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Assessment of Metal Pollutants in Moringa Oleifera Cultivated Through Irrigation, in Maiduguri, Nigeria

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Abstract

Heavy metal contamination of food crops is a globally recognized environmental issue, threatening human life seriously. The aim of the study was to assessed heavy metal bioaccumulation in Moringa oleifera vegetables cultivated through irrigation during dry season along the bank of river Ngadda in Maiduguri, Nigeria. Concentration values of heavy metals; Aluminum, Barium, Cobalt, Iron, Manganese, Chromium, Rubidium, Scandium, Samarium, Vanadium and Zinc in Moringa oleifera were determined using instrumental neutron activation analysis (INAA) analytical technique. The objective was to ascertain whether there was health risk potential associated with the consumption of moringa oleifera cultivated in the study area by comparing the bio-accumulated heavy metals concentration values with FAO/WHO recommended maximum permissible limit (MPL) for edible vegetables. The result showed that the concentration values of the heavy metals analysed ranged from below detection limit (BDL) for Cobalt, Chromium, and Samarium to 33 ± 9 ppm, 8.1 ± 0.3 ppm and 0.20 ± 0.01 ppm respectively, Aluminum 8,3 ± 17 to 213 ± 30 ppm Barium 16.4 ± 2.6 to 233 ± 13 ppm, Iron 394 ± 38 to 2955 ± 68 ppm, Manganese 124.3 ± 0.4 to 319 ± 1 ppm, Rubidium 5.4± 0.5 to 17 ± 2 ppm, *Scandium 0.17 ± 0.01to 17 ± 1ppm, Vanadium 1.65 ± 0.27 to 2.8 ± 0.5ppm and Zinc 13 ± 2 to 55± 3.1ppm. These values indicate that the maximum bio accumulated values of the heavy metals iron, manganese, chromium and cobalt in moringa oleifera exceed the MPL recommended by FAO WHO of 425,5, 25.95, 1.3, and 1 ppm respectively for vegetables therefore the consumption of moringa oleifera cultivated from the study site has a potential health risk due to presence of heavy metals above MPL values.*

Keywords: *Assessment, Accumulation, Heavy metals, Irrigation, moringa vegetable*

Introduction

Heavy metals have high density and mostly toxic in nature for human, plants and animals regardless of their concentrations (LWTAP (20004), Oves *et al* 2012, Ahmed *et al* 2019). High level of environmental contamination by heavy metals is deleterious to health because of their uptake by vegetables/plants and accumulate in these food crops which were consumed by humans and animals because they contain carbohydrates, proteins, vitamins, minerals as well as trace elements (Ahiokwo and Kingsley, 2019, Onakpa *et al* 2018).

Research has shown that human exposure to heavy metal and intake were basically through food, inhalation and dermal contact (Khan *et al* 2015, Ferre-Haguet *et al* 2008, Kim *et al* 2009, Matorrell *et al* 2011) and 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 *et al* 2015).

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) of which industrial and domestic effluents constitute largest sources of the 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, Sekhar *et al* 2003 Hamid *et al* 2016). Moringa oleifera were vegetables cultivated and consumed by many people in northern part of Nigeria, they form an essential part of the human diet as food crops and also believed to have medicinal properties but as vegetables generally consumed because of their nutritional value (Rumteke *et al* 2016, Hang *et al* 2016, Deribachew *et al* 2015) but might contain a number of essential and toxic metals (Yang *et al* 2011, Waqas *et al* 2015).

Contaminated soils on which plants were cultivated could make them absorbed the heavy metals by their roots and transported to the various parts of the plants to toxic levels as vegetables are known to accumulate heavy metals in their edible parts (Singh *et al* 2010, Khan *et al* 2014) and this could be a primary route of human exposure to metal toxicants (Nabulo *et al* 2011) hence heavy metals is viewed as an international problem because of the effects on ecosystem in most countries.

Studies had also shown 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 a*l 2009, *M*orton- Bermea *et al* 2009, Mmolawa *et al* 2011, Mathew-amune *et al* 2018, Muchuweti *et al* 2006, Tongesayi *et al* 2013). 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* 2007, Dan'azumi and Bichi.

The authors were of the opinion that anthropogenic activities might have contaminated both the soils used for the cultivation of the vegetable along the bank of river Ngadda and the water used for the irrigation hence the study was aimed to assessed heavy metal bioaccumulation in Moringa oleifera vegetables cultivated through irrigation during dry season along the bank of river Ngadda in Maiduguri, Nigeria with the objectives of Comparing the concentration values of the heavy metals accumulated in moringa oleifera with the values given by FAO/WHO as MPL recommended for consumable vegetables and to ascertain whether there was health risk potential associated with the consumption of moringa oleifera cultivated in the study area.

