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RESEARCH ARTICLE **OJER20200105**

ASSESSMENT OF HEAVY METALS IN OKRA (*Abelmoschus esculentus*) CULTIVATED THROUGH IRRIGATION, IN MAIDUGURI, NIGERIA

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ABSTRACT

The contamination of the environment with heavy metals is one of the challenges that constitute Nigeria's environmental problem with urbanization being one of the major causes; due to the unavailability of proper waste dumpsites and landfills for infrastructural development thereby resulting in the polluting rivers and streams. The cultivation of vegetables along channels and rivers that transcend major cities have been a source of concern globally in recent decades due to accumulation of heavy metals and introduction of heavy metals into the food chain. This study therefore assessed the level of concentration of heavy metals namely; Aluminum, Iron, Lanthanum, Manganese, Chromium, Rubidium, Antimony, Scandium, Barium, Samarium and Zinc in Okra (*Abelmoschus esclentus)* samples obtained on farmlands along the bank of river Ngadda and Alau dam cultivated through irrigation. The samples were analyzed using instrumental neutron activation analysis (INAA) analytical technique with the aim of assessing their level of accumulation with heavy metals. The objective was to ascertain the food safety status of the vegetable by comparing the values obtained with maximum permissible limit (MPL) recommended by FAO/WHO for vegetables. The study results show that the concentration levels ranged from below detection limit (BDL) for Aluminum, Chromium, and Antimony (843 ± 16 ppm, 1.3 ± 0.2 ppm and 0.26 ± 0.03 ppm respectively) to Barium (7 ± 1.0 to 12 ± 1.0 ppm, Iron 11 ± 0.4 to 303 ± 36 ppm), Lanthanum (0.203± 0.03 to 1.93± 0.05 ppm), Manganese (22.9 ± 0.2 to 40.2 ± 0.2 ppm), Rubidium (7 ± 1 to 13± 1 ppm), Scandium (0.02± 0.00 to 0.05 ± 0.01 ppm), Samarium (0.02 ± 0 to 0.24± 0.01ppm), and Zinc (8± 1.0 to 24±0.1 ppm). This result also indicates that the maximum concentration value of Manganese exceeds the 25.95 ppm value of MPL recommended by FAO/WHO for vegetables therefore the consumption of Okra (*Abelmoschus esclentus)* cultivated from the study site has a potential health risk due to the presence of Manganese above recommended value.

Keywords: *Assessment, accumulation, heavy metals, irrigation, Okra (Abelmoschus esclentus)*

In recent years, there has been an increasing ecological and global public health concern associated with environmental contamination by heavy metals. (Tchounwou *et al.,* 2014). Industrial and domestic effluents constitute the largest sources of heavy metals which contribute to the steady increase of metallic contaminant in aquatic and terrestrial environment in most part of the world (Jibrin and Adewuyi, 2008; Oshodi and Ipinmoroti, 1990; Sekhar, 2003; Hamid *et al.,* 2017). It has also been observed that heavy metals and other pollutants are continuously discharged into the soils on a daily basis through land waste disposal, input from the atmosphere, metals from vehicular exhaust emissions and irrigation by municipal waste water (Uwah *et al.,* 2009; Matthews-Amune, 2018). Thus, pollution of the river water in big cities of developing countries are common because waste water treatment is not given the necessary priority it deserves hence industrial waste and domestic sewage are discharged into nearby water bodies without treatment due to disposal needs (Asonye *et al.,* 2009; Dan'azumi and Bichi, 2010).

Heavy metals have high density and mostly toxic in nature for human, plants and animals regardless of their concentrations due to their accumulation in food chain and persisted in nature (LWTAP 2004; Oves, *et al.,* 2012; Ahmed *et al.,* 2019). Therefore, food safety issues and potential health risks make this as one of the most serious environmental concerns (Cui *et al.,* 2004) because when such water is used for cultivation of crops for a long period, these heavy metals may accumulate in soil. An investigation by (Mortan *et al.,* 2004 and Mmolawa *et al.,* 2011) showed that considerable concentrations of heavy metals were found along major roads in Mexico City and Botswana respectively. Cultivated crops such as vegetables on contaminated soils could absorbed the heavy metals by through their root systems and transported to various parts of the plants reaching toxic levels as vegetables are known to accumulate heavy metals in their edible parts (Singh *et al* 2010, Khan, 2015) more so, this could be a primary route of human exposure to metal toxicants (Nabulo, 2010) hence heavy metals are viewed as an international problem due to its effects on the ecosystem in most countries. (Egila, *et al.*, 2019).

