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Health Risk Assessment of Heavy Metals via Dietary Intake of Vegetables Grown in an Irrigated Farm around Dadin-Kowa, Gombe State

Muhammad, F. U.[1], Adamu, H. M.[2], Gungula, D. T.[3], Kapsiya, J.[4], Ahmad, A.[4] and Idris, A. H.[2]

[1]Yelwan Tudu Bauchi, Opp. Customs Barrack, Along Dass Road, Bauchi State, Nigeria
[2]Department of Chemistry, Abubakar Tafawa Balewa University, Bauchi, Bauchi State, Nigeria
[3]Department of Crop Production and Horticulture, Modibbo Adama University of Technology, Yola, Adamawa State, Nigeria
[4]Horticultural Department, Federal College of Horticulture, Dadin Kowa, Gombe State, Nigeria
[*]Corresponding Author: fatimamuhammadumar96@gmail.com; +2348061559120

Abstracts

The present study was carried out to assess health risk via dietary intake of different levels heavy metals like Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Lead (Pb) and Zinc (Zn) in some selected soil, water and vegetables grown in an irrigated farm of Dadin Kowa, Gombe State, North-East, Nigeria. They were determined using Atomic Absorption Spectrophotometry (AAS). Heavy metals concentration was found much less in irrigated water as compared to soil and vegetables. Although, the concentration value of these metals were below the maximum tolerable levels by FAO/WHO Cadmium (Cd) 25 mg/Kg, was found to be at toxic level. The levels found in vegetables were in order Cr > Fe > Zn > Cu > Cd > Pb > Mn. The levels found in irrigation water were in order Cu > Zn > Pb > Fe > Cd > Mn > Cr. The mean concentration values of the metals in the soil were 20, 16.5, 33, 21.7, 4.5, 15.8 and 20 mg/Kg for Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Lead (Pb) and Zinc (Zn) respectively. This means Cu > Fe > Zn > Cd > Cr > Pb > Mn. However, the regular monitoring of levels of these metals in vegetables and in other food materials is essential to prevent excessive build-up of these metals in the food around the study area.

Keywords: Vegetables; Soil; Irrigation Water; Heavy Metals; Dietary Intake

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Introduction

Due to rapid urbanization, the demand for food crops is rising day by day, and as vegetables can be grown in small fields with intensive use of inputs within shorter period, its cultivation is gaining popularity and fetching profitability in semi-urban areas and mega cities. This is a matter of serious concern since vegetables particularly leafy ones, being prolific accumulators of heavy metals provide an easy entry into food-chain to this dreaded metals. The excessive intake of these elements from the soil creates dual problem; first, the harvested crops get germinated, which serve as a source of heavy metal in our diet and secondly, the crop yield decline due to the inhibition of metabolic processes (Sanders, *et al.,* 1987; Singh and Aggarwal, 2006).

The effect of heavy metal contamination of fruit and vegetables cannot be underestimated as these food-stuffs are important components of human diet. Fruit and vegetables are rich sources of vitamins, minerals, fibres and as well as beneficial antioxidative effects. However, the intake of heavy metal in contaminated fruit and vegetables may pose a risk to human health; hence the heavy metal contamination of food is one of the most important aspects of food quality assurance (Radwan and Salama, 2006, and Khan, *et al.,* (2008). Heavy metals, in general, are not biodegradable, have long biological shelf-lives, and have the potential for accumulation in different body organs, leading to unwanted side effects (Jarup, 2003 and Sathawara, *et al.,* 2004).

Plants take up heavy metals by absorbing them from air borne deposits on the parts of plants exposed to the air from the polluted environments as well as from contaminated soils through root systems. Also, the heavy metals contamination of fruit and vegetables may occur due to irrigation with contaminated water (Aljassir, *et al.,* 2005). Based on their persistence and cumulative behaviour as well as the probability of potential toxicity effect, the absorption of heavy metals in human diet as a result of the consumption of fruit and vegetables means that, there is a requirement for the analysis of food items to ensure that the levels of trace heavy metals meet the agreed international standards. Waste water contains substantial amount of toxic heavy metals which create problem (Chen, *et al.,* 2004).

