UPTAKE AND RISK ASSESSMENT OF HEAVY METALS IN VEGETABLES GROWN IN BAYARA- BAUCHI, NIGERIA

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Abstract: Health risk index of chromium (Cr), cadmium (Cd)lead (Pb), copper (Cu), and zinc (Zn) have been determined on two vegetable samples (*Hibiscus cannabinus* and *Sesamumradiatum*), grown in Bayara–Bauchi. The levels of the heavy metals in the soil where the vegetables were grown were also determined. Atomic absorption spectrometer was used to estimate as well as evaluate the level of these heavy metals in the vegetables and soil. This study include the measurement of transfer factor (TF), daily dietary intake (DDI), daily intake of metal (DIM), health risk index (HIR) and target hazard quotient (THQ). The mean concentration of Cd, Cr, Pb, Cu, and Zn in *Hibiscus cannabinus*were 3.05±0.01, 0.78±0.01, 0.12±0.01, 3.55±0.02 and 21.88±0.01 mg/kg, were 3.0±0.00,0.55±0.02, ND, 0.22±0.01 , and 24.17±0.00 mg/kg in *Sesamumradiatum* and in the soil were 2.62±0.02, 6.50±0.01, ND, 1.67±0.02 and 26.55±0.03 mg/kg, respectively. All the values obtained were below the permissible limit recommended by WHO/FAO except for Cd in both *Hibiscus cannabinus* and *Sesamumradiatum*. It is concluded that these vegetables are safe for public consumption as they do not contain the amount of the heavy metals that would constitute danger of metal poisoning. The HRI and THQ ≥ 1 indicated that there is potential health risk associated with Cd. Precautionary measures should be taken to avoid bioaccumulation and biotransformation of the heavy metals.

Keywords: Heavy metals, vegetables, risk, Bayara–Bauchi.

Introduction

Vegetable plants form the major component of most African dishes providing the most needed nutritional needs of the consumers such as minerals, vitamins, iron, calcium, protein and other nutritional requirements. They also contain heavy metals at wide range of concentrations (Afshin and Masond, 2008). Heavy metals contamination of soil through anthropogenic activities is a widespread and serious problem confronting scientists and regulators throughout the world (Li *et al*., 2001). Heavy metals are non-biodegradable and persistent environmental contaminants which may be deposited on the surfaces and then absorbed into the tissue of vegetables. Plant take up these heavy metals by absorbing them from deposits on the parts of the plants exposed to the air from polluted environment as well as from contaminated soil (Sharm*et al.*, 2008). Contamination of vegetables with heavy metals such as Pb, Cr, Cd, Mn, As, Co and Ni may be due to irrigation with contaminated water, and metal-based pesticides, industrials emissions, transportation of the harvest products, storage and or at the point of sales (Afshin and Masound, 2008). Clearly, not only the ingestion or inhalation of contaminated particles, but also the ingestion of plants produced by contaminated area is another principal factor contributing to heavy metals of exposure for population (Dudka and Miller, 1999). The poisoning effects of heavy metals are due to their interference with normal body biochemistry in normal metabolic processes (Okunola *et al.*, 2011).

Vegetables are and also have beneficial anti-oxidative effects. Heavy metal contamination of vegetables cannot be underestimated as these foodstuffs are important component of human diets. Prolonged consumption of contaminated vegetables may lead to the increasing accumulation of toxic metals in the liver and kidney of humans resulting in the disturbance of biochemical processes such as liver, kidney, cadio-vascular, nervous and bone disorders. Therefore there is a need to ascertain the values of these heavy metals in vegetables grown in Bayara-Bauchi. The aim and objectives of this study is to determine the level of heavy metals in *Hibiscus cannabunus*and*Sesamumradiatum*vegetables grown in Bayara – Bauchi and their, transfer factor (TF), daily dietary intake (DDI) daily intake of metal (DIM), health risk index (HIR) and target hazard quotient (THQ).

Materials and Method

Samples collection

Samples of the edible vegetables (*Hibiscus cannabinus, Sesamumradiatum*) were randomly collected from a farm in Bayara. The samples were taken to the laboratory and washed with clean tap water first to remove the soil particles adhered to the sample of vegetable and then followed by double washing with distilled water (Lawal and Audu, 2011). The roots were cut off, the leaves and the stem were chopped into smaller pieces. The soil sample was collected from the same farm lands where the vegetables were collected at a depth of 15 cm from the surface of the soil. The samples were packaged in cleaned containers and properly labeled.The sample of vegetables was dried at 150^oC in the oven. The dried samples were ground into fine powder using mortar and pestle.