Research has shown that human exposure to heavy metal and intake were basically through food, inhalation and dermal contact (Khan, *et al.,* 2014; Ferre- Huguet *et al*., 2008; Kim, *et al.,* 2009; Martorell, *et al.,* 2011), Surveys have also shown that continuous consumption of concentrations of heavy metals through foodstuffs lead to large accumulations of the metals in the kidney and liver of humans causing disruption of numerous body processes, leading to cardiovascular, nervous, kidney and bone diseases (Sabina Braun 2015, Oladebeye, 2017).

Okra are vegetables that are cultivated and consumed by many people living in northern part of Nigeria, therefore they form an essential part of the indigenes diet and as food crops they are generally consumed for their nutrition value (Ramteke, *et al.,* 2016; Hang Zhou *et al., 2016*; Deribachew *et al.*, 2015) and they may contain a number of essential and toxic metals (Yang *et al.,* 2011; Waqas *et al.,* 2015).

The okra vegetables cultivated along the bank of river Ngadda and Alau dam during dry season were suspected to be contaminated with metal pollutants due to the fact that the soil and water might have mixed up with metal contaminants from solid waste deposal, sludge application, automobile exhaust, mining and smelting processes, urbanization, agricultural activities and industrialization which contribute heavy metals into the soil environment since the study area lies within the metropolis (Facchineli, *et al.,* 2001; Chen *et al.,* 1999; Tsai *et al.,* 2001; Shi *et al.,* 2005, Muchuweti, *et al.,* 2006, Tongesayi *et al.,* 2013) which the plant absorbed together with nutrients in the course of growth.

Therefore, the aim of the study was to assess the accumulation of heavy metals in okro cultivated through irrigation along the bank of river Ngadda and Alau dam with the objective to ascertain the food safety status of the vegetable by comparing the values obtained with the FAO/WHO MPL recommended for vegetables.

AIM OF RESEARCH

To assess the level of bio-accumulation of metal pollutants in okra cultivated during dry season through irrigation with water from river Nggada and Alau Dam.

OBJECTIVE

To compare the concentration values of the heavy metals accumulated in okra with the FAO/WHO recommended MPL for consumable vegetables so as to ascertain the health risk potential

MATERIALS AND METHODS

STUDY LOCATION

The major study areas were Shekwari and Custom bridge along river Ngadda in Maiduguri municipality and at Alau dam farmland along Bama road. These areas lie between 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. The work covers an area which is known for dry season farming of vegetables usually from the month of December to May because of the short rainy season of the region. The vegetation is of Savanna or tropical grassland with Sudan type of climate, light annual rainfall of about 864mm (34inches).

