J. Basic. Appl. Sci. Res., 2(7)6708-6714, 2012
© 2012, TextRoad Publication

ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Evaluation of Heavy Metals Uptake and Risk Assessment of Vegetables Grown in Yargalma of Northern Nigeria

[1*]Tsafe A. I, [1]Hassan L G, [2]Sahabi D.M, [3]Alhassan Y, [1]Bala B M,

[1] Department of Chemistry, Usmanu Danfodiyo University, P.M.B 2346, Sokoto-Nigeria
[2]Department of Biochemistry, Usmanu Danfodiyo University, P.M.B 2346, Sokoto-Nigeria
[3]National Research Institute for Chemical Technology, P.M.B 1052, Zaria-Nigeria

ABSTRACT

The presence of heavy metals in our environment (soil, water and air) and in food (vegetables, beverages, drinks and so on) is not a new phenomenon. The uptake of these metals by humans via consumption of such produce has been reported by many authors from different parts of the world. This work evaluated the HM uptake of vegetables grown in Yargalma in northern Nigeria and assessed risks involved in consumption of such vegetables were assessed. The results revealed the trend in soil metals concentration is Al > Fe > Mn > Mg > Zn > Pb > Ni > Cr > Co > Cu > Cd and for the plant the trend is Fe > Mn > Mg > Zn > Al > Co > Ni > Pb > Cr > Cu > Cd. The transfer pattern for metals from soil to plant is Co > Cu > Cd > Mg > Ni > Zn > Mn > Fe > Pb > Cr > Al. The trend of the DIM value was Fe > Mn > Mg > Zn > Al > Co > Ni > Pb > Cr > Cu > Cd. The trend in DDI was found to be slightly different to the one above, such that it followed the trend Al > Fe > Mn > Mg > Zn > Pb > Ni > Cr > Co > Cu > Cd. The result showed very high HRI values for Cd (65.38), Zn (11.48) and Cu (2.09) while the THQ was similar to the HRI. This confirmed that the soil and vegetables in the area were contaminated with the assayed metals.

Key words: heavy metals, DDI, HRI, THQ and Yargalma.

INTRODUCTION

In the last decades, there has been growing interest in determining heavy metals in foods and other common food contaminants. The poisoning effects of heavy metals are due to their interference with normal body biochemistry in the normal metabolic processes (Okunola *et.al*, 2011).

The mining industry has contributed in the development of many countries that have vast deposits of solid minerals. It plays a significant role in creation of jobs in most developing countries like Nigeria. However, mining activity is always associated with deposition of heavy metals into the environment as reported by many authors (Indrajit et al, 2011). The mining region of northern Nigeria has been known since the colonial era. The popular among them is the Jos and in late 70's the Zamfara mining belt. The Zamfara mining region has deposit of precious minerals like tantalite (Alhassan *et.al*) and gold among others. In early 2010, the Federal government of Nigeria had declared lead poisoning in this mining area. This was after reported deaths of over 80 children within few months in two communities where mining of gold were taking place. A total of over 350-400 deaths were reported in those communities. This had instigated an intensive research into the water and food sources. One of the major vegetable consumed by these communities is spinach. Contamination of vegetables with heavy metals may be due to irrigation with contaminated water, the addition of fertilizers and metal-based pesticides, industrials emissions, transportation, the harvest process, storage and or at the point of sales (Afshin and Masoud, 2008).

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 both essential and toxic elements, such as heavy metals at wide range of concentrations (Afshin and Masoud, 2008).

The health implications of heavy metals like Ni, Pb, Co, Cr, Al, Zn and Cd had been fully documented. Significant contamination of seeds, plants and plant products with toxic chemical elements due to contaminated soil and water has been observed as result of release of these toxicants into the sea, rivers and even into irrigation channels. Afterwards, the consumption of contaminated vegetables constitutes an important route of animal and human exposure (Sajjad *et.al*, 2009).

This paper presents the uptake of vegetables grown in the region to explain the heavy metals availability and possible entry into humans through food chain. It assessed the heavy metals in vegetables grown in the lead poisoned area with a view help in continues monitoring to prevent accumulation through provision of adequate

***Corresponding author**: Tsafe A. I , Department of Chemistry, Usmanu Danfodiyo University, P.M.B 2346, Sokoto-Nigeria.
E-mail: tsafeai@yahoo.co.uk.

information and prepare for cleanup and other remediation in case of another possible outbreak. To the best of our knowledge, there is no established literature on the acceptable or permissible limit of heavy metals in fresh vegetables in Nigeria, especially those grown in mining areas of the country.