Digestion of the sample

A 3.0 g sample of vegetables (*Hibiscus cannabinus* and *Sesamumradiatum*) and the soil sample was digested with 15 ml of tri acid mixture (HNO_3, H_2SO_4 & $HClO_4$ in 5:1:1 ratio) at 80^oC until transparent solution is obtained (Allen *et al.*, 1986). The solution was then cooled and filtered using Whatman No. 42 filter paper and the filtrate was maintained to 50 ml with distilled water.

Atomic absorption spectrophotometer analysis

The concentration of Pb, Cr, Cd, Cu and Zn in the filtrate of digested plant samples was estimated by using an atomic absorption spectrophotometer. The instrument was calibrated manually with prepared standard solution of respective heavy metal and the blank.

Transfer factors (TF)
The transfer factor is an index of the ability of the vegetable to accumulate a particular metal with respect to its concentration in the soil substrate which was calculated for each metal species as follow:

$$TF = \frac{metalconcentrationinplanttissue}{metalconcentrationinsoil}$$

Daily intake of metal (DIM)
The daily intake of metal (DIM) was determined using the equation

$$DIM = \frac{C_{metal} \times C_{factor} \times D_{foodintake}}{BW_{average}}$$

Where C_{mental}= the heavy metal concentration in vegetable (mg/kg), C_{factor}= conversion factor
The conversion factor 0.085 is to convert fresh vegetable weight to dry weight.
D_{food}intake = The average daily vegetable intake for 20 people (male and female) was calculated to be 0.688 kg/person/day and having an average body weight ($BW_{average}$) of 64.3 kg from the experimental area.

Daily dietary intake (DDI)
The Daily Dietary intake of metals expresses the dietary availability of metals in a particular food and is essential in risk assessment of metal.
The daily dietary intake of metal was determined by using formula:

$$DDI: \frac{x \times Y \times Z}{B}$$

Where x = metal in vegetable, Y= dry weight of the vegetable, Z= approximate daily intake, B= average body weight 64.3kg

Health risk intake (HRI)
The health risk index for the locals through the consumption of contamination vegetable is defined as a quotient between the estimated exposure to daily metal intake (DIM) from soil through food chain and reference dose (RfDo). Therefore the health risk index can be calculated by using formula:

$$HRI = \frac{DIM}{RfDo}$$

Where DIM represents the daily intake of metals
RfDo represent reference oral dose. RfDo value for Pb, Cr, Cd, Cu, & Zn is 0.004, 1.5, 0.001, 0.04 and 0.30 (mg/kg bw/day), respectively (US-EPA IRIS, 2006).

Target harzard quotient (THQ)
This is defined as the ratio of the body intake dose of a metal to the reference dose. The THQ can be calculated by using formula: $THQ = \frac{D_{foodintake} \times C_{metal}}{RfDo \times BW_{average}}$

Where $D_{food\ intake}$ = Daily intake of vegetables (kg/day)
C_{metals} = Heavy metal concentration in vegetable.
RfDo = Represent reference oral dose for metal (mg/kg bw/day)
$BW_{average}$ = average body weight 64.3 kg
- If the THQ ≥ 1 there will be potential health risk.
- If the THQ < 1 there will be no potential health risk.

Results and Discussion
The results obtained from the health risk index of heavy metals (Cd, Cr, Pb Cu and Zn) in *Hibiscus cannabinus*, *Sesamumradiatum*and the soil where these vegetables were grown.The availability of a metal in its different forms to migrate from the soil through the plants part and makes itself available for consumption was represented by the transfer factor as seen in Fig 1. The Daily Dietary Intake of Zinc metal in both vegetables is higher than the DDI of the other metal as shown in the Fig 2. Also, Fig. 2 indicates that the daily dietary intake (DDI) of Zn in both vegetables (*Hibiscus cannabinus and Sesamumradiatum*) was the highest 70.23x10^{-5} and 77.59 x 10^{-5} mg/person/day.The trend for DDI of *Hibiscus cannabinus* is found to be in the order Zn>Cu>Cd>Cr>Pb while in *Sesamumradiatum* is Zn>Cd>Cr>Cu>Pb.
In Fig. 3, the DIM as a function of body weight and intake, Zn has the highest value of DIM of both vegetables (*Hibiscus cannabinus* and *Sesamumradiatum*) of 198.9 x 10^{-4} and 219.8 x10^{-4} mg/kg/person/day.The trend of DIM in *Hibiscus cannabinus*was found to be in the order of Zn>Cu>Cd>Cr>Pb andZn>Cd>Cr>Cu>Pb in *Sesamumradiatum*