Materials and Methods

The location of study was irrigation farmlands along bank the river Ngadda which cover an area that lies between latitude 11^{o} 48' N to 11 ^{o} 52'N and longitude 13 º 06' E to 13 º 14'E at an altitude of 345m above sea level Figure 1. The area of study is in a region known for its long dry season hence practice dry season farming of vegetables usually from the end of November to May because of the short rainy season. The vegetation is of Savanna or tropical grassland with Sudan type of climate, light annual rainfall of about 864mm (34inches).

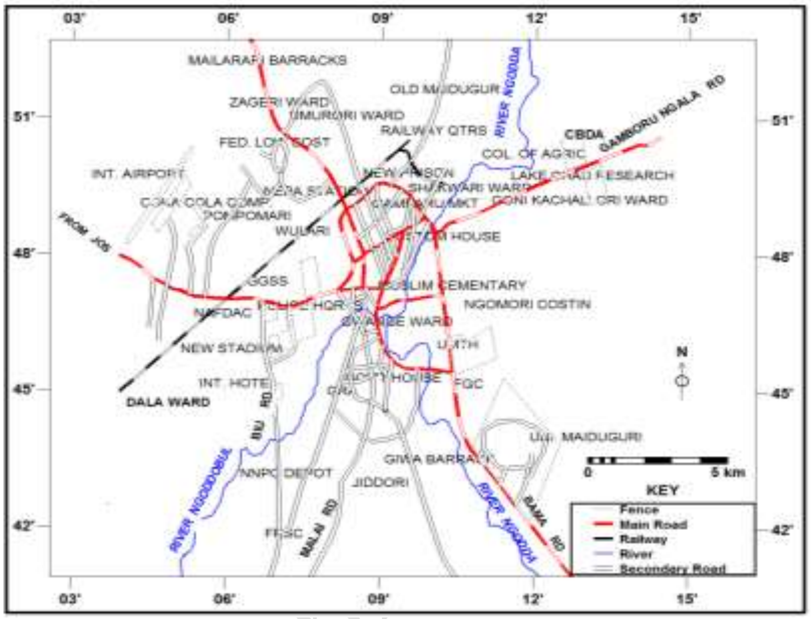

Figure1: Maiduguri Township Map
Source: Land and Survey 2012

Figure 2: Moringa Oleifera vegetable Sample Sites along the Bank of River Ngadda. Source: Google Earth.

Sample Collection.

Samples of fresh moringa oleifera vegetables were collected directly on three different sites on farmlands at different locations along the bank of river Ngadda and assigned the codes F1, F2, and F3 Figure 2. The samples collected were moringa vegetables cultivated during dry season using irrigation farming process with water from the river. The locations for the sampling points were obtained using Global Positioning System (GPSs). Samples were collected at different locations in an area and homogenized to constitute a sample site.

Sample Preparation.

The samples were transported to Herbarium in Biology Department at Ahmadu Bello University, Zaria for proper identification and thereafter taken to laboratory where they were 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. Samples were first air dried before 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

Instrumental neutron activation analysis (INAA) analytical techniques is a sensitive method for accurate determination of elemental concentration in a matrix. In this work, we used 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).

After preparation of the sample using the conventional method for sample preparation of vegetables for irradiation, the samples were put in a high density polythene vial, capped and sealed. Also Standard Reference Material (SRM) NIST) which was a direct representative of the sample was prepared using the same method and protocol 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)

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

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)

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

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.

Thus in this study, the relative method of neutron activation analysis for element determination in sample analysis was adopted, whereby 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)

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

where A_t is activity of element Q at the end of irradiation (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 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)

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

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

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

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

Result and Discussion.

Figure 3a-3c present the concentration values of the various heavy metals determined in moringa oleifera vegetable samples obtained from the three study sites using INAA analytical technique. It can be observed that the concentration values of the heavy metals varied from site to site therefore the values were grouped into three according to their magnitudes concentration values of bioaccumulation in the vegetable samples at the various site and plotted into three graphs. This grouping was made for clarity, convenience and easy assessment only Figures 3a -3b.

Figure 3a showed the graph of the concentration values of aluminum, iron, and manganese determined in moringa oleifera samples obtained on three sites along the bank of river Ngadda. It can be observed from the graph that at all the sites F1, F2, F3, concentrations of Al > Fe > Mn. The high concentrations of aluminum and iron could be attributed to the fact that firstly, aluminum and iron are naturally abundant and secondly since the study sites were predominantly either within or around the municipal council, anthropogenic activities might have contributed significantly to the deposit of the two heavy metals in the soils used for the cultivation of the moringa oleifera vegetables therefore absorbed by the plants during growth.