Study area

Yargalma is a small community of not more than Five thousand people. It is located about 6 KM off Gummi-Zurmi road in Bukkuyum local Government area of Zamfara state in Northern Nigeria. The main mining activity is not carried out in the area, but artesian miners from the village bring the mined tillage into their houses to complete the isolation and purification. These processes include; milling and continues washing until the concentrate is gotten. Consequently, there was so much interaction with the tillage.

MATERIALS AND METHODS

All the reagents used were analytical grade (AnalaR) chemicals and all the glassware, containers and tools were washed with liquid detergent first, rinsed with 20% (v/v) nitric acid and finally rinsed with distilled water. The containers and glassware were kept in oven until needed. Distilled water was used throughout the work.

Sample collection and Treatment

Samples of the edible vegetables (Spinach) were randomly collected during dry season from the community farmlands around the area in October, 2010. A total of thirty samples were collected from three different farmlands in Yargalma, one of the affected villages. The edible portions of the samples were washed with tap water first and then followed by double washing with distilled water (Lawal and Audu, 2011) and chopped the whole plant except the roots into smaller pieces and then oven dried at 80^0C. The dried samples were ground and passed through 155 microns for digestion.

The same number of soil samples collected from the same farmlands where the vegetables were collected. All soil samples were collected from a depth of 2cm from the surface soil. This is believed to be the depth at which people can easily get in contact with. The samples were packaged in cleaned containers properly labeled.

Digestion of samples

The digestion of vegetable was conducted as reported by Kudirat and Funmilayo (2011). 1.0g each of the powder samples were digested with 10ml of 98% nitric acid was added and a water bath was used to heat for 72hrs until the light colored solution was obtained. The digested solution was allowed to dry during digestion and made to 25ml with distilled water. Triplicate digestion of each sample was carried out together. The analysis was conducted using AA6800S Shimadzu spectrophotometer at the National Research Institute for Chemical Technology-Zaria, Nigeria.

The soil samples were digested in which soil samples were homogenized and air-dried in the oven at 30^0C to a constant weight and passed through a 2mm sieve. 5g of soil samples were placed in 100ml beaker. 3ml of 30% hydrogen peroxide was added according to Awode et.al (2008). This was left to stand for 60mins until the vigorous reaction ceased. 75ml of 0.5M solution of HCl was added and the content heated gently at low heat on hot plate for about 2 hrs. The digest was then filtered into 50ml standard flask. Triplicate digestion of each sample together with blank was also carried out. Then the analysis was conducted using flame Atomic Absorption Spectrophotometer (AA6500) at the National Research Institute for Chemical Technology, Zaria-Nigeria.

Transfer factor

The transfer factor was calculated according to Sajjad et.al (2009) who defined it as the relative tendency of a metal to be accumulated by a particular species of plant. Generally, transfer factor expresses the bioavailability of a metal at a particular position on a species of plant. This is however, dependant on different factors such as the soil pH and the nature of the plant itself. This is because different authors have reported different transfer factors for the same species of plant and across different parts of the plants, such as roots and leafy parts. The transfer factor calculated in this study was based on the total metal content of the whole plant without taking into consideration the various parts of the plant. The formula used was stated by Cui *et al.* (2004);

$$TF = \text{concentration of metal in edible part}/\text{concentration of metal in soil}$$

Daily Intake of Metal (DIM)

The daily intake of metals (DIM) was calculated to averagely estimate the daily metal loading into the body system of a specified body weight of a consumer. This will inform the relative phyto-availability of metal. This does not take into cognizance the possible metabolic ejection of the metals but can easily tell the possible ingestion rate of a particular metal. The daily intake of metal in this study was calculated based on the formula proposed by Sajjad et.al (2009).

$$\text{Daily Intake of Metal} = C_{(\text{metal conc})} \times C_{(\text{factor})} \times D_{(\text{food intake})} / BW_{(\text{average body weight})}$$

Where
C = heay metals conc. in plants (mg/kg)
C = conversion factor
D = daily intake of vegetables
The conversion factor of 0.085 is to convert fresh vegetable weight to dry weight [Sajjad et.al, 2009], while the average body weight used was 65Kg for this study.