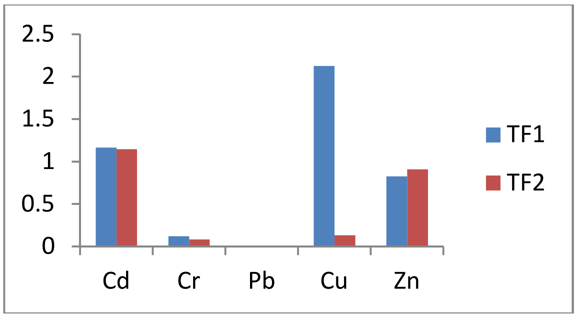

Fig. 1: TF for for *Hibiscus cannabinus* (TF1) and *Sesamumradiatum* (TF2)

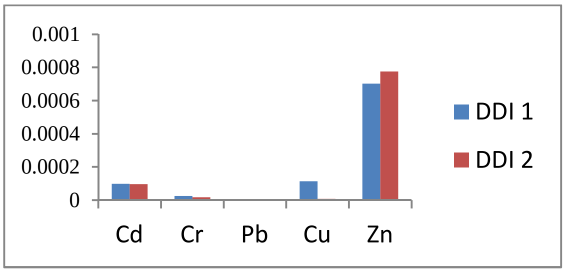

Fig. 2: DDI for *Hibiscus cannabinus* (DDI 1) and *Sesamumradiatum* (DDI 2)

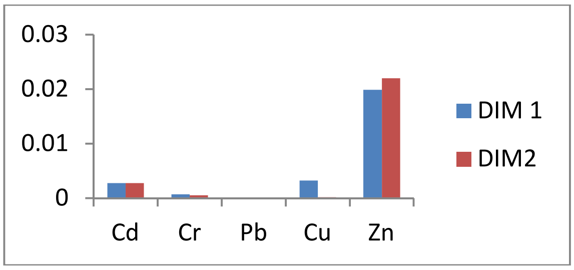

Fig. 3: DIM for *Hibiscus cannabinus* (DIM1) and *Sesamumradiatum* (DIM2)

Health risk index for metals in *Hibiscus cannabinus* and *Sesamumradiatum*and presented in Fig. 4. The results showed that the order of HRI in *Hibiscus cannabinus* was Cd>Cu>Zn>Pb>Cr and Cd>Zn>Cu>Cr>Pb in *Sesamumradiatum*. This simply means that the inhabitants were highly exposed to health risk associated with these metals, especially Cadmium (Cd). In Figs. 4 and 5, the health risk index (HRI) and target harzard quotient (THQ) for Cd, Cr, Pb, Cu and Zn were calculated. The results showed that Cd had the highest of HRI (2.7700) and THQ (32.64) in *Hibiscus cannabinus* and Cd still had the highest of HRI (2.7300) and THQ (32.100) in *Sesamumradiatum.* The HRI and THQ values of Cd for both vegetables were ≥1. Therefore, there is potential health risk of Cd related diseases e.g renal, prostrate and ovarian cancers. The THQ for all the metal is less than 1 except Cd in both plants. Therefore, there is potential health risk associated with Cadmium (Cd).

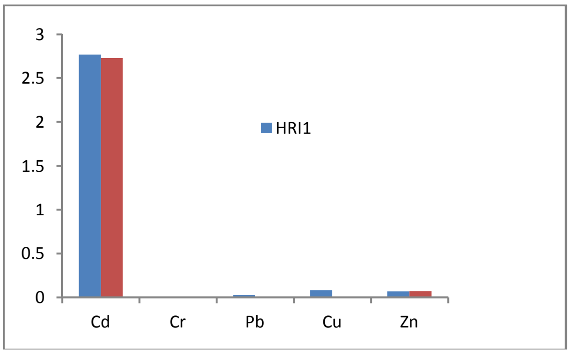

Fig. 4: Health Risk Index for *Hibiscus cannabinus* and (HRI1) *Sesamumradiatum* (HRI2)