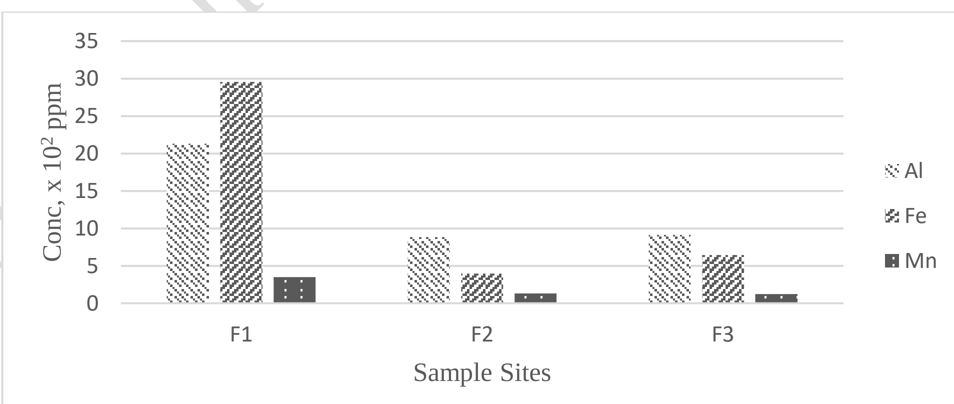

Figure 3a: Concentration of Elements Determined in Moringa Oleifera Samples

Figure 3b showed the graph of concentrations of Rubidium, Barium, Zinc, Vanadium and Cobalt. It can be observed that at Site F1; Zn > Ba > Rb > V > Co. The high concentration of Zinc at this site could be attributed to the fact the area of study was just after custom bridge and at a location just on the outskirt of the town in the direction of the flow of river Ngadda hence these could be either due to the deposition of waste materials on the land used for cultivation by the resident or the waste were eroded to the river sediment/farmland by natural phenomenon such as erosion, wind storm etc. At site F2; Ba > Zn > Rb > V > Co while at site F3; Co >Ba > Rb >Zn > V>. The high concentration value of cobalt at site F3 indicates that either anthropogenic activities such as excessive application of agrochemical was responsible for the high value or there was a natural occurring factor beneath the soil surface such as rock that release cobalt in the soil used for the cultivation of the vegetables

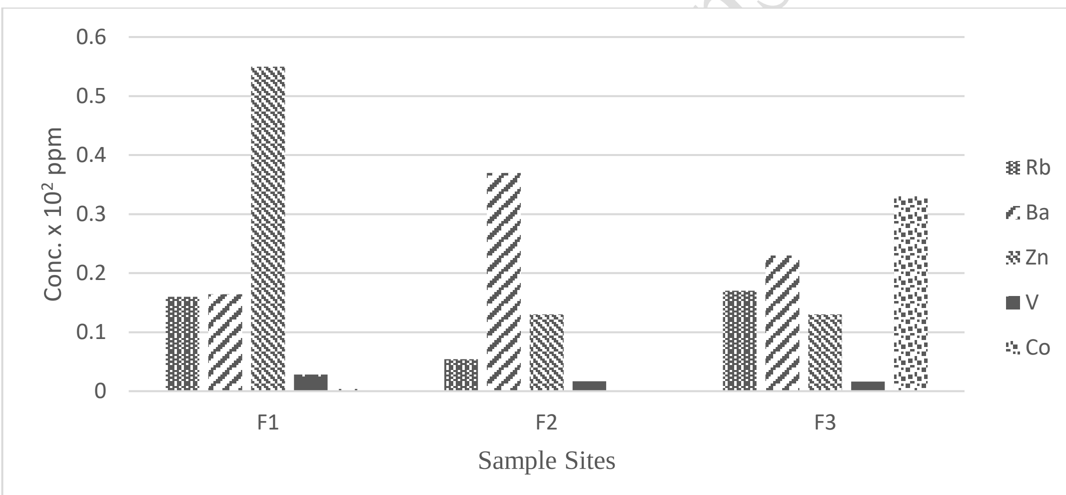

Figure 3b: Concentration of Elements Determined in Moringa Oleifera Samples

Figure 3c showed the graph of Chromium, Scandium and Samarium determined in moringa oleifera samples obtained on the three different sites F1, F2 and F3 along the bank of river Ngadda. The concentrations values of the heavy metals accumulated in the vegetable at site F1 varied as Cr > Sm > Sc. The high concentration of chromium bio accumulated in moringa suggest that there might be high concentration of the element in the soil which could be due to human enhanced activities or there was a rock with composition of chromium beneath the soil surface which release it in the soil. At site F2; Sc > Cr > Sm, while at site F3 Scandium was the only element bio accumulated to a detectable value.

