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GENERATION OF HEAVY METAL RISK ASSESSMENT VARIABLES FROM VEGETABLES

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ABSTRACT

The major point of procurement of vegetables regardless of their sources of cultivation and contamination by organic and inorganic pollutants such as crude oil and heavy metals, is the market. However, there is increasing concern in the consumption of vegetables as a result of food safety issues and potential health risks associated with these food materials. Therefore, this study was objectively done to ascertain and unbiasedly generate health risk variables of heavy metal contaminations of vegetables sold and consumed in Oghara in order to form a basal reference for the future. In order to actualise the set objective, three vegetable types namely Telfaria occidentalis, Talinum triangulare and Amaranthus hybridus were sampled from two markets (Ogharefe and Otefe markets), in Oghara. A total of twelve fresh samples with four samples for each variety, were randomly procured aseptically and subjected to heavy metal analysis of Fe, Zn, Cu, Mn, Cd, Cr and Pb respectively using the atomic absorption spectrophotometer. Cd, Mn, Cr and Pb were not detected in any of the vegetable samples. However, the average mean concentrations of Fe, Zn and Cu in Telfaria occidentalis, Talinum triangulare and Amaranthus hybridus respectively, which ranged 256.67-

272mg/kg, 42.72-47.67mg/kg and 17.51-24.38mg/kg, were within the FAO/WHO permissible limits. Health risk assessment variables, which include daily intake rate (DIR), hazard quotient (HQ) and health risk index (HRI) were computed for both children and adults, and the results obtained so far indicated that the consumption of these vegetables is safe and healthy for the exposed population of Oghara community.

INTRODUCTION

Vegetables constitute an integral part of human diet owing to its nutritional adequacies to fortify the body against diseases. As human activities increase, especially with the application of modern technologies, pollution and contamination of the human food chain has become inevitable. Heavy metal uptake by plants grown in a polluted soil has been studied to a considerable extent (1). Consequently, heavy metal contamination in vegetables cannot be underestimated as these foodstuffs are important components of human diet. Heavy metal contamination of food items is one of the most important aspect of food quality assurance (2 and 3). International and National regulations on food quality have lowered the maximum permissible levels of toxic metals in food items due to an increased awareness of the risk, these metals pose to food chain contamination(4).

Strictly speaking, heavy metals are defined as those with higher density than $5mgl^{-1}$ but the collective term now includes arsenic, cadmium, chromium, copper, lead, nickel, molybdenum, vanadium and zinc (5). Some interest also exist in aluminium, cobalt, strontium and other rare metals. Physiologic roles are known for iron (haem moieties of haemoglobin and cytochromes), copper(amine oxidases, dopamine hydrolase and collagen synthesis), manganese (superoxide dismutase), zinc (protein synthesis, stabilization of DNA and RNA) with low requirements of chromium (glucose homeostasis). Other heavy metal ions are not believed to be essential to health even in trace amounts.

The heavy metals, cadmium, lead and mercury are common air pollutants, being emitted mainly as a result of various industrial activities. Although the atmospheric levels are low, they contribute to the deposition and build-up in soils. Heavy metals are persistent in the environment and are subject to bioaccumulation in food chains. Cadmium exposures are associated with kidney and bone damage. Cadmium has also been identified as a potential human carcinogen, causing lung cancer. Lead exposures have developmental and neurobehavioural effects on foetuses, infants and children and elevated blood pressure in adults. Heavy metals such as cadmium, lead and mercury are common air pollutants emitted as a result of various industrial activities. One of the consequences of the current stage of industrialization and the demand for improved quality of life has been increased exposure to air pollution coming from industrial activities, traffic and energy production (6).

Heavy metals are non-biodegradable and persistent environmental contaminants, which may be deposited on the surfaces and then absorbed into the tissues of vegetables. Plants take up heavy metals by absorbing them from deposits on the parts of plants exposed to the air from the polluted environment as well as from contaminated soils (7 and 8).

Recently, Sharma *et al.* (7) reported that atmospheric deposition can significantly elevate the levels of heavy metals contamination in vegetables commonly sold in the market. Therefore, prolonged consumption of unsafe concentrations of heavy metals through foodstuffs may lead to the chronic accumulation of heavy metals in the kidney and liver of humans, causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (5 and 9).

