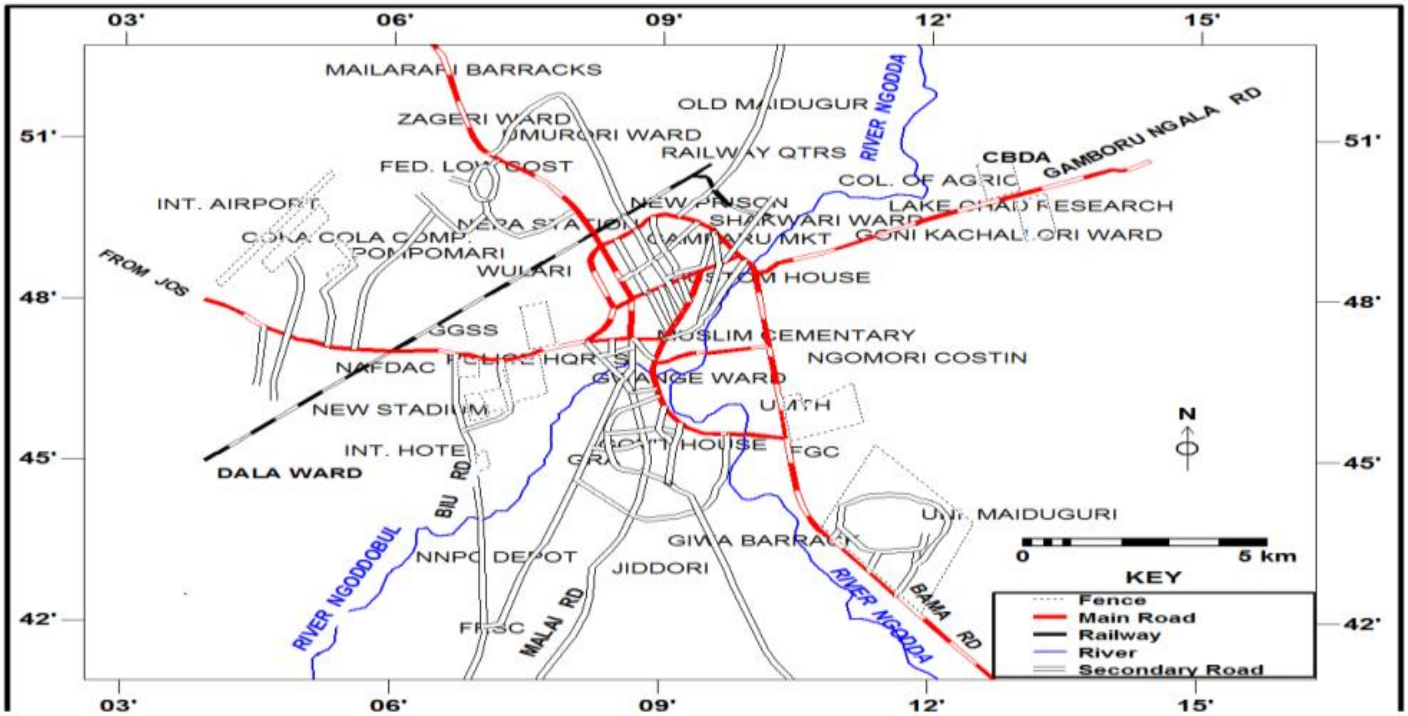

Figure 1: Maiduguri Township Map Showing River Ngadda

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 Reyes-Gutiérrez et al. (2006).

In many developing countries it is a common practice to grow vegetables along banks of rivers, streams and channels that passes through urban centers so as to meet the food demands of the populace of which most often waters of such rivers, streams and channels have often been reported to be polluted by heavy metals (Kashem and Singh, 1999; Othman, 2001).