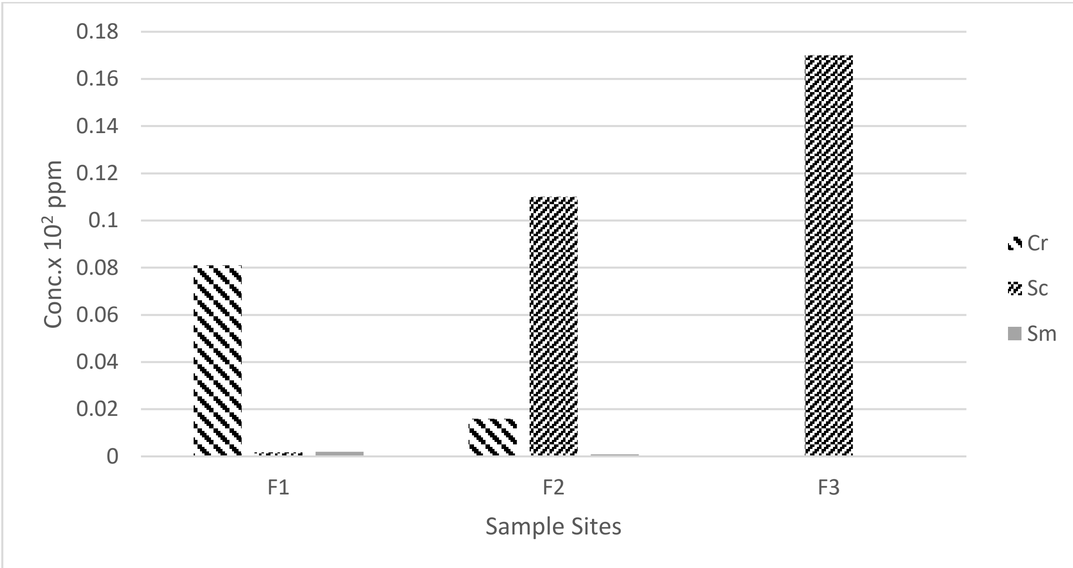

Figure 3c: Concentration of Elements Determined in Moringa Oleifera Samples

On comparing the concentration values of some of the heavy metals determined in moringa oleifera with the values obtained in the work carried out by (Ukpabi *et al* 2016) with regard to heavy metals in water leaf samples obtained at Aba, south east of Nigeria, concentrations of iron in water leaf samples ranged from 86.0 ± 1.92 to 110 ± 0.67 while Zn concentrations in water leaf samples ranged from 3.16 ± 0.87 to 76.1 ± 0.02. This values fairly correlate with values obtained in this work with little difference that could be attributed to difference in location and the type of vegetables involved in each of the study.

Daily Intake of Metals (DIM).

The level of exposure from consumption of Moringa oleifera 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 *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 for Aluminum, Iron manganese and Zinc was carried out and based on the stated assumptions revealed that for aluminum a minimum of 4.6×10^{-1}mg and a maximum of 11.17×10^{1} mg for adults and a minimum of 5.325×10^{-1} mg and a maximum of 12.85×10^{1}mg for children, for iron a minimum of 2.066×10^{-1}mg and a maximum of 15.50×10^{1}mg for adults and a minimum of 2.376×10^{-1}mg and a maximum of 17.82×10^{1} mg for children, for manganese a minimum of 6.520×10^{-2} mg and a maximum of 1.830×10^{-1} mg for adults and a minimum of 7.496×10^{-2} mg and a maximum of 2.104×10^{-1} mg for children while for Zinc a minimum of 6.819×10^{-3} mg and a maximum of 2.885×10^{-2} mg for adults and a minimum of 7.839×10^{-3} mg and a maximum of 3.316×10^{-2} mg for children, It can be observed from the results that the daily intakes of the heavy metals; aluminum, iron, manganese and zinc in moringa oleifera vegetables 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.

Conclusion

The concentrations of the heavy metals values determined in moringa oleifera vegetable samples cultivated during dry season through irrigation along the bank of river Ngadda were found to have iron, manganese, chromium and cobalt maximum values above the FAO/WHO maximum permissible limit (MPL) for vegetables. This result implies that the consumption of moringa oleifera vegetables cultivated along the bank of river Ngada via irrigation during dry season constitute potential health risk due to the high level of iron, manganese, chromium and cobalt bio accumulated by the vegetables at some cultivation sites.

The heavy metals with concentrations values within recommended limit notwithstanding, need to be assessed from time to time to ascertain their health risk potential posed to human being when consumed especially to children who were found to have higher DIM values than adults. The authors therefore recommended that regular investigation of the concentration levels of heavy metals bio accumulated in moringa oleifera vegetables obtained from the study sites be assessed periodically even for those heavy metals found to be currently below the safe limit as the buildup of these elements in soil or water used for the cultivation and irrigation might increase unnoticed thereby absorbed by the plants above threshold levels of which only with experimental investigations that the values would be ascertained.

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