Food and water are the main sources of our essential metals; these are also the media through which we are exposed to various toxic metals. Heavy metals are easily accumulated in the edible parts of leafy vegetables, as compared to grain crops (Mapanda *et al.,* 2005). The safe values for Copper, Lead and Cadmium in fruit and vegetables recommended by the WHO/FAO are 40, 0.3, 0.2 mg/Kg respectively (Hussain, *et al.,* 1995). In view of these, this study was carried out with the objective to investigate and compare the concentration of some specific heavy metals (Cd, Cr, Cu, Fe, Mn, Pb and Zn) found in some selected fruit and vegetables grown in an irrigated farm of Dadin Kowa, Gombe State, Nigeria.

Addo *et al.* (2012) studied heavy metal in biosphere by human activities as an important process in the geochemical recycling of these metals. Addo *et al.,* (2012) reported that the results of the metal analysis indicated that some metallic levels were in excess of natural background and critical limits for the soil and plants respectively. However, he observed that the mean metal concentration of the soil and plants decreases as distance from the cement facility increased for most metals. This indicated that the facility which is only the industrial source in the area is the major cause of the pollutant contamination in its vicinity. Maxwell, *et al.,* (2012) carried out an assessment of some heavy metals concentration in lettuce irrigated with waste water in Tamale, Ghana. Analysis of water, soil and lettuce revealed that the concentrations of heavy metals were within the FAO recommended level.

Singh *et al.,* (2002) works on different vegetable crops on heavy metal contaminated soil which showed in metal accumulation, uptake and distribution pattern. Based on metal contamination in edible parts and whole plants, root vegetables which include radish and carrot registered lower accumulation of almost all heavy metals except Zinc (Zn) in radish root. However, leafy vegetables such as spinach, amaranthus, mustard and fenugreek recorded higher accumulation of both essential and non-essential heavy metals except Cadmium (Cd) and Nikel (Ni) which showed less accumulation in fenugreek, potato and onion. Cauliflower and cabbage, however, showed greater accumulation of Lead and Nikel but less accumulation of Copper and Cadmium. Among fruit type vegetables, pea, soybean and cluster bean showed greater accumulation of Cadmium. Generally, the root and leafy vegetables such as radish, carrot, spinach, amaranthus, mustard, cauliflower and cabbage showed higher distribution of metals to the edible parts, whereas fruit type vegetables especially tomato exhibited least transport of metals to fruit except leguminous fruit vegetables. Leafy vegetables seemed to be unsafe and not suitable for cultivation on heavy metals contaminated soil (Singh *et al.,* 2002).

Orish *et at.,* (2012) assessed Lead, Cadmium and Nikel levels in food crops, fruits and soil samples from Ohaji and Owerri in South-Eastern Nigeria and estimated the potential health risk of metals. The concentration of Lead, Cadmium and Nikel in Ohaji exceeded the maximum allowable concentrations for agricultural soil as recommended by European Union (EU). An important concern for human health is the uptake of contaminant plants from soil and river (Mirela *et al.* (2000). Monu *et al.* (2008) assessed different levels of heavy metals like Iron, Manganese, Copper and Zinc in vegetables irrigated with water from different sources. The results indicated a substantial build-up of heavy metals in vegetables irrigated with waste water. However, regular monitoring of levels of these metals from effluents and sewage in vegetables and in other food materials is essential to prevent excessive build-up of these metals in the food chain (Monu *et al.,* 2008).

Materials and Methods

The study was carried out in the laboratories of the Department of Science Laboratory Technology, Federal Polytechnic Bauchi, and Department of Chemistry, Abubakar Tafawa Balewa University, Bauchi, Bauchi State, Nigeria.