Daily Dietary Intake (DDI)

The Daily Dietary Intake of metals expresses the dietary availability of metals in a particular food. The DDI therefore, differs from the later in the sense that it gives an approximate available metal in food and is essential in risk assessment of metals.
The Daily Dietary Intake of metals was determined by the following formula:

$$DDI = X \times Y \times Z / B$$

Where
X = metal in vegetable
Y = dry wt. of the vegetable
Z = approximate daily intake
B = average body weight in this study was 65K

RESULTS AND DISCUSSION

The results of the Heavy metals concentration in the soil and vegetables in Yargalma area was presented in table 1.0 the results showed the highest concentration of metals in the soil with Al (3111.29 mg/Kg) and the lowest was Cd (0.965 mg/Kg). The vegetable however, had the highest concentration of Fe (54.05 mg/Kg) and the lowest was in Cd (0.5 mg/Kg)

Table 1.0: **Heavy metals concentrations (mg/Kg) for soil and vegetable grown in Yargalma area of Zamfara state.**

Element	Soil conc (mg/Kg)	V conc (mg/Kg)
Mn	142.91	44.5875
Zn	68.91	26.335
Pb	29.66	5.9325
Mg	100.81	43.125
Al	3111.29	22.58
Cd	0.965	0.5
Cr	16.73	3.0825
Ni	19.195	7.545
Co	1.505	8.44
Cu	1.13	0.64
Fe	195.25	54.05

The results also showed an irregular pattern in the HM metals availability. Mn has the highest value in soil (142.91 mg/Kg) and lowest in plant (44.59 mg/Kg). The same pattern was observed for Zn in soil was (68.91 mg/Kg) and in plant was (26.33mg/Kg), Pb was (29.66 mg/Kg) in soil and in plant was (5.93 mg/Kg), Mg was high in soil (100.81 mg/Kg) and in plant was (43.12 mg/Kg). All the metals except for Co in soil (1.51 mg/Kg) and in plant (8.44 mg/Kg). The generally, the trend in soil is Al > Fe > Mn > Mg > Zn > Pb > Ni > Cr > Co > Cu > Cd and for the plant the trend is Fe > Mn > Mg > Zn > Al > Co > Ni > Pb > Cr > Cu > Cd. The variation in the HM in plants and soil is due to differences in the sources of the metal. Some of the metals are already present in the plant and the soil will contribute to the metal bioavailability. The total metal concentration of plants in this study was a contribution of all the plants part.

Table 2.0: comparative heavy metals concentration (mg/Kg) in soil samples with similar works reported in the literature and the maximum permissible limits in some countries

Metal/work	This study (mg/Kg)	Wu Yao-guo 2010 (mg/Kg)	*Great Britain (mg/Kg)	**USEPA (ppm)
Pb	29.66	216.93	400	300
Cu	1.13	54.13	100	50
Zn	68.91	118.06	300	200
Fe	195.25	ND	NA	NL
Cr	16.73	44.72	50	400
Ni	19.19	ND	50	50
Cd	0.97	0.55	3	3
Mg	100.81	ND	NA	NA
Mn	142.91	ND	NA	80
Al	3111.29	ND	NA	NA
Co	1.505	ND	NA	NA

* Maximum permissible limits of metals (mg/Kg) in soil in Great Britain
**Maximum permissible limit of metals (ppm) in soil by USEPA
ND: Not Determined
Source: Chipo Masona (2011)

The comparative heavy metals of soil (mg/Kg) presented (table 2.0) above showed a significant difference from the one reported in the literature by Wu et.al (2010), even though the same mineral ore is explored in the two sites. The greater variations were in Pb (29.66 to 216.93) and Cu (1.13 to 54.13) but the results in this study were far less than the British and Japan standard permissible limits of metals in the soils of those countries with the exception of Cd. Cadmium was greater than what was obtained by Wu et.al (2010). This is a very toxic heavy metal that should be monitored to prevent further outbreak of Cd related sicknesses.