Although literatures are separately available in the assessment of heavy metal concentrations in the varieties of vegetables, but a comparative study of *Telfaric occidentalis, Talinum triangulare and Amaranthus hybridus* is still lacking. The present study sought to assess the health and environmental risk

variables of the aforesaid vegetables in children and adults respectively in a bid to ensure safe consumption of these vegetables in Oghara community. The computation of the risk assessment variables, (daily intake rate, hazard risk and health risk index), was actualized through the quantification of heavy metal concentrations in vegetables.

MATERIALS AND METHODS

Experimental site

Oghara clan with a population size ranging over 30,962, is a community located in Ethiope West Local Government Area of Delta State, Nigeria. The community has two markets namely; "Ogharefe Market" situated on latitude N5° 55' 52.121" and longitude E5° 39' 37.528'', and "Otefe Market" situated on latitude N5°56' 45.098" and longitude E5°41'30.168 respectively.

Vegetable sampling

Sequel to their authentication at the Department of Botany, University of Benin, Benin City, Nigeria, the three varieties of vegetables purchased from the two study areas were Pumpkin (*Telfaria occidentalis L.*, with voucher number UBHt 187),Waterleaf (*Talinum triangulare L.*, with voucher no. UBHb 185) and Green (*Amaranthus hybridus L.* with voucher no. UBHa 188). These vegetables are the common vegetables repeatedly consumed by people of this area. Vegetable samples were purchased randomly by hand using vinyl gloves carefully packed into polyethylene bags and the whole plant body was brought to the laboratory from the study area in order to estimate heavy metals. Cleaning (soil removal) of vegetable plant samples was performed by shaking and also by means of a dry pre-cleaned vinyl brush. Only edible parts of different vegetables were randomly taken from the study area.

Freshly collected matured vegetable samples from the experimental area were brought to the laboratory and washed primarily with running tap water, then in distilled water and finally rinsed carefully in deionized water to remove any attached dust pollen particles.

Heavy metal analysis

For heavy metal extraction, 1g dried sample of vegetable was digested in 15 ml of HNO_3, H_2SO_4 and $HClO_4$ mixture (5:1:1) at 80 °C until a transparent solution was obtained. Water samples (50ml) were digested with 10 ml concentrated HNO_3 at 80°C until the solution became transparent. These transparent solutions were then filtered through Whatman No. 42 filter paper and diluted to 50 ml with distilled water. The concentrations of Fe, Zn, Cd, Pb, Mn and Cr in the filtrate were determined by using atomic absorption spectrophotometer (Model 210VGPO, Buck Scientific Inc. USA), fitted with a specific lamp of the particular metal using appropriate drift blanks.

Risk assessment variables of heavy metal contamination in vegetables

Risk of intake of metal contaminated vegetables to human health was characterized by the computation of hazard quotient (HQ) and Health Risk Index (HRI). These parameters were determined by the following;

Daily intake rate (DIR)

For the daily intake rate (DIR), the average metal content in each vegetable was calculated and multiplied by the respective consumption rate. DIR was determined by the following equation (10 and 11).

$$DIR = \frac{C_m \times C_f \times D}{B_w} \quad (1)$$

where: C_m= Heavy metal concentration (mg/kg), C_{factor}= Conversion factor (0.085)

D = Daily Intake of Vegetables (Vegetable intake) (Kg person^{-1} day^{-1} FW)

N.B: The conversion factor of 0.085 is set to convert fresh vegetables weight to dry weight equation (2) (12)

$$IR_{dw} = \frac{IR_{ww}(100 - W)}{100} \quad (2)$$

where: IR_{dw} = Dry weight intake rate, IR_{ww} = Wet weight intake rate, W = Percent water constant.

Average daily dose (ADD mgkg^{-1} day)

The average daily vegetable dose (ADD) was calculated by conducting a survey, where 100 people having average body weight of 60kg were asked for their daily intake of a particular vegetable from the experimental area (11 and 13), where the average daily dose for adults and children were set to 0.345kg and 0.232kg person^{-1} day^{-1} expressed as fresh weight respectively, while the average adult and children body weight were set to 60 and 32.7kg in the study based on equation (3) (14).

$$ADD = \frac{C \times IR \times FI \times EF \times ED}{B_w \times AT} \quad (3)$$

where: C = contaminated concentrations in vegetables (mg/kg), IR = Ingestion role per unit time (Kg/day), FI = Fraction ingestion from contaminated source (no unit), EF = Exposure frequency (days/year), ED = Exposure duration (70yr), B_w = Body weight, AT = Pathway specific period for non-carcinogenic effects (i.e. ED × 365 days/yr) and 70yrs lifetime for carcinogenic effects (i.e. 70years × 365 days/yrs).