Sample Collection

Soil samples, fruit/vegetables and water were collected from an irrigated farm (fruit/vegetables farm) of Dadin Kowa, Gombe State. The depth of soil collected for analysis was 0 – 15 cm and the size/area of the farm was 186 X 78 m^2. Water sample was collected in a transparent bottle container and refrigerated.

Sample Preparation and Treatment

All the collected samples of various vegetables were washed with distilled water to remove air borne pollutants. The edible parts of the vegetables samples were weighed and air dried to high reduce moisture content. All the samples were then oven dried in a hot air oven at 75^{0o}C for 24 hours to remove all moisture. After hot air drying, the dried samples were ground into powder and sieved (0.02 mm sieve opening). Soil samples were grounded and sieved separately.

Digestion of Samples

For each vegetable, three powdered samples from each source of irrigation (0.5 g each) were accurately weighed and placed in crucibles. The ash was digested with perchloric acid and nitric acid (1:4) solution. The samples were left to cool and contents were filtered through Whatman filter paper No 42. Each sample solution was made up to a final volume of 25 ml with distilled water and analyzed by Atomic Absorption Spectrophotometry (AAS) (model 210 VGP ion Spectrophotometry).

Standards Solution

Standards solution of heavy metals (1000 mg/l), namely Copper, Zinc, Manganese, Iron, Lead, Cadmium and Chromium were prepared from inert solutions of varying concentrations for all the metals by diluting the standards.

Secondary Stock Solution 1

Transfer by pipette, 100 ml of standard stock solutions [1000 mg/l] of Cd, Cr, Cu, Fe, Mn, Pb and Zn and 20 ml of the standard stock solution (1000 mg/l) of cadmium to a litre standard volumetric flask, and diluted to 1 litre with deionised distilled water. This solution contains 20 mg/l Cd, and 100 mg/l Cr, Cu, Fe, Mn, Pb and Zn.

Secondary Stock Solution 2

Transfer by pipette, 100 ml of secondary stock solution 1 to a 1 litre standard volumetric flask, and diluted to 1 litre deionised distilled water. This solution contains 2 mg/l Cd and 10 mg/l Cr, Cu, Fe, Mn, Pb and Zn. Add the quantities of secondary stock solution 1 and 2 to 250 ml standard volumetric flasks, each containing

2, 5 ml nitric acid and 25 ml perchloric acid and dilute to 250 ml with deionised distilled water.

Data Analysis

Daily intake of metals (DIM)

The daily intake of metals (DIM) was assessed to estimate the average daily loading of metal into the body system of a specified body weight of a consumer. Although this does not take into account the possible metabolic ejection of the metals, it will however tell the possible ingestion rate of a metal in question. The daily intake of metal in this study was calculated based on the formula proposed by (Sajjad *et al.*, 2009). The average adult daily vegetable intake rate of 0.345 kg/person/day and body mass of 55.9 kg was used as reported by (Wang *et al.*, 2005).

The daily intake of metals (DIM) was calculated by the following equation:

$$\text{DIM} = \frac{\text{Cplant (mg/kg) X K (kg/day)}}{\text{BM (kg)}}$$

Where C_{plant}, K, and BM represent the heavy metal concentrations in plants (mg/kg), conversion factors daily intake of vegetables and average body weight respectively.