Table 3.0: comparative heavy metals concentration (mg/Kg) in Plant samples with similar work reported in the literature and the maximum permissible limits in some countries

Metal/work	This study (mg/Kg)	Anthony and Balwant, 2005 (mg/Kg)	Zhuang et.al, 2009 (mg/Kg) (	*Indian standard (mg/Kg)	WHO/FAO/Indian standard (mg/Kg)
Pb	44.5875	4.31	0.14	2.5	**5.0
Cu	26.335	1.01	1.23	30.0	40.0
Zn	5.9325	54	19.10	50.0	60.0
Fe	43.125	ND	ND	NA	**5.0
Cr	22.58	ND	ND	20.0	NA
Ni	0.5	ND	ND	1.5	NA
Cd	3.0825	0.361	0.50	1.5	0.2
Mg	7.545	ND	ND	NA	NA
Mn	8.44	ND	ND	NA	NA
Al	0.64	ND	ND	NA	NA
Co	54.05	ND	ND	NA	50

Source: *Anita et.al, 2010
**WHO/FAO (2011)

The results of heavy metals (table 3.0) in vegetable in this work were compared with similar work reported by Anthony and Balwant (2005) as well as Zhuang et.al (2009). It revealed that most of the results of this work were higher that the compared results and in some cases higher than the maximum permissible limits of India and WHO/FAO (2007). A good example of this can be seen in Pb. This variation however, is a function of the availability and the uptake of a particular plant species to a given element referred to as the transfer factor of the metal.

The ability of a metal species in its different forms to migrate from the soil through the plant parts and makes itself available for consumption was represented by the transfer factor (TF). The transfer factor is a function of different factors such as the soil pH, soil organic matter, metals availability and soil particle size. The figure below represents the results of the TF of the various metals.

From the figure below, Co has the highest transfer factor of 5.60, this could be attributed to the low retention rate of the metal in soil and therefore it is more mobile in the soil. The lowest was Al (0.10) probably because Al is a major composition of the soil and therefore it binds more to the soil and it becomes bind to other soil compositions. This means that a greater percentage of the metal from the soil was adsorbed to the plants tissue for the former and a very insignificant percentage for the later. The transfer pattern for metals is Co > Cu > Cd > Mg > Ni > Zn > Mn >

Fe > Pb > Cr > Al. Variations in transfer factor 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; Zheng *et al*. 2007).

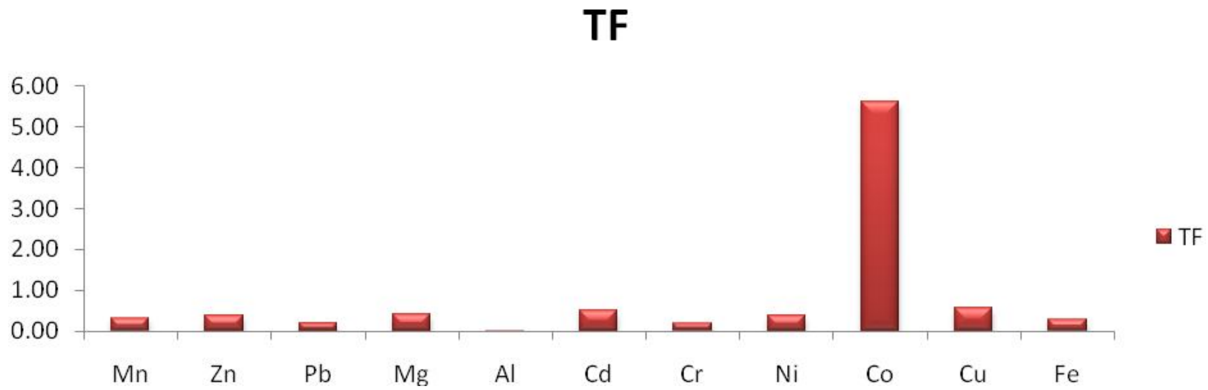


Figure 1.0: presents the calculated transfer factor for the various Heavy metals from soil to plant.

