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A Health Risk Assessment of Heavy Metal Levels in Some Vegetables sold in Gwagwalada Central Market, Abuja, Nigeria

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ABSTRACT

Vegetables are rich sources of vitamins, minerals and fibres. They have beneficial anti-oxidative effects. The consumption of vegetables containing heavy metals is a significant cause of many diseases. In this study, the concentrations of heavy metals in the frequently consumed vegetables sold in Gwagwalada central market , Abuja, Nigeria was investigated. Quantitative analysis of heavy metals was done using Atomic Absorption Spectrophotometer (AAS). The concentration level of lead showed that cucumber, cabbage, banana, lettuce, green peas, carrot, and onion had 8.65 ± 1.1, 0.0, 100.40 ± 10.0, 68.00 ± 7.0, 64.76 ± 5.8, 61.28 ± 5.6, and 8.92± 1.1, respectively. There was no traceable level of nickel in the fruits and vegetables while cadmium was observed to be 0.10 ± 0.1 in cabbage alone. The study showed that the fruits and vegetables sampled were contaminated with heavy metals higher than the WHO permissible limits.

Keywords: Heavy metals, Spectrophotometry, Vegetables, Contaminants

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INTRODUCTION

Vegetables are recommended as dietary components because they contain high concentrations of fiber, vitamins, minerals, electrolytes, and phytochemicals, especially antioxidants [1]. Regular consumption of vegetables has been associated with reduced risk of many non-communicable diseases and much interest are in recent times, focused on the vital role of antioxidants which impart vegetables with properties to act as scavengers of free radicals which cause detrimental health effects [2].

Heavy metals such as chromium (Cr), manganese (Mn), zinc (Zn), copper (Cu), and iron (Fe) are considered essential components of biological activities in the body, however, in excess are reported to cause problems to humans [3]. On the other hand, lead (Pb), cadmium (Cd) and arsenic (As) are toxic to the body, hence are considered as toxic elements [3]. Heavy metals are toxic because they react with biomolecules in the body, clog up receptor sites, break and bend sulphur bonds in important enzymes such as insulin and damage the DNA [4]. Heavy metal contamination is an important aspect of food quality assurance and cannot be underestimated as these foodstuffs are an important component of the human diet [5, 6, 7].

In recent times, the consumption of vegetables has increased drastically due to their value as sources of vitamins A and C, iron, calcium, folic acid and dietary fibre [8]. However, a number of studies have shown that heavy metals rank high among the contaminants of vegetables [7]. Vegetables take up heavy metals by absorbing them from contaminated soils, as well as from deposits on different parts of the vegetables exposed to the air from polluted environments [9].

In Nigeria, as is the case with most African and other developing countries, it is common practice to sell foodstuff in an open market without proper handling and processing conditions [10] and there are serious hazards associated with this ugly practice [11]. Prolonged consumption of vegetables contaminated with heavy metals pose a risk to human health as the unsafe concentrations of these toxicants in foodstuffs may lead to the disruption of many biological and biochemical processes in the human body which may result in several chronic diseases [12, 13]. Regular monitoring of these contaminants in vegetables and other foodstuff is essential for preventing excessive build-up in the food chain. The aim of this study therefore, was to assess the concentrations of heavy metals in some vegetables sold in Gwagwalada central market, Abuja, Nigeria.

MATERIALS AND METHOD

Study Area

The study was carried out in Gwagwalada Area Council of the Federal Capital Territory (FCT) Abuja, Nigeria (Figure 1). Gwagwalada is located at the south west near the flood plain of river Gurara which transverses the territory from north to south at an elevation of 70 m above sea level [14]. The area lies between latitude $07^{0}.57^{'}$N and longitude $07^{0}.7^{'}$E [14]. The vegetation combines the features of the southern tropical rain forest and guinea savanna of the north. This reflects the full transitional nature of the area as between the southern forest and northern grassland which have the woods and shrubs respectively. The soil is reddish with isolated hills filled by plains and well drained sandy clay loams which support farming of diverse crops [14]. The duration of sunshine ranges from 8 to 10 hours per day with an average annual rainfall of 1650 mm [15]. The original settlers are Gwari, Koro, Bassa, Gade and the Hausa-Fulani as well as

immigrants' population of other Nigerians and expatriates.

The Gwagwalada Area Council has an area of about 1,043 km^2 and a population of 402,000 at the 2016 census [16, 17]. It is the industrial zone of the Federal Capital Territory and over 26 headquarters of federal agencies are situated in the Area Council including the University of Abuja and the University of Abuja Teaching Hospital. The major occupation of the inhabitants is large scale farming and sales of farm produce including fruits and vegetables.