Hazardous quotient (HQ)

Hazardous quotient (HQ) for the (consumers) through the consumption of contaminated vegetables was assessed by the ratio of DIR to the oral reference doses (R_fD) for each metal (15). The RfD values for Fe, Zn, Cd, Cu, Cr and Pb are 0.70, 0.30, 0.001, 0.004, 1.5 and 0.004 mg/kg (16).

If the value of HQ is less than 1, then the exposed local population (consumers) is said to be safe. If HQ is equal or greater than 1, it is considered as not safe for human health, therefore, potential health risk has occurred, and related interventions and protective measurements should be taken (15). An estimate of risk to human health (HQ) through consumption of heavy metal contaminated vegetable was calculated by the following equations.

$$HQ = \frac{DIR}{R_f D} \tag{4}$$

Health risk index (HRI)

To estimate the risk to human health through more than one heavy metal, the health risk index (HRI) has been developed (15). The health risk index is the algebraic sum of the hazard quotients for all HMs, which was calculated by the equation (5), (17).

$$HRI = \sum_{r=1}^{n} HQ_i \tag{5}$$

The HRI<1 means the exposed population is assumed safe. It assumes that the magnitude of the adverse effect will be proportioned to the sum of multiple metal exposures. It also assumes similar working mechanisms that linearly affect the target organ.

Statistical analysis

Statistical analysis was done by SPSS 20.0 using one-way ANOVA. Statistical significance of means was computed using Schaffe and Duncan multiple tests comparison with a significance level of $p<0.05$.

RESULTS

Table I. Concentrations of heavy metals in vegetables

Heavy metals	*Telfaric occidentalis*	*Talinum triangulare*	*Amaranthus hybridus*
Fe	256.67 ± 1.67	272.00 ± 1.70	266.90 ± 1.70
Cd	< 0.005	< 0.005	< 0.005
Zn	42.72 ± 0.18	43.27 ± 0.18	47.67 ± 0.18
Cu	24.38 ± 0.34	17.51 ± 0.59	20.26 v 0.34
Cr	< 0.001	< 0.001	< 0.001
Pb	<0.002	< 0.002	< 0.002

Note: Results are expressed as mean±SEM (standard error of mean). The mean differences of the above results were significant at the 0.05 level ($p<0.05$).

Table II. Generation of risk assessment variables of heavy metal contamination in vegetables

Vegetables	Heavy metals	DIR(mg/kg)		HQ(unitless)		HRI(unitless)	
		Child	Adult	Child	Adult	Child	Adult
Telfaria occidentalis	Fe	0.155	0.125	0.224	0.018	0.678	0.547
	Zn	0.026	0.021	0.086	0.070		
	Cu	0.015	0.012	0.386	0.298		
Talinum triangulare	Fe	0.164	0.133	0.234	0.190	0.546	0.475
	Zn	0.014	0.021	0.047	0.070		
	Cu	0.011	0.009	0.265	0.215		
Amaranthus hybridus	Fe	0.161	0.130	0.230	0.186	0.631	0.512
	Zn	0.029	0.023	0.096	0.078		
	Cu	0.012	0.010	0.305	0.248		

DISCUSSION

The risk of procuring vegetables from the market without knowing their sources is of critical appraisal to environmental researchers as a result of the potential presence of contaminants, which may bioaccumulate and elicit hazardous effects on consumers. Vegetables become contaminated either due to soil pollution or due to long exposure to polluted environments and accumulate unfavourable levels of metallic elements within them (18). The uptake of metals by roots mainly depends on metal and soil characteristics and plant species etc.

Thus, metal mobility in plants is very important to determine the effect of soil contamination on plant-metal uptake (8 and 19). In view of the above, the health risk assessment of heavy metals in vegetables purchased from Oghara markets regardless of their sources of cultivation are the major pre-occupations of this study.

Heavy metal concentrations in the edible vegetable portions of *Telfaria occidentalis L., Talinum triangulare L.* and *Amaranthus hybridus L.* purchased from Oghara markets were compared with standards set for vegetables. According to the WHO/FAO (20), the maximum permissible limits of Fe for vegetables and fruits is 450mg/kg, on a dry weight basis. There is, therefore, a clear indication that the trace metal with concentrations 256.67, 272.00 and 266.90mg/kg in *Telfaria occidentalis, Talinun triangulare L* and *Amaranthus hybridus L.* respectively fell within the safe limit. The concentration of Fe was highest in *Talinum triangulare,* which may be a better option in the management of pathological conditions relating to Fe deficiency.