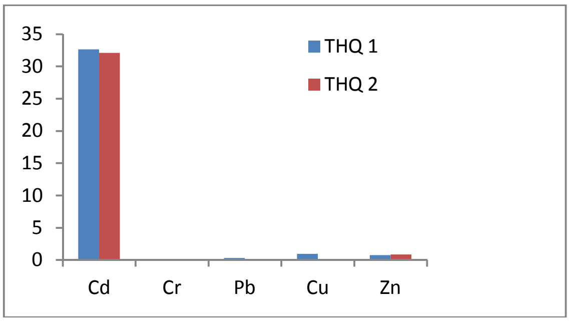

Fig. 5. Target Hazard Quotient for *Hibiscus cannabinus* (THQ1) and *Sesamumradiatum* (THQ2)

The result showed that, in *Hibiscus cannabinus,* Zn has the highest value (21.88 mg/kg), while Cr (0.78 mg/kg) and Pb (0.12 mg/Kg) levels were low. In the *Sesamumradiatum,* Zn value (24.17 mg/kg) was also the highest and Pb was not detected in the soil, Zn also has the highest value (26.55 mg/kg) and Cu has the lowest (1.67 mg/kg), Pb was not detected in the soil sample as shown in Table 1. The trend in the plant *Hibiscus cannabinus* was Zn>Cu>Cd>Cr>Pb, Zn>Cd>Cr>Cu>Pb in *Sesanumradiatum* and Zn>Cr>Cd>Cu>Pb in the soil sample. The variation of the heavy metals in the plant and the soil is due to the differences in the sources of the metals. Some of the metals may be present in the plant and the soil will also contribute to the metal bioavailability.

Table 1: Heavy metal concentration (mg/kg) in soil and vegetables (*Hibiscus cannabinus* and *Sesamumradiatum*)

Heavy Metals	Soil	*Hibiscus cannabinus*	*Sesamumradiatum*
Cd	2.62 ± 0.02	3.05 ± 0.01	3.00 ± 0.00
Cr	6.50 ± 0.01	0.78 ± 0.01	0.55 ± 0.02
Pb	ND	0.12 ± 0.01	ND
Cu	1.67 ± 0.02	3.55 ± 0.02	0.22 ± 0.01
Zn	26.55 ± 0.03	21.88 ± 0.01	24.17 ± 0.00

ND = Not Detected

Table 2: Comparative heavy metals concentration (mg/kg) in soil samples with similar work reported in the literature and the maximum permissible limits in some countries

Heavy Metal	Conc. in Soil	Wu, 2010	Great Britain*	USEPA**
Cd	2.62	0.55	3	3
Cr	6.50	44.72	50	400
Pb	ND	216.93	400	300
Cu	1.67	54.13	100	50
Zn	26.55	118.06	300	200

*Maximum permissible limit of metals (mg/kg) in soil in Great Britain; ** Maximum permissible limit of metals (ppm) in soil by USEPA (1985); ND: Not determine

Comparisons of heavy metals in soil in this study and other literatures (Table 2) showed a difference from the one reported in the literature by Wu *et al*. (2007). The result in this study is less than the British, USEPA and Japan standard permissible limit of metals in the soil of those countries with the exception of Cd which is greater than Japan standard permissible limit but less than the Britain and USEPA permissible limits. This is a very toxic heavy metal that should be monitored to prevent further outbreak of Cd related sicknesses. It is found that Copper has the highest TF value (2.126) in the *Hibiscus cannabinus* and Cd has the highest TF value (1.145) in the *Sesamumradiatum*. Sridthara *et al*. (2008) reported that high TF for heavy metals through leafy vegetables. The TF does not present the risk associated with the metals in any form.

The concentration of Cd, Cr, Pb, Cu and Zn for soil and vegetables (*Hibiscuscannabinus* and *Sesamumradiatum*) is shown in Table 1. The results showed an irregular pattern of heavy metal availability. Zn has the highest in the soil (26.55 mg/kg) and in vegetables (*Hibiscus cannabinus* and *Sesamumradiatum*) 21.88 mg/kg and 24.17 mg/kg, respectively. Pb was not detected in both soil and *Sesamumradiatum* but detected in *Hibiscus cannabinus* (0.12 mg/kg). These variations of heavy metal in soil and vegetables are due to differences in the sources of the metal. Some of the soil will contribute to the metal bioavailability in the plant.

Comparisons of heavy metals in soil in this study and other literatures (Table 2) showed a difference from the one reported by Wu *et al.* (2010). The result of heavy metals (Table 3) in vegetables in this work were compared with similar work reported by Anthony and Balwant (2005) as this work were less than that of the compared results and in some cases higher than the maximum permissible limit of the Indian standard and WHO/FAO (2007). Example, Cd in *Hibiscus cannabinus*and *Sesamumradiatum*was higher than the maximum permissible limit when compared with WHO/FAO (2007), Indian(2007) and Anthony Balwant (2005) standards.Cu in *Hibiscus cannabinus*is higher than that of Anthony Balwant 2005 but less than the Indian and WHO/FAO (2007) standards.Therefore, it has to be monitored in order to prevent further outbreak of Cd sickness.