Transfer quotient of 0.1 indicates that plant is excluding the element from its tissues, the greater the transfer coefficient value than 0.50, the greater the chances of vegetables for metal contamination by anthropogenic activities will be (Sajjad et.al, 2009). Reference to this statement, only Al (0.01) is excluded in the plants tissue and this statement could be seen if one considered the concentration of Al in the soil (3111.29 mg/Kg) having the highest but in the vegetable the concentration significantly dropped to (22.58 mg/Kg), however, Co (5.61), Cu (0.57) and Cd (0.52) in a decreasing order can be contaminated by anthropogenic activities. The transfer factor does not present the risk associated with the metals in any form. The degree of toxicity of heavy metals to human being depends upon their daily intake (Anita et.al, 2010).

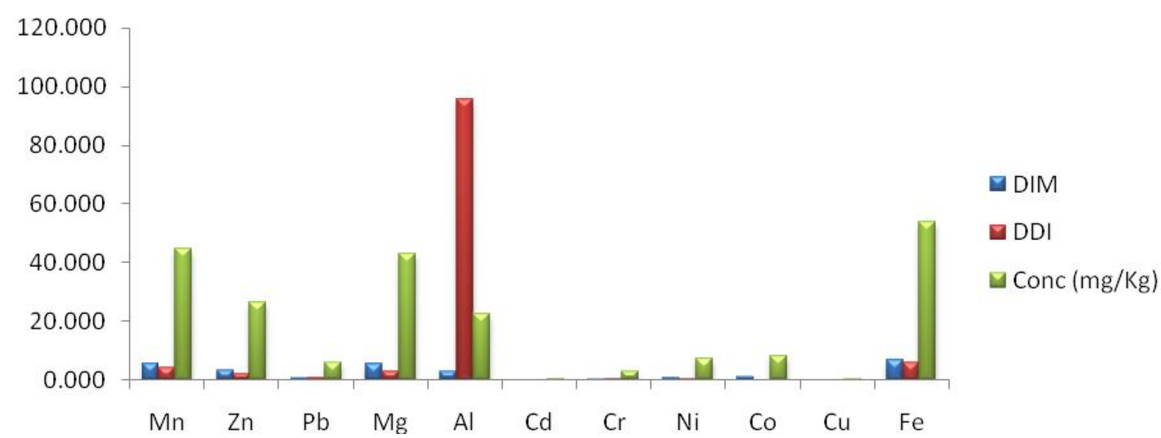


Figure 2.0: The calculated Health risk indices (DIM and DDI) for the various Heavy metals in the vegetable.

The Daily Intake of Metals (DIM) as defined earlier, was compared with the Daily Dietary Intake (DDI) and the vegetable metal concentration in the figure above. The vegetable metal concentration (mg/Kg) was higher than the other parameters compared with except in the case of Al in which the DDI out shoot all the values. The DIM as a function of body weight and intake and the DDI, Fe had the highest vegetable metal concentration (54.05 mg/Kg) and the highest DIM (7.068) while it had the second highest DDI (6.01). In general, the trend of the DIM value was Fe > Mn > Mg > Zn > Al > Co > Ni > Pb > Cr > Cu > Cd. The trend in DDI was found to be slightly different to the one above, such that it followed the trend Al > Fe > Mn > Mg > Zn > Pb > Ni > Cr > Co > Cu > Cd. In the trends above, the common fact was that essential metals in the body like Fe, Mn, Mg and Zn were high in the DIM and DDI were generally high and some of those in the vegetable were as a result of the vegetable their concentration in the vegetable itself was high. Therefore, those metals were not at risk level because of their friendliness to the body while some of the other elements were are toxic and therefore, the health risk index (HRI) and the target hazard quotient (THQ).