Cadmium is very toxic, its long-term exposure to lower levels leads to a build up in the kidneys and possible kidney disease, lung damage, and fragile bones. Hypertension, arthritis, diabetes, anaemia, cancer, cardiovascular disease, cirrhosis, reduced fertility, hypoglycemia, headaches, osteoporosis, kidney disease, and strokes are its some odd long term results (21). The concentration of cadmium in the varieties of vegetables fell below the detection limit (Table I). Therefore, the consumption of these vegetables by local inhabitants of Oghara community may not in any way pose any serious health challenges relating to cadmium toxicity.

In this present study, the concentration of Zn was highest in *Amaranthus hybridus,* (47.67mg/kg), followed by *Talinum triangulare*, (43.27mg/kg), and least in *Telfaria occidentalis* (42.72mg/kg) (Table I). However, the significant amount of Zn present in the varieties of vegetables fell within the set standards put forward by WHO/FAO (20). Since Zn is an essential trace element to plant and animal physiology, its concentrations in the vegetables may be adequate to meet the metabolic needs of the inhabitants engaged in the consumption of these vegetables.

The concentrations of Cr and Pb was observed to be below the detection limits of 0.001 and 0.002mg/kg (Table I). Chromium (VI) compounds are toxic and known human carcinogens, whereas chromium (III) is an essential element. Breathing high levels can cause irritation to the lining of the nose; nose ulcers; running nose; and breathing problems, such as asthma, cough, shortness of breath, or wheezing.

Long term exposure can cause damage to liver, kidney, circulatory and nerve disorders, as well as skin irritation (4). Lead enters into the body system through air, water and food, and cannot be removed by washing fruits and vegetables.

It is a serious cumulative body poison, which can affect every organ and system in the body. Exposure to its high levels can severely damage the brain, kidneys and ultimately cause death, and long-term exposure result in decreased performance in some tests that measure the functions of the nervous system; weakness in fingers, wrists, or ankles; small increases in blood pressure; and anaemia. Others are abdominal pain, anaemia, arthritis, attention deficit, back problems, blindness, cancer, constipation, convulsions, depression, diabetes, migraine headaches, thyroid imbalances and tooth decay (21).

Copper is an essential substance to human life, but its critical doses can cause anaemia, acne, adrenal hyperactivity and insufficiency, allergies, hair loss, arthritis, autism, cancer, depression, elevated cholesterol, depression, diabetes, dyslexia, failure to thrive, fatigue, fears, fractures of the bones, headaches, heart attacks, hyperactivity, hypertension, infections, inflammation, kidney and liver dysfunction, panic attacks, strokes, tooth decay and vitamin C and other vitamin deficiencies (4 and 22). In this study, the significant concentration of Cu was highest in *Telfaria occidentalis* with magnitude 24.38mg/kg and least in *Talinum triangulare* with magnitude 17.51mg/kg. Therefore, since the concentrations of Cu in these vegetables was within the permissible range. the consumption of these food types may not elicit any of the aforementioned pathologic symptoms.

The hazard quotient (HQ) and the health risk index (HRI) are two separate risk assessment variables employed in the assessment of health indications of exposed populations to the toxic effects of heavy metal contamination in vegetables. As assessment tools, HQ is an indicator of hazardous effect of individual contaminants in plants while the HRI shows a composite effect of all detected contaminants in the vegetables. Therefore, the computation of risk assessment variables showed different magnitudes of HQ and HRI for exposed children and adults of Oghara community involved in the consumption of the three named vegetables (Table II). Although there were no clear-cuts among the HQ and HRI values in adults and children for the respective vegetables, the results explained succinctly that consumption of these vegetables by the exposed population was considered safe and therefore, they may not be prone to any carcinogenic risk.

CONCLUSION

In the present work carried out at the local markets of Oghara town, the quantifications of heavy metal concentrations in the sampled vegetables were within the international safety criteria. Consequently, the findings of this study regarding DIR, HQ and HRI showed that the consumption of these vegetables were free of any potential risk. However, the situation could change in the future since one does not know the sources of the vegetables sold in the respective markets.

Therefore, a regular monitoring for heavy metal contamination of vegetables commonly sold in the market is of utmost relevance, and consumption of contaminated vegetables should be avoided in attempt to reduce health risks in the consumption of such contaminated vegetables.

