



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

P. H. Bukar^{1*}, M. A. Onoja², J. A. Audu¹ and M. U. Saidu²

¹*Nigerian Institute of Leather and Science Technology, Zaria, Nigeria.*
²*Ahmadu Bello University, Zaria, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. Author PHB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MAO and MUS compute the daily intake of metals. Author JAA managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2020/v21i330135

Editor(s):

(1) Dr. Chandra Shekhar Kapoor, Mohanlal Sukhadia University, India.

Reviewers:

(1) Georgiana Eurides de Carvalho Marques, Federal Institute of Education, Science and Technology of Maranhão, Brazil.

(2) Paul Kweku Tandoh, Kwame Nkrumah University of Science and Technology, Ghana.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/55919>

Received 09 February 2020

Accepted 15 April 2020

Published 20 April 2020

Original Research Article

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 ± 18 to 3369 ± 54

*Corresponding author: E-mail: paul.hena@yahoo.com;

ppm, Co 0.12 ± 0.03 to 40 ± 4 ppm, La 1.00 ± 0.03 ppm to 38 ± 4 ppm, Manganese 112 ± 0.4 to 176 ± 1 ppm, Rubidium 4 ± 0.5 to 21 ± 1 ppm, Sc 0.10 ± 0.007 to 27 ± 1 ppm Sm 0.106 ± 0.004 to 17.2 ± 0.4 ppm, V 1.10 ± 0.3 to 4 ± 1 ppm and Zn 17 ± 3 to 63 ± 4 ppm, and Fe 379 ± 33 ppm to 2316 ± 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.

Keywords: Assessment; guinea sorrel; metal pollutants; permissible limit; fadama soils.

1. 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 [3-5] 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 could 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 Etorh [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 had shown that municipal refuse might 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.

2. 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°14'E at an altitude of 345 m above sea level Fig. 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.

2.1 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) Fig. 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.

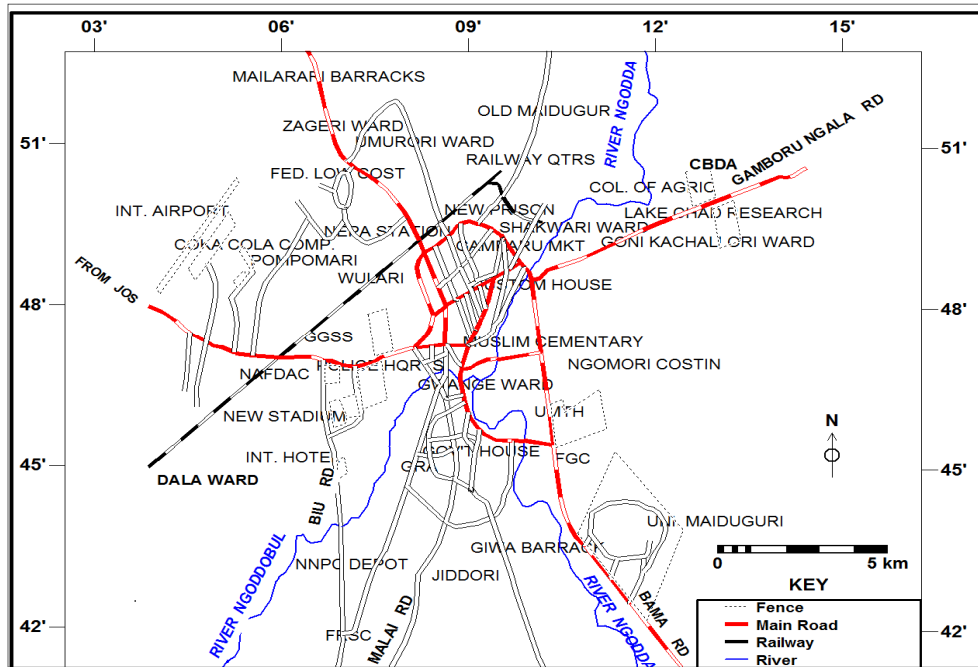


Fig. 1. Maiduguri township map showing river Ngadda
 Source: Ministry of Land and Survey



Fig. 2. Guinea sorrel sampled sites along river Ngadda and Alau dam

2.2 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.

2.3 Sample Preparation for Neutron Activation Analysis

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

Conventional method of sample preparation of vegetable samples for irradiation was used as provided by Jonah et al. [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.

2.4 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 Liyu [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 ($d s^{-1}$), σ_Q is neutron capture cross section of element (cm^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 ($m^{-2} s^{-1}$) and W_Q is weight of element Q irradiated.

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

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

where A_{sam} is activity of the unknown sample, A_{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)

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

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

3. 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 Figs. 3-5 by grouping them according to their concentration magnitudes and this was done for convenience and clarity.

3.1 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:

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

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

where M is the metal concentration in the vegetable (mg/kg), C is the conversion factor/ l 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 several authors [21-22].