Studies have shown that vegetables take up heavy metals and accumulate them in their edible parts (Bahemuka and Mubofu, 1991) and the heavy metals are easily accumulated in the edible parts of leafy vegetables, as compared to grain or fruit crops (Mapanda et al., 2005). The quantities accumulated can be high enough to cause clinical problems both to animals and human beings when they consume these metal-rich plants (Alam, 2003). Lettuce are plants with fresh raw edible leaves. They are important edible vegetable that form an essential part of the human diet and as vegetable they are generally consumed because of their nutrition value(Rumteke et al., 2016; Hang et al., 2016; Deribachew et al., 2015). Lettuce are also one of the predominant vegetables cultivated throughout dry season along the bank of river Ngadda and Alau dam via irrigation and usually consumed fresh as a delicacies (salad). This work aimed to determine to what extent the lettuce cultivated during dry season along the bank of river Ngada and Alau Dam through irrigation been bio-accumulated with heavy metals and does the level of accumulation of trace and heavy metals by lettuce cultivated via irrigation along the bank of river Ngadda and Alau dam has potential health risk associated with its consumption.

MATERIALS AND METHODS

This work was carried out within a study area that lies on latitude 11°48'N to 11° 52'N and longitude 13°06'E to 13°14'E at an altitude of 345m above sea level. Figure 1 shows the Maiduguri township map with river Ngadda transcending the metropolis around which most of the study sites were located.

Sample Collection and Preparation

Fresh lettuce (*Lactuca sativa*)) vegetable samples were collected on four different farm plots at different sites along the bank of rive Ngadda and Alau dam and labeled the sampling points in the sites of study area with the codes COA1, COA2, COA3,COA4. Figure 2 whereby subsequently COA1will be B1, COA2 beB2, COA3 be B3 and COA4 be B4).The codes assigned to the samples was according to the sites of collection for easy identification during preparation and experimentation process. Vegetable samples were collected directly on the farmlands at five different points on each plots, four at a point along the diagonal and one at the center to constitute a sampled site. The fresh vegetables

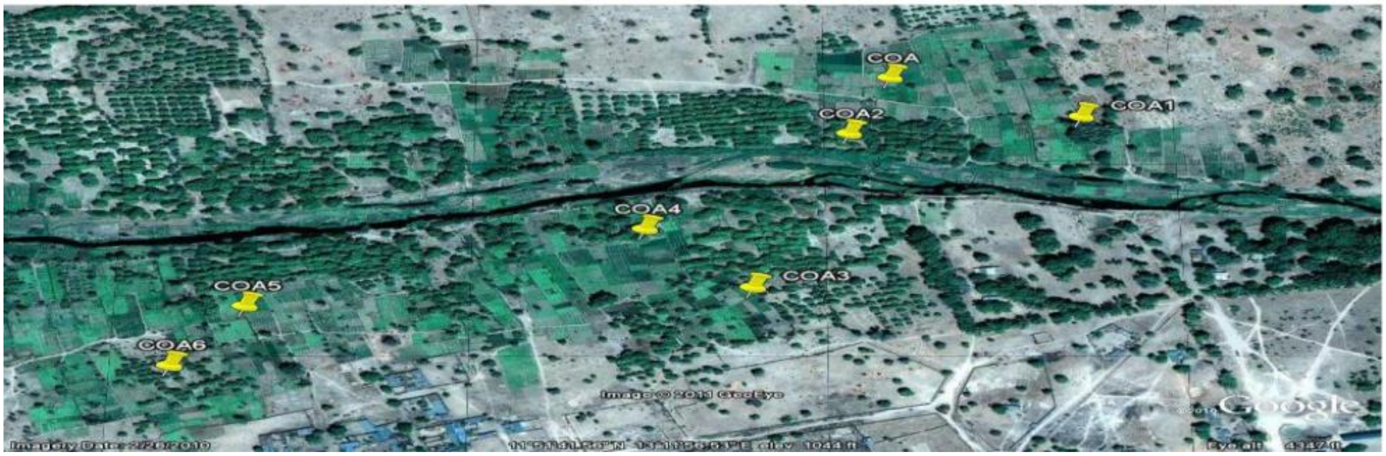

Figure 2: Google map Showing COA1, COA2, COA3, COA4 Sampling points

were put in a clean black polyethylene bags, and labelled. Ordinate of collection position were obtained from Global Positioning System (GPS) and the fresh lettuce samples were taken to herbarium laboratory in Biology Department of Ahmadu Bello University, Zaria for identification. After 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 pollutants. The samples were air dried and subsequently oven dried at low temperature for several hours and then grounded and sieved to required particle size using a sieve that were pre-cleaned. The sample was then put in a sample bottle, labeled, caped and taken to Centre for Energy Research Training (CERT) Ahmadu Bello University, Zaria for further preparation and analysis.