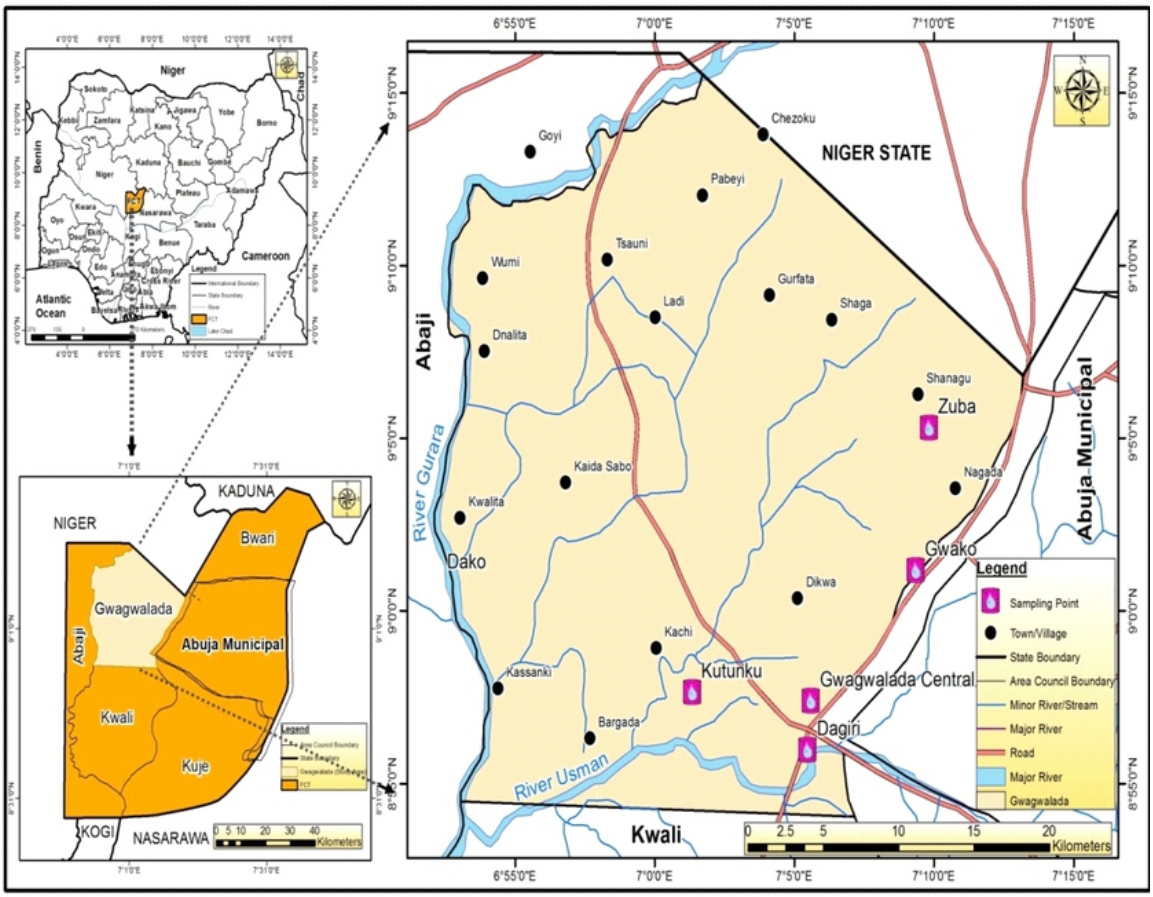

Figure 1: Map of Gwagwalada (Abuja GIS, 2004)

Sampling and Sampling Technique

Using the random sampling technique, edible portions of cabbage (*Brassica oleracea*), carrot (*Dactus carota*), cucumber (*Amaranthus cruentus*), lettuce (*Latuca sativa*), green peas (*Pisum sativum*), onion (*Allium cepa*) and banana (*Musa spp.*) were sourced from the Gwagwalada Central Market in the month of July, 2019.

Sample Preparation

The vegetables were properly washed with distilled water and chopped into small pieces in order to facilitate drying at 100^{o}C at the same rate. The dried samples were ground using an electric grinder (Superpulvar 234, Chn) and then sieved to obtain fine powder which was subsequently stored in well labelled polythene bags and transported to Sheda Science and

Technology Complex (SHESTCO), Abuja, Nigeria, for analysis. The samples were further prepared by digesting 2 g of the ground sample with 10 ml of nitric acid at 80°C, allowed to cool until a clear solution was obtained. The digest was allowed to cool and then filtered using Whatman No. 42 filter paper and the filtrate was diluted to a 100 ml standard flask and made up to mark with de-ionized water.

Determination of Heavy Metals

The determination of the heavy metals was carried out using atomic absorption spectrophotometer (AAS) (Thermo Scientific, Waltham, MA, iCE3000 AA02134104 v1. 30) equipped with air-acetylene flame. The presence of Cd, Cr, Ni, and Pb was measured using granite furnace AAS (detection limits of 0.002 µg/L, 0.004 µg/L, 0.07 µg/L, and 0.05 µg/L respectively) and the presence of Cu and Mn by air-acetylene flame AAS (detection limit of 0.0015 µg/L for all the heavy metals), both using the AAS. Hollow cathode lamps were used as sources of radiation from detection.