Results

The results obtained can be seen in Table 1, 2 and 3. Table 1 shows the concentrations of heavy metals in an irrigated soil, Table 2 shows the concentrations of heavy metals in the vegetables grown while Table 3 shows heavy metal concentrations in the irrigated water. Cadmium (Cd) concentrations in Table 1 were 15, 20 and 25 mg/kg for soil sample 1, 2 and 3 respectively. Cadmium concentrations in Table 2 for the vegetables were 25, 25, 25 and 15 mg/kg for spinach, tomato, pepper and sweet pepper respectively, while the Cadmium found in the irrigation water was 2.5 mg/l. The highest concentration of Chromium in Table 1 was in soil sample 3 with the value of 16 mg/kg, however, the mean value for Chromium in the soil was 16.5. In Table 2, the Chromium level found in vegetables was in pepper with Cr value of 46 mg/kg while in Table 3, the Chromium value found in the irrigation water was 2.07 mg/l. Copper (Cu) concentration was found to be highest in soil sample 2 with the value of 45 mg/kg in Table 1. However, the average mean value of Copper from Table 1 was 33 mg/kg. In Table 2, sweet pepper had the highest concentration of 32 mg/kg while in Table 3, the concentration of Copper in the irrigation water was 18.25 mg/l. From the result, the highest and the mean concentrations of Iron in Table 1 in the soil were 29 and 21.7 mg/kg respectively. In Table 2, Iron was found to be highest in pepper with its value of 42 mg/kg while in Table 3, the value of Iron found in irrigation water was 7.6 mg/l.

The average mean concentrations of Manganese were 4.5 and 9 mg/kg in Table 1 and 2 respectively while Manganese in Table 3 was 2.5 mg/L. The standard for irrigation water approved by National Environmental Quality Standard (NEQS) for Mn is 1.5µg/ml. The mean concentration of Lead in Table 1 was 15.8 mg/kg and the highest concentration of Lead was found in soil sample 1 with value of 38.5 mg/kg, in Table 2, the concentration of Lead was found to be higher in spinach with value of 11.5 mg/kg and Table 3 shows 11.25 mg/l concentration of Lead in the irrigation water.

The average mean concentration of Zinc was found to be 20 and 23.25 mg/kg and the highest value of 25 and 35 mg/kg were obtained from soil sample 1 and pepper in Table 1 and 2 respectively. In Table 3, the Zn concentration was found to be 14.5 mg/l in the irrigation water.

Consequently, the daily intake of metals were estimated according to the average vegetable consumption grown in treated wastewater irrigated soils for adults and are given in Table 4.

Discussion

These values of Cadmium shows that it has a high value and is said to be at toxic level, since the detection limits for Cadmium is 0.07 mg/l WHO (2004). Cadmium from the result obtained shows that it is below the recommended concentration of 100 mg/kg in soil (Tanzanian Standard, 2003). Cadmium is extremely toxic; it causes learning disability and hyper activities in

Table 1: Heavy metal concentrations in irrigated soil (100 mg/kg)

Sample	Cadmium	Chromium	Copper	Iron	Manganese	Lead	Zinc
S1	15	12.5	32	29	4.5	38.5	25
S2	20	21	45	19	4.5	7	19
S3	25	16	22	17	4.5	2	16
Mean	20	16.5	33	21.7	4.5	15.8	20

S= Soil sample

Table 2: Heavy metal concentrations in grown vegetables (100 mg/kg)

Vegetable	Cadmium	Chromium	Copper	Iron	Manganese	Lead	Zinc
Spinach	25	41	27	15	9	11.5	20
Tomato	25	16	27	13	4	2.2	16
Pepper	25	46	27	42	9	4.5	35
Sweet Pepper	15	33	32	19	9	16	22
Mean	20	26	28.25	22.25	7.75	8.55	23.25

Table 3: Heavy metal concentrations in the irrigation water (100 mg/l)

Sample	pH	Temperature	Cadmium	Chromium	Copper	Iron	Manganese	Lead	Zinc
Irrigation water	4.3	19.5^{0o}C	2.5	2.07	18.25	7.6	2.25	11.25	14.5

Table 4: Daily Intake (DIM, mg/day) of Cd, Cr, Cu, Fe, Mn, Pb And Zn In Individual Vegetables