Sample Preparation for Irradiation and Analysis

Method of sample preparation conventional to vegetable samples for irradiation using Nigeria Research Reactor-1 (NIRR-1) was adopted (Jonah et al., 2006; Jonah, 2008) after which the samples were weighted using MettlerTeledo balance model AE 240, put in an irradiation vial which were high density polyethene vials, capped and sealed. Standard Reference Material (SRM) NIST 1573a which is a representative of the vegetable sample was put in the same type of vial with that of the sample and then irradiatedsimultaneously.

Sample Analysis

The interaction of the sample and the neutron flux is based on the activation Equation (1)

$$R = \mathcal{N} \int_o^{\infty} \sigma\ (E)\varphi\ (E)dE \qquad (1)$$

R = reaction rate, N = number of interacting isotope, σ(E) =cross-section (in cm) at neutron energy E (in eV), ω = neutron flux per unit of energy E (eV). In terms of neutron velocity Equation (2)

$$R = \int\sigma(v)\phi'(v)dv\infty0 = \int n(v)v\sigma(v)dv\infty0 \qquad (2)$$

Where *v* the neutron velocity (m s−1), *σ(v)* the neutron cross section (in m^2) for neutrons with velocity v; *n(v)dv* the neutron density (m^{-3}) of neutrons with velocities between *v and v+dv,* considered to be constant in time.

In this work, the relative method of neutron activation analysis for element determination in sample analysis was employed using the NIRR-1, therefore the sample and standards were irradiated simultaneously and had their intensities measured using a horizontal dip stick hyper pure Germanium (HPGe) detector with relative efficiency at 10% at 1132,5 KeV gamma ray line. For data processing the gamma-ray spectrum analysis software WINSPAN,2004 used by (Liyu, 2004) based on the practice of using the activity induced at time after irradiation for time *t* was employed according tothe Equation(3)

$$A_t = \frac{s\sigma_Q\rho W_Q\varphi}{M_Q} = N_A\left(1 - e^{-\lambda t_i}\right)ds^{-1} \qquad (3)$$

where A_t is activity of element Q at the end of radiation (ds^{-1}), σ_Q is neutron capture cross section of element (m^2), ρ 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}) , λ is decay constant of induced radionuclide (s^{-1}), t_i is irradiation time (s), φ is the flux of neutron used in irradiation **(**$nm^{-2}s^{-1}$**)**and W_Q is weight of element Q irradiated.

The sample and standard parameters were then related by the equation

$$\frac{A_{sam}}{A_{std}} = \frac{\phi\omega\epsilon I N_A\left(1-e^{-\lambda t_{irr}}\right)sam\left(e^{-\lambda t_d}\right)sam\left(1-e^{-\lambda t_c}\right)sam}{\phi\omega\epsilon I N_A\left(1-e^{-\lambda t_{irr}}\right)std\left(e^{-\lambda t_d}\right)std\left(1-e^{-\lambda t_c}\right)std} \qquad (4)$$

Table 1. Concentration of elements determined in lettuce in different sites by INAA

Sampled/Site	Al	Co	Fe	La	Mn	Cr	Rb	Sb	Sc	Ba	Th	Eu	Zn
B1	2983±042	72±11.00	1087±71	2.49±0.06	168±0.5	5±1.0	57±3	4.2±0.1.00	37.1±1.40	135±14	1.1±0.10	32±5.000	42±4
B2	1634±051	0.33±0.04	783±45	1.6±0.10	170±1.0	1.7±0.3	19±1	0.10±0.03	0.15±0.01	17±02	1.33±0.06	0.021±0.004	36±3
B3	6450±213	BDL	349±31	0.40±0.05	116.7±0.5	1.8±0.3	13±1	0.29±0.03	0.07±0.01	10±02	0.15±0.04	0.023±0.006	25±3
B4	1799±040	0.2±0.03	691±44	0.92±0.06	113±1.0	1.3±0.2	19±1	BDL	0.16±0.01	18±02	20±3.00	0.026±0.007	30±3