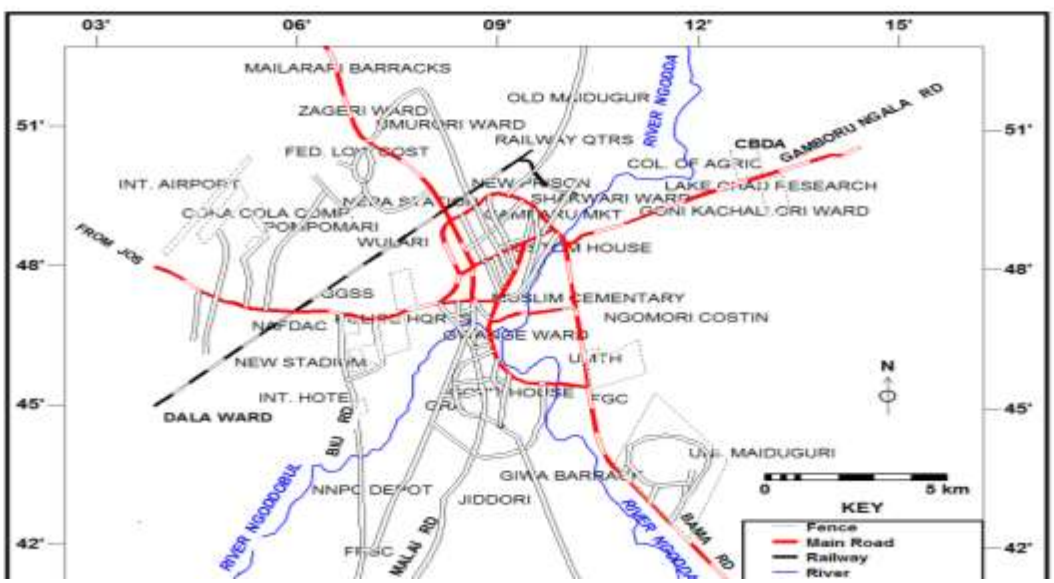

Figure 1: Maiduguri Township Map

Source: Land and Survey 2012

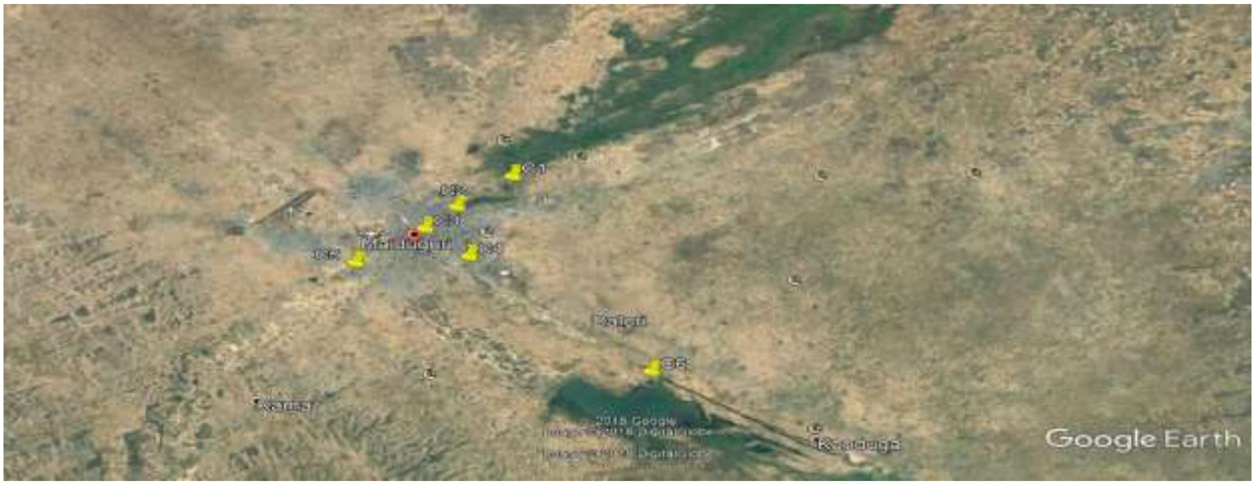

Figure 2: Okra Sample Sites Along the Bank of River Ngadda and Alau dam.

Source: Google earth

SAMPLE COLLECTION

Samples of fresh Okra were collected directly from the farm at six different locations along the bank of river Ngadda and Alau dam and labeled with codes (C1, C2, C3, C4, C5, C6) Figure 2 with their ordinates Table 1.

Table 1: Ordinates of Sample Locations

Locations	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
Ordinates	11^0 52´ 40´´ N	11^0 43´ 25´´ N	11^0 49´ 55´´ N	11^0 48´ 60´´ N	11^0 48´ 17´´ N	11^0 43´ 18´´ N
	13^0 12´ 12´´ E	13^0 16´ 70´´ E	13^0 09´ 16´´ E	13^0 10´ 72´´ E	13^0 48´ 17´´ E	13^0 16 63´´ E

The okra samples were cultivated during dry season using irrigation farming process with water from the river and the dam. The locations for the sampling points were obtained using Global Positioning System (GPSs). Samples were collected at different point in an area and homogenized to constitute a sample site.

SAMPLE PREPARATION

The samples, after collection, were transported to Herbarium in Biology Department at Ahmadu Bello University, Zaria for identification and thereafter taken to laboratory, thoroughly washed with running tap water and properly rinsed with double distilled water to remove any particulate pollutants that might had adhered to the samples. They were air dried and oven dried at low temperature and there after grounded using a clean mortar and pestle and sieved to required particle sizes using a sieve that was pre-cleaned. The samples were put in sample bottles, labeled, capped, and taken to Centre for Energy Research and Training (CERT) at Ahmadu Bello University, Zaria for further preparation and analysis.

INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS TECHNIQUE

Instrumental Neutron Activation Analysis (INAA) techniques is a sensitive method for accurate determination of elemental concentration in a matrix. In this work, we employed the Nigeria Research Reactor-1 (NIRR-1) facility located at (CERT), Ahmadu Bello University Zaria, Kaduna state, Nigeria. The detail and function of NIRR-1 was obtained in the work of Jonah, *et al.*, 2006; Jonah 2008).

Conventional method for sample preparation of vegetable samples for irradiation was adopted. The samples were put in a high density polythene vial, capped and sealed. Also Standard Reference Material (SRM) NIST) which is a direct representative of the sample was weighted of the same amount and put in the same type of vial with that of the sample, capped and sealed and both irradiated simultaneously.

SAMPLE ANALYSIS

The interaction of the sample and the neutron flux was based on the activation process expressed in Equation (1)

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

Where R = reaction rate, N = number of interacting isotope, σ(E) = cross-section (in cm) at neutron energy E (in eV), φ = neutron flux per unit of energy E (eV) and in terms of neutron velocity the interaction was as expressed in Equation (2)

$$R = \int \sigma(v)\phi'(v)dv\infty 0 = \int n(v)v\sigma(v)dv\infty 0 \qquad (2)$$

Where v the neutron velocity (m s^{-1}), $\sigma(v)$ 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 study, the relative method of neutron activation analysis for element determination in sample analysis was adopted, therefore the samples and standard were irradiated together and the induced intensities was measured. 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 to Equation (3)

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

where A_t is activity of element Q at the end of irradiation (d^{s-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 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 (4)

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

where A_{sam} is activity of the unknown sample, A_{std} is activity of the standard. Since the standard is irradiated and counted under similar conditions as the sample, common parameters in equation (4) cancelled out then the mass of the element in the sample relative to the standard comparator is calculated using equation

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

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

RESULTS AND DISCUSSION

The results of the concentration of the various heavy metals determined in okra samples from the various sites using INAA analytical is presented in Table 2. It was observed that the concentration values of the heavy metals varied from site to site therefore the values were grouped into three according to their magnitude of accumulation in the samples at the various site. and plotted into three graphs. This grouping was done for convenience and easy assessment only Figures 3a -3b.

Table 2: Concentration of elements determined in Okra at different locations

Sample Location	Al	Ba	Cr	Mn	Fe	Sm	Sb	Rb	Zn	La	Sc
C1	518±13	9±2.0	1.1±0.2	24±0.2	124±30.0	0.029±0.004	BDL	12±1	24.0±0.1	0.21±0.04	0.03±0.004
C2	452±19	10.4±1.6	1.0±0.2	22.9±0.2	219±35.0	0.24±0.01	0.13±0.03	11±1	24±3.0	1.93±0.05	0.040±0.06
C3	843±16	12±1.0	1.3±0.2	27.8±0.2	204±25.0	0.05±0.01	0.15±0.02	11±1	23±3.0	0.30±0.03	0.033±0.00
C4	437±10	10±2.0	1.2±0.2	25.0±0.2	303±36.0	0.044±0.00	0.26±0.03	12±1	8±1.0	0.29±0.03	0.04±0.01
C5	477±11	7±1.0	BDL	40.2±0.2	256±32.0	0.053±0.00	BDL	7±1	21±2.0	0.34±0.03	0.05±0.01
C6	BDL	8±2.0	BDL	22.9±0.2	1.1±0.4	0.02±0.00	BDL	13±1	8±1.0	0.203±0.03	0.02±0.00
LoD	2.2	0.28	0.23	1.0	0.83	0.1	NA	0.3	0.12	0.2	0.2
MPL	NA	NA	1.3	25.95	425.5	NA	NA	NA	99.4	NA	NA

Al Aluminum, Ba Barium, Co Cobalt, Mn Manganese, Fe Iron, Sm Samarium, Sb Antimony, Rb Rubidium, Zn Zinc, La lanthanum, Sc Scandium

LoD: Limit of Detection

BDL: Below Detection Limit

NA: Not available

MPL: Maximum Permissible Limit

All values in part per million (ppm)

DAILY INTAKE OF METALS (DIM)

The level of exposure from consumption of Okra vegetable investigated could be quantified using an index referred to as daily intake of metals (DIM) which was calculated using Equation (6)

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

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 of 0.085 from fresh to dry weight of vegetable 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 2005) and (FAO/WHO.