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 1.2×10^{-3} mg and a maximum of 836.7×10^{-3} mg for adults, while the children had a minimum of 1.4×10^{-3} mg and a maximum of 961.9×10^{-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.

4. 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. Fig. 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 occurrence which might have aided 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 deposied the element on the cultivation soil through erosion, wind or town storm and absorbed by by the vegetable during growth. The concetratrion value of iron in Guinea Sorrelwas above MPL given by FAO/WHO.

Fig. 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

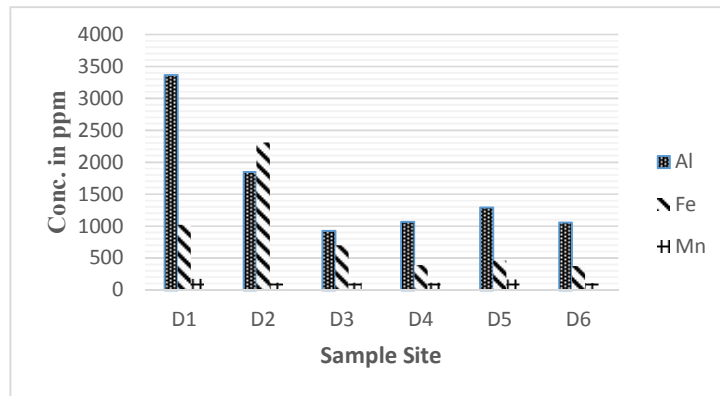


Fig. 3. Concentrations of elements determined in guinea sorrel

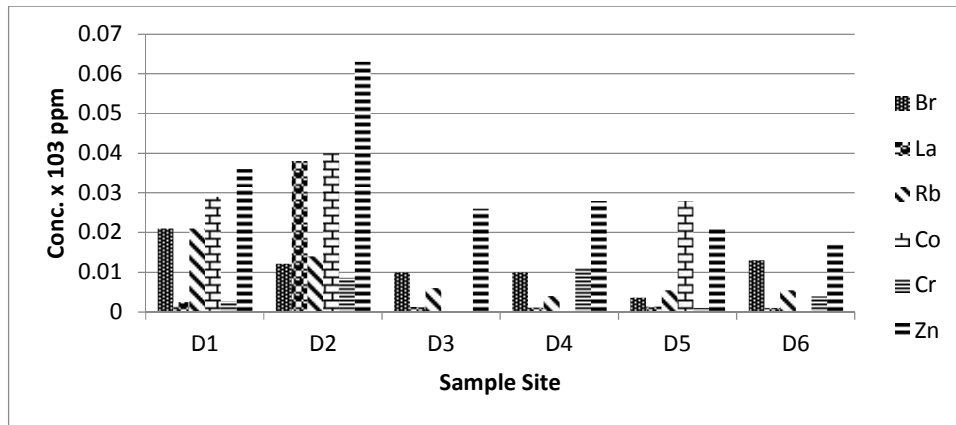


Fig. 4. Concentrations of elements determined in guinea sorrel

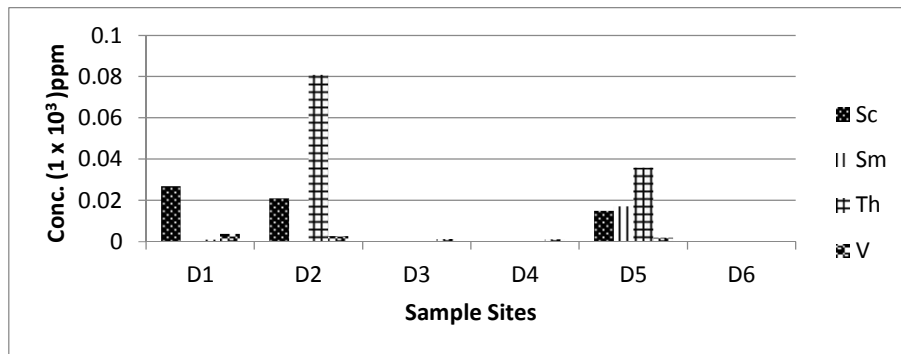


Fig. 5. Concentrations of elements determined in guinea sorrel

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.

Fig. 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.