Vegetables	Cadmium	Chromium	Copper	Iron	Manganese	Lead	Zinc
Spinach	0.154	0.253	1.667	0.093	0.056	0.071	0.123
Tomato	0.154	0.099	1.667	0.093	0.025	0.014	0.099
Pepper	0.154	0.284	1.667	0.080	0.056	0.028	0.216
Sweet Pepper	0.154	0.204	1.197	0.259	0.056	0.099	0.136
Mean	0.154	0.210	0.174	0.131	0.048	0.053	0.143
WHO/FAO (mg/day)	0.060	0.05-0.2	3	18-20	1.8-2.3	0.214	60

WHO/FAO values in mg/day are based on a 60 kg body weight adult

Children, Khan, (2008). It can be said that they Chromium were below the (Tanzanian Standard, 2003) maximum limits of 200 mg/kg. High concentration of Cr shows that it is carcinogenic. Chromium plays a vital role in the metabolism of cholesterol, fat and glucose. Its deficiency causes hyper-glycemia, elevated body fat and decreased sperm count (Hunt, 2013). It has been estimated that whatever is taken as food might cause metabolic disturbance if it does not contain the permissible upper and lower limits of heavy metals. Thus, both deficiency and excess of essential micronutrients (Iron, Zinc and Chromium) may produce undesirable effect (Konofal *et al.*, 2004; Kocak *et al.*, 2005).

According to (Tanzanian Standard 2003), Copper permissible limit in the soil is 100 mg/kg and for vegetables is 40 mg/kg. Therefore, the results obtained shows that the Copper values were below the (Tanzanian Standard, 2003) limits of 100 mg/kg and 40 mg/kg for soil and vegetables respectively. Copper being an essential trace element, is necessary for many enzymes. It needed for normal growth and development. Iron is not an essential constituent for all plants and animals at higher concentration, it causes tissue damage and also responsible for anaemia neurodegenerative conditions in human (Adeleka and Abegunde, 2011). It may be higher due to high absorption capacity of plant root or it may be due to the presence of higher amount of Iron in the respective soil.

Manganese is very essential trace heavy metals for plant and animal growth. Its deficiency produces severe skeletal and reproduces abnormalities in mammals (Jarup, 2003). However, concentration of Lead in soil and vegetables does not exceed the (Tanzanian Standard, 2003). The concentration of Lead in the irrigation water exceeds the WHO (2004) drinking water limit of 0.01 mg/l. The values had low level of Zinc as compared to the maximum value of 40 mg/l in food proposed by WHO (2004). Finally, the general low levels of heavy metals may indicates the existence of little or no industrial activities such as battery production, metal production, metal smelting and cable coating which are known to be major contributing factors for these metals in the environment (Bigdeli and Seilsepour, 2008).

In the present study, the mean DIM values of 1.154 and 0.210 for Cd and Cr respectively were higher than the WHO/FAO 2007 values. The DIM values for Cu, Fe, Mn, Pb and Zn were within the safe limit of the Joint WHO/FAO values, considering their large standard deviations of 0.174, 0.131, 0.048, 0.053 and 0.143 respectively. Thus, the DIM values for Cu, Fe, Mn, Pb and Zn were far below the 60 mg/day (WHO/FAO 2007). According to findings of this study, it can therefore be concluded that the local population certainly ingest high levels of Cd and Cr. Once these metals enter the human body, they can lead to high health risks (Khan *et al.,* 2010).

Conclusion

Among other routes, food is one of the main sources of consumer exposure to heavy metals. Since increased dietary metals intake may contribute to the development of various disorders. The soil sample and vegetables were both found to be below the maximum limits of heavy metals. Thus, the deficiency and excess of essential micro-nutrients (Iron, Zinc and Chromium) may produce undesirable effects. On the other hand, the irrigation water exceeded the permissible limit set by (World Health Organization, 2004) and (Tanzanian Standard, 2003) for drinking water. Various heavy metals in soil and water are consequences of wide range of human activities in the area.

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