Table 3: Comparison heavy metals conc. (mg/kg) in vegetable samples with similar work reported in the literature and the maximum permissible limit in some countries and WHO/FAO

Heavy Metals	*Hibiscus cannabinus*	*Sesamumradiatum*	Indian standard	Anthony Balwant 2005	**WHO/ FAO
Cd	3.05	3.00	1.5	0.361	0.2
Cr	0.78	0.55	20	ND	NA
Pb	0.12	ND	2.5	4.31	**5.0
Cu	3.55	0.22	30.0	1.01	40.0
Zn	21.88	24.17	50.0	54	60

Source: *Anita *et al*. (2010); **WHO/FAO (2011); ND = Not Determined NA = Not Analyzed

Table 4a: Different parameters (TF, DDI, DIM, HRI, THQ) for *Hibiscus cannabinus*

Heavy Metals	Conc. in Soil	Conc. in *Hibiscus cannabinus*	TF	DDI (mg/person/day)	DIM (mg/kg/person/day)	HRI	THQ
Cd	2.62	3.05	1.164	$9.79x10^{-5}$	$27.7x10^{-4}$	2.7700	32.64
Cr	6.50	0.78	0.120	$2.50x10^{-5}$	$7.1x10^{-4}$	0.0005	0.006
Pb	ND	0.12	0.000	$0.39x10^{-5}$	$1.1x10^{-4}$	0.0275	0.321
Cu	1.67	3.55	2.126	$11.39x10^{-5}$	$32.3x10^{-4}$	0.0808	0.949
Zn	26.55	21.88	0.824	$70.23x10^{-5}$	$198.9x10^{-4}$	0.0663	0.7804

Table 4b: Different parameters (TF, DDI, DIM, HRI, THQ) for *Sesamumradiatum*

Heavy Metals	Conc. in Soil	Conc. in *Sesamumradiatum*	TF	DDI (mg/person/day)	DIM (mg/kg/person/day)	HRI	THQ
Cd	2.62	3.00	1.145	$9.63x10^{-5}$	$27.3x10^{-4}$	2.7300	32.100
Cr	6.50	0.55	0.085	$1.77x10^{-5}$	$5.0x10^{-4}$	0.0003	0.004
Pb	ND	ND	-	-	-	-	-
Cu	1.67	0.22	0.132	$0.71x10^{-5}$	$2.0x10^{-4}$	0.0050	0.059
Zn	26.55	24.17	0.910	$77.59x10^{-5}$	$219.8x10^{-4}$	0.0733	0.862

ND: Not Determined; TF: Transfer Factor; DDI: Daily Dietary Intake; DIM: Daily Intake of Metal; HRI: Health Risk Index; THQ: Target Harzard Quotient

Cu had the highest transfer factor (TF) value (2.126) in *Hibiscus cannabinus* while Cd was the highest (1.145) in *Sesamumradiatum*. Sridthara *et al*. (2008) reported that high TF for heavy metals for leafy vegetables. The TF does not present the risk associated with metals in any form.

The trend of the TF value was Cu>Cd>Zn>Cr>Pb in *Hibiscus cannabinus* while in *Sesamumradiatum* was Cd>Zn>Cu>Cr>Pb. Variations in TF among different vegetables may be attributed to differences in the concentration of metals in the soil and differences in element uptake by different vegetables (Cui *et al.,* 2004). In Fig. 2, the daily dietary intake (DDI) of Zn in both vegetables (*Hibiscus cannabinus* and *Sesamumradiatum*) was the highest $70.23x10^{-5}$ and 77.59×10^{-5} mg/person/day.

Conclusion

Based on the results obtained from the analysis using AAS technique and the analysis made by comparing the detected concentration of Cd, Cr, Pb, Cu and Zn in *Hibiscus cannabinus*, *Sesamumradiatum*andthe soil sample with the recommended concentration put forward by WHO. These vegetables were safe for public consumption as they do not contain the amount of the heavy metals that would constitute danger of metal poisoning. The HRI and THQ indicate that the heavy metals are not dangerous to consumers. Only Cd in *Hibiscus cannabinus* and *Sesamumradiatum*exceeded the maximum permissible limit and has to be monitored in order to prevent Cd disease outbreak.

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