All concentrations are in ppm
BDL: Below detection Limit

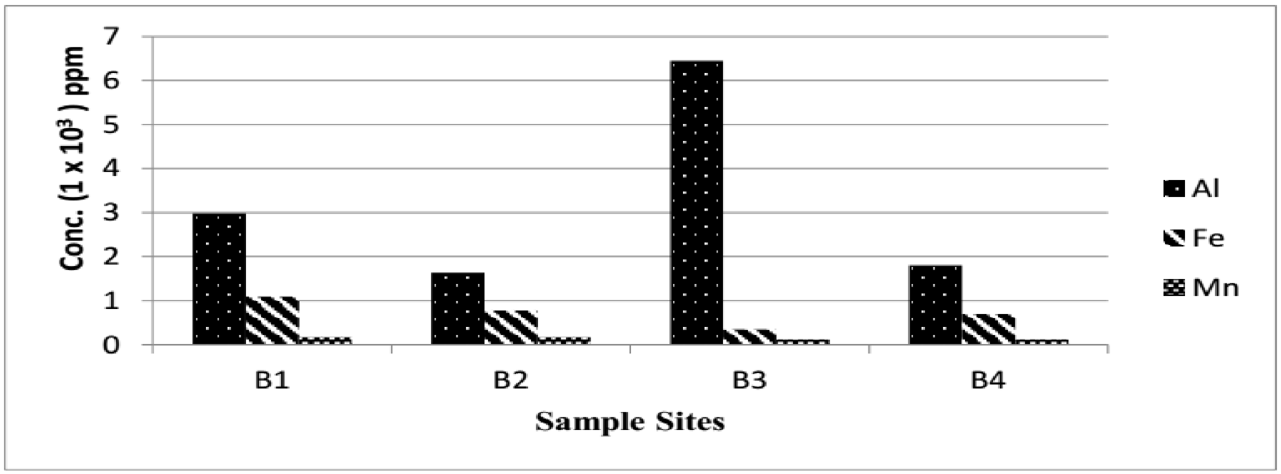

Figure 3a: Concentration of elements determined in lettuce vegetable

Where A_{sam} is activity of the unknown sample, A_{std} is activity of the standard. When the sample and the standard were irradiated and counted under similar conditions then common parameters in equation (4) cancelled out and the equation become:

$$\frac{A_{sam}}{A_{std}} = \frac{m_{sam}}{m_{std}} \frac{(e^{-\lambda t_d})_{sam}}{(e^{-\lambda t_d})_{std}} \quad (5)$$

m_{sam} = mass of element in the sample, mstd = mass of element in standard,λ = decay constant for the isotope.

RESULTS AND DISCUSSION

The concentration values of the various elements determined in the lettuce vegetable samples obtained from different sites were presented in Table 1 and represented graphically as indicated in figures 3a to 3c according to their concentration values. The concentration values were plotted against the sample sites. It can be observed from the graphs that there were distinct variations of the bioaccumulation of the different elements in respect of different cultivation sites. This could be attributed to the fact that concentrations of the various elements in soil at a particular site depend on either the natural source or the anthropogenic source which enhance deposition in the soil.