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 for two of the naturally abundant heavy metals Aluminum and Iron was carried out and based on the stated assumptions revealed a minimum of 2.32×10^{-1} mg and a maximum of 4.42×10^{-1} mg for adults and a minimum of $2{,}63 \times 10^{-1}$mg and a maximum of 5.08×10^{-1} mg for children in the case for Aluminum and a minimum of 3.3×10^{-4} and a maximum of 1.58×10^{-1} mg for adults and a minimum of 5.90×10^{-4} mg and a maximum of 1.82×10^{-1} mg for children in the case for Iron It can be observed from the results that the daily intakes of the two heavy metals; aluminum and iron in okra 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.

Figure 3a showed the graph of the concentrations of aluminum, manganese and iron determined in okra samples obtained on six farming sites along the bank of river Ngadda and Alau dam. It can be observed from the graph that at sites C1-C5 concentrations of Al > Fe > Mn. This variation trend in concentrations could be attributed to the fact that firstly, Al and Fe are naturally abundant and secondly since the study area was predominantly within or around the municipal council, anthropogenic activities might have contributed significantly to the deposit of heavy metals in the soils used for the cultivation of the vegetable and absorbed by the plants during growth. At site C6, Mn > Fe > Al, this is the reverse of the concentration value for trend of C1-C5. This variation trend could be due to the fact that site C6 was a sample site along Alau dam which was up the outskirt of Maiduguri metropolis and does not receive contaminants from the city storm therefore the soils used for the cultivation of okra had less abundance of aluminum and iron.

On comparing the concentration values of some of the heavy metals determined in okra with the values obtained in the work carried out by Chiroma *et al.*, in 2014 with regard to Okra cultivated through irrigation with urban grey waste water in Yola the state capital of Adamawa in the north eastern part of Nigeria, Fe, Mn and Zn had concentrations of 883, 306 and 478 ppm respectively. This values were much higher compared to the values obtained in this work. This could be attributed to the high concentrations of Fe, Mn and Zn of values 8, 2.93 and 2.4 ppm respectively in the grey waste water used for the irrigation compared to the 0.50, 0.20 and 0.20 ppm as the maximum allowable limit for irrigation water.

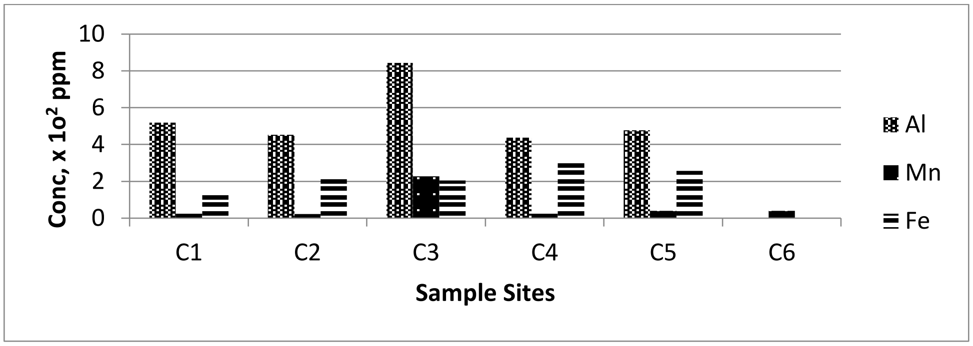

Figure 3a: Concentration of Elements Determined in okro samples

Figure 3b showed the graph of concentrations of Barium, Lanthanum, Rubidium, Zinc and Chromium. It can be observed that at Site C1- C5, Zn > Rb >Ba while at C6, Rb >Zn > Ba. The high values of zinc okra obtained at sites C1 – C5 could be due to the fact that they lied within the area where contaminants from city storm was predominant and might have mixed with soils and the water of river Ngadda therefore enhancing the concentrations of heavy metals in the soil used for the cultivation of okra vegetable.