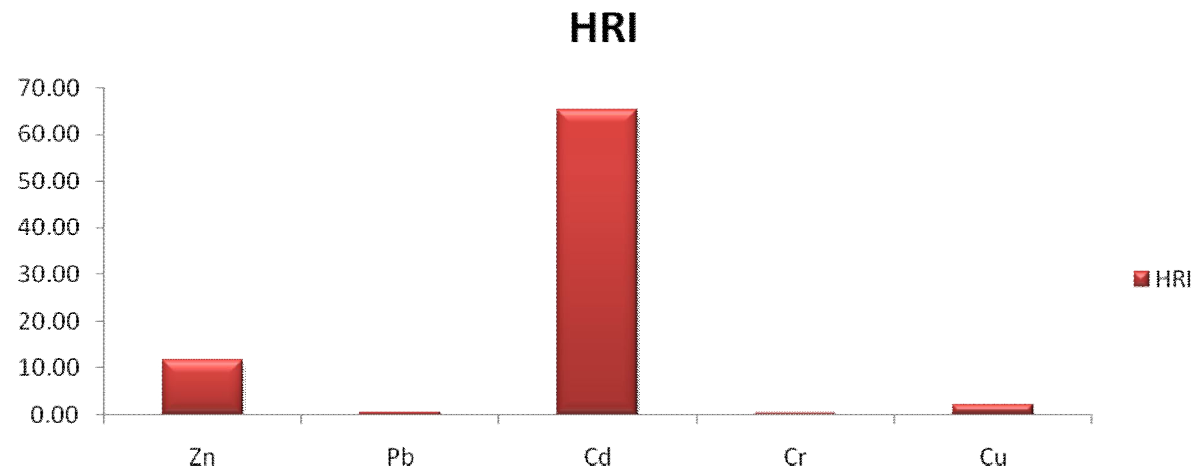
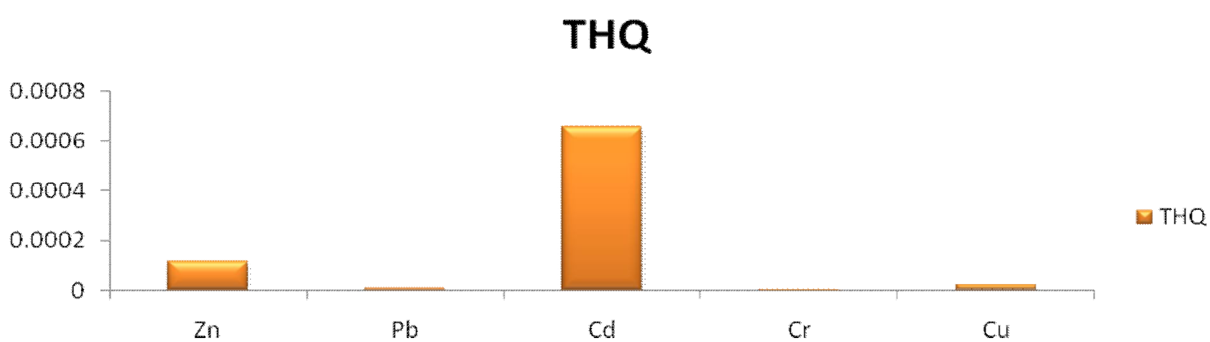


Fig 3.0: The Health Risk Index for selected Heavy metals of Health concern.

The HRI for HM Zn, Pb, Cd, Cr and Cu were calculated. The result showed very high HRI values for Cd (65.38), Zn (11.48) and Cu (2.09) were high values than Pb and Cr with values less than 1. The value for Cd was high possible because Cd and Pb are considered as the most significant heavy metals affecting vegetable crops (Anthony and Balwant, 2007). The population is therefore at greater risk of Cd, Zn and Cu since their values were greater than 1. The population will pose no risk, if the ratio is less than 1 and if the ratio is equal or greater than 1 then population will experience health risk (Sajjad et.al, 2009).



The THQ is a ratio between the measured concentration and the oral reference dose, weighted by the length and frequency of exposure, amount ingested and body weight (Declan and Andrea, 2008). The parameter defines the exposure duration and the risk with that period. The results therefore reflected the risk associated with Cd, Zn and Cu exposure for the period of life expectancy considered in this study. This simply means that the inhabitants are highly exposed to health risks associated to these metals in the order Cd > Zn > Cu > Pb > Cr. The THQ in all metals is far less than 1, therefore, it does not poses concern.

Conclusion

The paper evaluated and assessed the heavy metals composition of the vegetables grown in the mining area of Yargalma, Northern Nigeria. The metals presence in both the soil and the vegetables samples assessed showed significant contamination of the HM and their risk assessment for DDI, DIM, THQ and HRI were determined and showed serious health risk for such metals like Cd, Pb and Zn. It was suggested that further monitoring and evaluation of bioaccumulation of these metals should be conducted to prevent further outbreaks in the area.