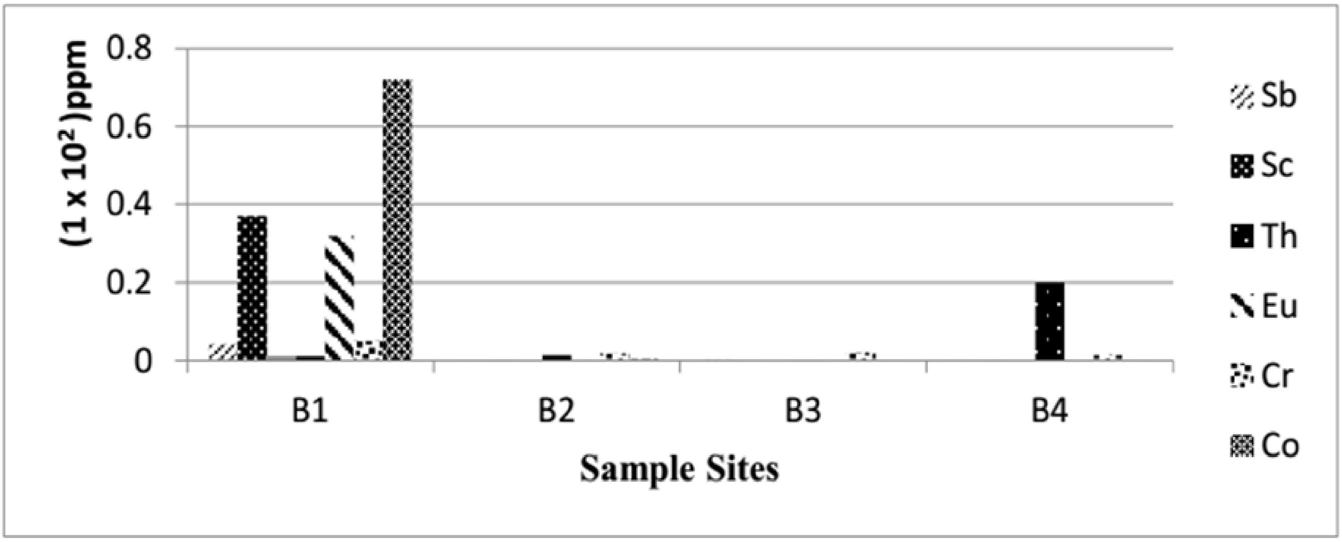

Figure 3b: Concentration of elements determined in lettuce vegetable

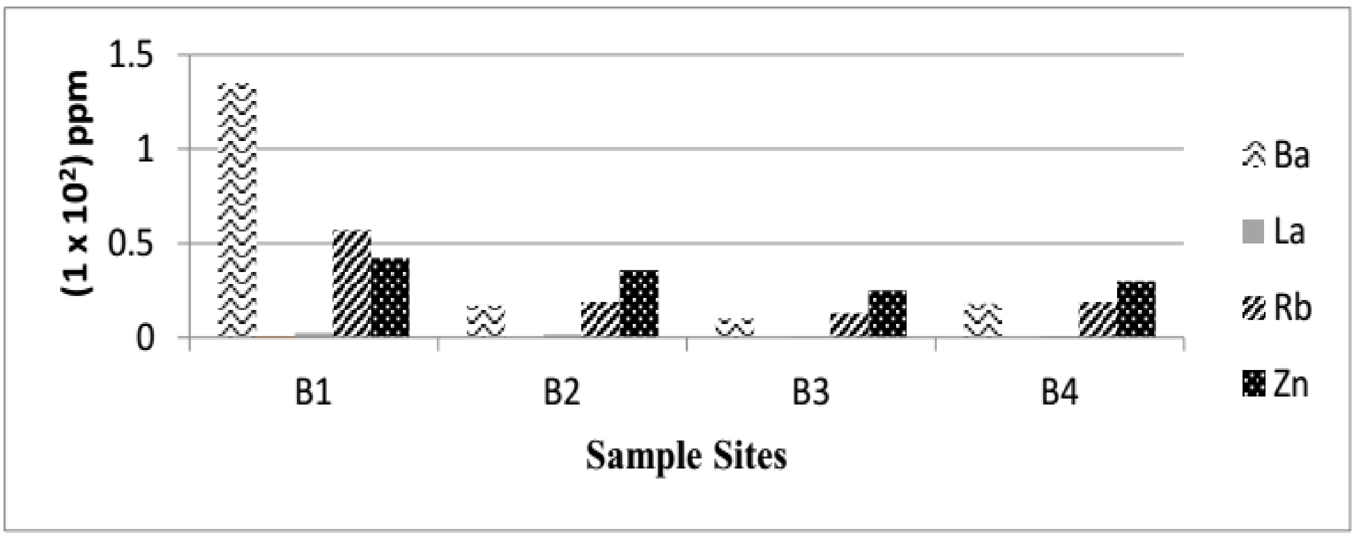

Figure 3c: Concentration of elements determined in lettuce vegetable

Daily Intake of Metals (DIM)

The level of exposure from consumption of the vegetable investigated can be quantified using an index referred to as daily intake of metals (DIM) which was calculated using the expression:

$$DIM = \frac{M*C*I}{W} \quad (6)$$

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 (Ge, 1992) 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 (Wang et al., 2005) and (FAO/WHO 2005).