REFERENCES

1. Yusuf, A.A., Arowolo, T.A. and Bamgbose, O. Cadmium, copper and nickel levels in vegetables from industrial and residential areas of Lagos City, Nigeria. Food Chemistry and Toxicology. 41 : 375 - 378. 2003.

2. Marshall, F.M. Enhancing food chain integrity: Quality assurance mechanism for air pollution impacts on fruits and vegetables systems. Crop Post Harvest Program, Final Technical Report (E7530). 2004.
3. Khan, S. Q., Gao, Y. M., Zheng, Y.Z. and Zhu, Y. G. Health risk of heavy metals in contaminated soils and food crops irrigated with waste water in Beijing, China.Environmental Pollution, 152 : 686 - 692. 2008.
4. Radwan, M. A. and Salama, A. K. Market basket survey for some heavy metals in Egyptian fruits and vegetables. Food Chemistry and Toxicology. 44 : 1278 - 1286. 2006.
5. Jerup, L. Hazards of heavy metal contamination. British Medical Bulletin. 68 : 187 - 182. 2008.
6. WHO. Health risk of heavy metals from long-range trans-boundary air pollution. Joint task force on the health Aspects of long-range trans-boundary air pollution, Geneva. 2007.
7. Sharma, R. K., Agrawal, M. and Marshall, F. M. Atmospheric deposition of heavy metals (Cu, Zn, Cd and Pb) in Varanasi City. Indian Environmental Monitoring and Assessment. 142 : 262 - 278. 2008.
8. Singh, A., Sharma, R.K., Agrawal, M. and Marshall, F.M. Risk of heavy metal toxicity through contaminated vegetables from waste water irrigated area of Varanasi City. Indian Tropical Ecology. 51 : 375 - 387. 2010.
9. WHO. Cadmium. Environmental Health Criteria, Geneva. Vol., 134. 1992.
10. Arora, M., B., Kiran, S., Rani, A. R., Kaur, B. and Mittal, N. Heavy metal accumulation in vegetables irrigated with water from different sources. Food Chemistry. 111 : 811 - 815. 2008.
11. Sajjad, K., Robina, F., Shagufta, S., Mohammad, A. and Maria, S. Health Risk Assessment of Heavy Metals for Population via Consumption of Vegetables, World Applied Science Journal. 6 : 1602 - 1606. 2009.

12. United States Department of Agriculture (USDA). USDA nutrient database for standard reference, release. USDA, Washington DC. 2007.
13. Wang, X., Sato, T., Xing, B. and Tao, S. Health risks of heavy metals to the general public in Tianjin China via consumption of vegetables and fish. Science Total Environment. 350 : 28 - 37. 2005.
14. EPA. The limits of pollutants in food. China: State Environmental Protection Administration. GB2762. 2010e
15. USEPA, Reference dose (RfD): Description and use in health risk assessments, Background Document 1A, Integrated risk information system (IRIS); United States Environmental Protection Agency: Washington, DC, 15 March 2013.
16. WHO/FAO. Guidelines for the Safe Use of Wastewater and food stuff; Wastewater Use in Agriculture, World Health Organization, Geneva. 2 (14) : 988. 2013.
17. Guerra, K., Konz, J., Lisi, K. and Neebrem, C. Exposure Factors Handbook. USEPA, Washington DC. 2010
18. Sridhara, C. N., Kamala, C.T. and Samuel Suman, R.D. Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. Ecotoxicology and Environmental Safety. **69** : 513 - 524. 2008.
19. Sharma, R.K., Agrawal, M. and Marshall, F.M. Heavy metals contamination in vegetables grown in waste water irrigated areas of Varanasi City. India. Bulletin of Environmental Contamination and Toxicology. 77 : 311 - 318. 2006.
20. WHO/FAO. Joint FAO/WHO Food Standard Programme Codex Alimentarius Commission 13th Session. WHO, Geneva. 2007.

21. Eriyamremu, G.E., Asagba, S.O., Akpoborie, A.and Ojeaburu, S.I. Evaluation of lead and cadmium levels in some commonly consumed vegetables in the Niger-Delta oil area of Nigeria. Bulletin of Environmental Contamination and Toxicology. 75 : 278 - 283. 2005.
22. Sekhar, K.C., Supriya, K.R., Kamala, C.T., Chary, N.S., Rao, T.N., and Anjaneyulu, Y. Speciation, accumulation of heavy metals in vegetation grown on sludge amended soils and their transfer to human food chain–a case study, Toxicological and Environmental Chemistry. 82 : 33 – 34. 2001.

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