REFERENCES

Afshin Maleki and Masoud Alasvand Zarasvand (2008); Heavy metals in selected edible vegetables and estimation of their daily intake in Sanandaj, *Iran Southeast Asian J Trop Med Public Health* Vol 39 No.2 pp 335- 340

Alhassan Y, Tsafe A.I, Birnin Yauri U.A, Okunola O.J, Yargamji G.I, Yebpella G.G and Ndana M (2010); EDXRF analysis of tantalite deposit of Mai-Kabanji, North-Western Nigeria, *Journal of Environmental Chemistry and Ecotoxicology* Vol 2(6) pp 185-188 Available online http://www.academicjournal.org/jece

Anita Singh, Rajesh Kumar Sharma, Madhoolika Agrawal and Fiona M. Marshall (2010); Risk assessment of heavy metal toxicity through contaminated vegetables from waste water irrigated area of Varanasi, India; *Tropical Ecology* 51(2S): *International Society for Tropical Ecology*; pp 375-387; available online www.tropecol.com

Anthony George Kachenko and Balwant Singh (2005); heavy metals contamination in vegetables grown in urban and metal smelter sites in Australia, *Springer* 169: pp 101-123

Awode U.A, Uzairu A, Balarabe M.L, Harrison G.F.S, Okunola O.J (2008); Assessment of Peppers and Soils for some Heavy metals from Irrigated Farmlands on the Bank of River Challawa, Northern Nigeria. *Pakistan Journal of Nutrition* 7 (2) pp 244-248

Chipo Masona (2011); Assessment of Heavy Metal Accumulation in Wastewater Irrigated Soil and Uptake by Maize Plants (Zea Mays L) at Firle Farm in Harare; *Journal of Sustainable Development* Vol. 4, No 6. PP 132-137 Published by the Canadian Centre of Science and Education available online www.ccsenet.org/jsd

Cui, Y.L., R.H. Zhu, R.H. Zhi, D.Y. Chen, Y.Z. Huang and Y. Qiu, (2004); Transfer of metals from soils to vegetables in an area near a smelter in Nanning, China, *Environ. Intl*., 30: pp 785-791.

Declan P Naughton and Andrea Petroczi (2008); Heavy metal ions in wines: meta-analysis of Target Hazard Quotient reveals health risks. *Chemistry Central Journal* 2:22 available online http://journal.chemistrycentral.com/content/2/1/22

FAO/WHO (2011); Joint FAO/WHO food standards programme codex committee on contaminants in foods, fifth session pp 64-89

Indrajit Sen, Ajay Shandil and Shrivastava V.S (2011); Study for Determination of Heavy Metals in Fish Species of the River Yamuna (Delhi) by Inductively Couple Plasma-Optical Emission Spectroscopy (ICP-OES), *Pelagia Research Library*, pp 161-166 Available online at www.pelagiareseachlibrary.com

Ladipo Margaret Kudirat and Doherty Victoria Fumilayo (2011); Heavy metal levels in vegetables from selected markets in Lagos, *Nigeria African Journal of Food Science and Technology* (ISSN: 2141-5455) Vol. 2(1) pp. 018-021, January, 2011 Available online http://www.interesjournals.org/AJFST

Okunola O J, Alhassan Y, Yapbella G G, Uzairu A, Tsafe A I, E Embassey, Abechi S (2011); risk assessment of using mobile phone recharge cards in Nigeria, *Journal of Environmental Chemistry and Ecotoxicology* Vol. 3(4) pp 80-85 Available online http://www.academicjournal.org/jece

Sajjad Khan, Robina Farooq, Shagufta Shahbaz, Mohammad Aziz Khan and Maria Sadique (2009); Health Risk Assessment of Heavy Metals for Population via Consumption of Vegetables, *World Applied Sciences Journal* Vol. 6 (12): pp 1602-1606

Wu Yao-guo, XU You-ning, ZHANG Jiang-hua, HU Si-hai (2010); Evaluation of ecological risk and primary empirical research on heavy metals in polluted soil over Xiaoqinling gold mining region, Shaanxi, China, *Trans. Nonferrous Met. Soc. China* 20 pp 688-694 Available online at www.sciencedirect.com

Zhuang P, Murray B.M, Hanping X, Li N and Li Z (2009); Health risk from heavy metals via consumption of food crops in the vicinity of Dabaoshan mine, South China. *Elsevier: science of the total environment* 407: pp 1551-1561