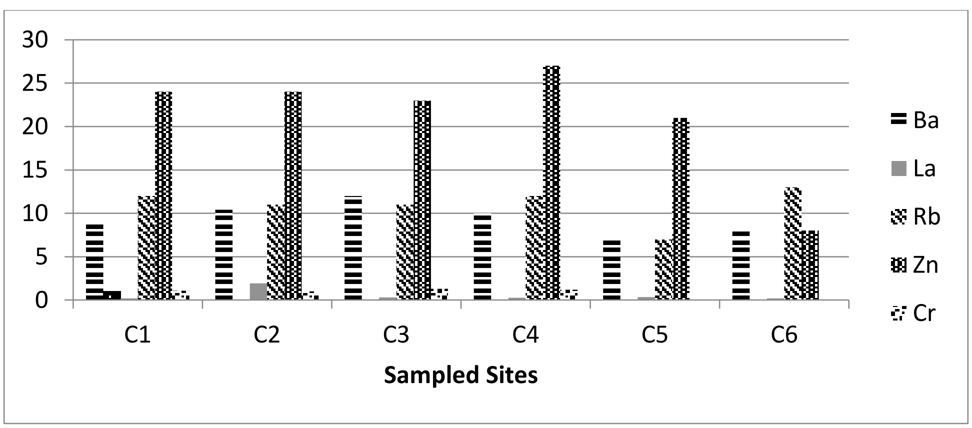

Figure 3b: Concentration of Elements Determined in okro samples

Figure 3c was the graph of Antimony, Samarium and Scandium determined in Okra samples obtained on six different sites C1- C6 along the bank of river Ngadda and Alau dam. The concentrations values of the heavy metals accumulated in okra was of the trend Sb > Sm > Sc with insignificant variation values.

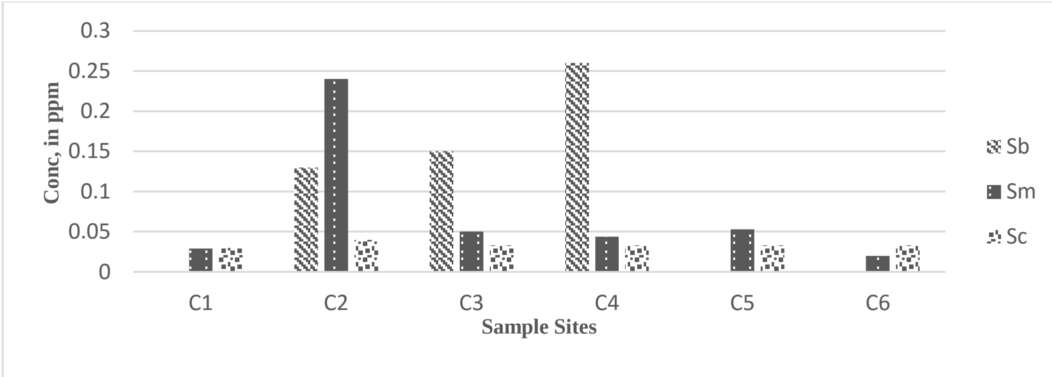

Figure 3c: Concentration of Elements Determined in okro samples

CONCLUSION

The concentrations of the heavy metals determined in Okra vegetable samples cultivated via irrigation on farmlands along the bank of river Ngadda and Alau Dam were mostly found to be within the acceptable limits recommended by FAO/WHO for vegetable besides those of manganese whose values were above the acceptable value. This result implies that the consumption of okra cultivated along the bank of river Ngada and Alau dam via irrigation during dry season constitute a public health risk due to the concentration of high level of level of manganese The heavy metals with concentrations values within recommended limit notwithstanding, does not rule out the possibility of a health risk since all heavy metals have potential to accumulate in the body and disrupt sensitive organs overtime. The study therefore recommends that regular evaluation and or monitoring of the levels of heavy metals in okra vegetables obtained from the study site be carried out even for those heavy metals found to be below the safe limit as the buildup of these elements in soil or water used for the cultivation and irrigation may increase unnoticed resulting in public health threats which only with experimental investigations that the values would be known.

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