5. 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 ± 65 , cobalt 29 ± 4 ppm, Chromium 11.3 ± 0.4 ppm, and Manganese 176 ± 1 ppm exceeded the safe limit recommended by FAO/WHO [23] of 425.5 ppm, 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Muchuweti M, Birkett JW, Chinyanga E, Zvauya R, Scrimshaw MD. Heavy metals content of vegetables irrigated with mixture of waste water and sewage sludge in Zimbabwe: Implication for human health. *Agril Ecos Env.* 2006;1124-48.
- Othman OC. Heavy metals in green vegetables and soils from vegetable gardens in Dar Es Salaam, Tanzania, Tanzania. *J.I of Scie.* 2001;27:37-48.
- Ramteke S, Sahu BL, Dahariya NS, Patel KS, Blazhev B. and Matini L. Heavy metal contamination of leafy vegetables. *J. of Env.l Protect.* 2016;7:996-1004.
Available:<http://dx.doi.org/10.4236/jep.2016.77088>
- Hang Z, Wen-Tao Y, Xin Z, Li L, Jiao-Feng G, Wen-Lei W, Jia-Ling Z, Tao T, Pei-Qin P, Bo-Han L. Accumulation of heavy metals in vegetable species planted in contaminated soils and the health risk assessment: *Int. J. Env. Res. and Public Health.* 2016;13:289.
- Deribachew B1, Amde Z, Nigussie-Dechassa R, Tadesse1 AM. Selected heavy metals in some vegetables produced through wastewater irrigation and their toxicological implications in Eastern Ethiopia African Scholarly Sci. Trust. 2012;15(3).
- Bahemuka TE, Mubofu EB. Heavy metals in edible green vegetables grown along the sites of the Sinza and Msimbazi Rivers in Dar es Salaam, Tanzania. *Food Chemistry.* 1991;66:63-66.
- Mapanda F, Mangwayana EN, Nyamangara J, Giller KE. The effect of long term irrigation using waste water on heavy metal content of soil under vegetable in Harare, Zimbabwe *Agric. Ecosystem Env.* 2005;105:153-165.
- Kalagbor IA, Barisere V, Barivule G, Barile S, Basse C. Investigation of the presence of some heavy metals in four edible vegetables, bitter leaf (*Vernonia amygdalina*), scent leaf (*Ocimum gratissimum*), water leaf (*Talinum triangulare*) and fluted pumpkin (*Telfairia occidentalis*) from a cottage farm in Port Harcourt Research. *J. of Env. and Earth Sci.* 2014;6(1):18-24.
- Alam MG, Snow ET, Tanaka A. Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh. *Sci. Total Env.* 2003;308:83-96.
- Zurera G, Mureno R, Salmeron J, Pozo R. Heavy Metal Uptake from Greenhouse Border Soil for Edible Vegetables. *J. of the Sci. of Food and Agric.* 1989;49:307-314.
- Nabulo G, Black CR, Young SD. Trace metal uptake by tropical vegetables grown on soil amended with urban sewage sludge. *Env. Pollut.* 2011;159:368-376.
- Egila JN, Ibrahim, EG, Ibrahim, MAG. Sequential extraction of lead, copper, zinc, cadmium and chromium in soil samples from Dumpsites in Lafia, Nasarawa State Nigeria, *Chem. and Materials Res;* 2014.
- Edorh P. Heavy metal action. *TWAS Newsletter.* 2007;19(2):42-45.
- Okoronkwo NE, Igwe, JC, Onwuchekwe, C. Risk and health implication of soils polluted for crops production. *Afric. J. of Biotech.* 2005;4:1521-1524.
- Okoronkwo NE, Odeelam SA, Ano OA. Levels of toxic elements in soil of abandoned waste dumpsite. *Afric. J. of Biotech.* 2006;5(13):241-244.
- Reyes-Gutiérrez R, Romero-Guzmán ET, Cabral-Prieto A, Rodríguez-Castillo R. Characterization of chromium in contaminated soil studied by SEM, EDS, XRD and mössbauer spectroscopy. *J.I of Minerals & Mat. Charact. & Eng.* 2007;7(1): 59-70.
- Jonah SA, Umar IM, Oladipo MOA, Balogun I, Adeyemo DJ. Standardization of NIRR-1 irradiation and counting facilities for instrumental neutron activation analysis, *Appl. Rad. and Isot.* 2006;64:818-822.
- Jonah SA. Epithermal neutron activation analysis of metal contaminants in Nigeria food additives using NIRR-1 facility, *Proceedings of the 3rd Env. Physics Conf., Aswan Egypt;* 2008.
- Liyu W. WINSPAN. A multi process Gamma-ray spectrum analysis software CIAS Beijing China; 2004.
- Rattan RK, Datta SP, Chhonkar PK, Suribabu K, Singh AK. Long-term impact of irrigation with sewage effluents on heavy metal contents in soil, crops and ground water – a case study. *Agric., Ecos and Env.* 2005;109:310–322.

21. Ge KY. The status of nutrients and meals of the Chinese in the 1990s. Beijing People's Hygiene Press. 1992;415–434.
22. Wang X, Sato T, Xing B, Tao S. Health risks of heavy metals to the general public in Tianjin, China via Consumption of Vegetables and Fish. *Sci. of the Total Env.* 2005;350:28–37.
23. FAO/WHO. Fruits and vegetables for health report of joint FAO/WHO workshop Kobe, Japan. 2005;39:1-3.

© 2020 Bukar et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<http://www.sdiarticle4.com/review-history/55919>