Therefore, 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 and since 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 of1.83 x 10^{-1} mg and a maximum of 8.57 x 10^{-1} mg for adults, while the children had a minimum of 2.10 x 10^{-1} mg and a maximum of 9.85 x 10^{-1} mg. It can be observed from the results that all the daily intakes of heavy metal in lettuce for all the elements for children were higher than the corresponding values for adults which imply 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 = 3.385 mg, Fe = 0.570 mg for adults and Al = 4.225 mg, Fe = 0.712 mg for children) are mainly major elements with high natural abundances.

DISCUSSION

From the result obtained and presented in this work, it is obvious that the bioaccumulation of the naturally abundant heavy metals was more than the less abundant ones. This difference could be attributed to the fact that apart from the fact that these elements were naturally abundant, they were also utilized by crafts men, mechanics and almost every household on a daily basis which may generate waste and be disposed along the bank of river Ngadda and Alau dam or be transported directly to the farmlands along the bank of the river through rain storm, wind and erosion. Also the elements that got deposited at the bottom of the river can be carried with irrigation water and be deposited on the farmland soils during irrigation processes hence can be absorbed by the vegetables cultivated on the farms. Figure 3a showed the graph of the concentrations of elements with natural abundant values namely Aluminum, iron and Manganese determined in lettuce samples. It is obvious from the graph that at all the four site the values of Al> Fe>Mn. This variation trend in concentration is in agreement with earlier statement which attribute the high values to natural abundance and anthropogenic activities within the municipal council, which contributed significantly to their deposit in the soils used for the cultivation of the vegetable and absorbed by the plants during growth.

It can be observed from Figure 3b, at sample site B1, concentration of Co >Sc>Eu, at sites B2 and B3 all the elements determined were almost of the same concentration while at B4,Th> Cr > Co >Eu>Sc>Sb.The concentration cobalt at site B1 suggest that there was either certain human activity which had influence the deposit of the element in the site or there was a rock beneath that was rich in cobalt and weathering process taking place thus enhancing the concentration of the element in the soil used for cultivating the vegetable.

Figure 3c present the graph of the concentrations of the elements Zn, Ba, Rb and La. It is obvious from the graph that at site B1, Ba>Rb>Zn>La, at site B2, Rb>Zn>Ba>La and at site B3 and B4, Zn>Rb>Ba>Rb. The high concentration of Ba at site B1 could be due to human activities that enhance the level of concentration of the element or could be due to natural occurrence.

Generally, the level of concentrations of some of the elements determined in lettuce are in close agreement with values obtained by other researchers' in other parts of Nigeria outside the country. For example, in the work of Ukpabiet al. (2016) whereby they determined heavy metals in leafy vegetables cultivated and marketed in Aba, south east, Nigeria, with specific reference to water leaf. The concentration of iron was 110 ±0.67, Zn 76 ±0.07, Co 0, 10 and Cr 1, 28 ppm. These values were in agreement with some of the values obtained in this work. Also in work done by Rajesh kumar et al. (2006) in which they investigated heavy metal concentration in vegetable grown in waste water irrigated area of Varansi, India, they found concentration of Zn in amaranthus, cabbage and okro as 116.41, 98.54 and 130.14 ppm respectively while Cr was 14.42, 3.40 and 11.73 respectively. These results were also in agreement with what was obtained in this work

Conclusion

From the result obtained and presented in this work, it is obvious that there was bioaccumulation of heavy metals by lettuce cultivated during dry season through irrigation along the bank of river Ngadda and Aluu dam. It was also found that the maximum concentration values of Fe and Co in lettuce was above the FAO/WHO maximum permissible limit (MPL) recommended for vegetables hence the consumption of lettuce obtained from the study area might constitute or accumulate to constitute health risk therefore, there is the need for such investigation to be carried out periodically so as to monitor the concentration buildup of heavy metals in the vegetables cultivated in the study area with the view to enlighten the authorities concern of the food safety status of the vegetables.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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