Quality Control and Quality Assurance

Blanks and quality control standards were measured at every five samples to detect contamination and drift. The elemental concentrations of procedural blanks were generally < 5 % of the mean analytes' concentrations for all the metals. Precision and accuracy of analyses were also ensured through replicate analyses of samples against standard reference materials for all the heavy metals. The results were found to be within ±2 % of certified values, thus demonstrating the accuracy of our findings.

Health Risk Assessment

Estimated Daily Intake of Metals (DIM)

The daily intake of the heavy metals Cu, Mn, Cr, Pb, Ni, and Cd (DIM) was calculated as a product of the concentration of the heavy metals in vegetables and the amount of the respective vegetable consumed. The DIM of metals was determined by the following equation:

Daily intake of metals (DIM) = DVC × VMC

DVC = Daily vegetable consumption

VMC = Mean vegetable metal concentration (mg/kg)

where daily vegetable consumption (DVC) was considered to be 98 g of vegetables per person per day for an average adult of 60 kg body weight [18].

Health Risk Index (HRI)

The health risk index (HRI) for the consumption of contaminated vegetables was estimated as the ratio of the daily intake of metals to the reference oral dose (RfD) for each metal. The HRI < 1 means the exposed population is safe.

$$HRI = \frac{DIM}{R_fD \times B_o \text{ (Body weight)}}$$ [18]

The oral reference dose (RfD) is an estimate of a daily oral exposure of the human population, which does not cause deleterious effects during a lifetime, generally used in USEPA's non-cancer health assessments [19]. The oral reference dose (RfD) values for Cu, Mn, Pb, Ni, Cd, and Cr are 0.3, 0.7, 0.0035, 1.5, 0.01, and 0.04 mg/kg/day, respectively [19].

Hazard Index (HI)

The hazard index (HI) as developed by USEPA [20] was calculated as the summation of the

potential health risk index (HRI) arising from all the metals examined.

$$HI = \Sigma (HRI_{Cu} + HRI_{Mn} + HRI_{Pb} + HRI_{Ni} + HRI_{Cd} + HRI_{Cr}$$

The value of the hazard index is proportional to the magnitude of the toxicity of the vegetables consumed.

Data Analysis

Descriptive statistics such as mean and range were used to summarize data collected from sampling sites. The data were expressed as mean ± standard error of the mean and were analyzed with the Mann–Whitney two tailed test using GraphPad Prism version 7.04 for Windows (GraphPad software, San Diego, CA). Values of $p < 0.05$ were considered statistically significant.

RESULTS

Concentrations of Heavy Metals in the Vegetables

Heavy metal concentrations showed variations among different vegetables purchased at the Gwagwalada central market as shown in Table 1. Among the vegetables, Cr concentration was highest in green peas while Pb concentration was highest in banana. The concentration of copper observed in cucumber, cabbage, banana, lettuce, green peas, carrot and onion were 12.45±1.2, 10.68±3.0, 16.14±1.1, 17.89±1.2, 17.28±1.1, 19.78±1.2 and 12.94 ±1.2 respectively, and 9.81±0.6, 39.30±0.3, 6.16±0.03, 43.28±12.6, 35.32±4.6, 26.51±2.0 and 10.26±3.1 for manganese was cucumber, cabbage, banana, lettuce, green peas, carrot and onion respectively.

When the present concentrations of metals were compared with permissible limits and safe limits [21], it was found that Cu, Mn, Pb and Cr concentrations were higher in all the vegetables.

Estimated Daily Intake of the Heavy Metals

The daily intake of metals was estimated according to the average vegetable consumption for adults (Table 2). The heavy metal levels in all the vegetables exceeded the USEPA oral reference dose.

Health Risk Index from Consuming the Vegetables

The potential health risk from consuming the individual vegetables were all above 1.0 except for Ni (HRI = 0) regardless of the population type (Table 3). Therefore, the consumption of these vegetables can be considered unsafe with high risks to human health.

The Hazard Index

The results of the hazard index for the individual heavy metals are presented in Table 4.

Table 1 : The concentrations of heavy metals in the vegetables

Heavy metals (mg/kg)	Cucumber (mg/kg)	Cabbage (mg/kg)	Banana (mg/kg)	Lettuce (mg/kg)	Green pea (mg/kg)	Carrot (mg/kg)	Onion (mg/kg)	NAFDAC acceptable limits (mg/kg)	FAO/WHO Permissible values (mg/kg) [26]
Copper	12.45 *[a]± 1.2	10.68*[d]± 3.1	16.14*[b]± 1.1	17.89*[b]± 1.2	17.28*[b]± 1.1	19.78*[c]± 1.2	12.94*[a]± 3.1	**40.00**	**73.3**
Manganese	9.81*[a]± 0.6	39.30*[b]± 0.3	6.16*[c]± 0.03	43.28*[d]± 12.6	35.32*[c]± 4.6	26.51*[c]± 2.0	10.26*[c]± 3.1	**30.00**	**0.7**
Lead	8.65*[a]± 1.1	BDL	100.40*[b]± 10.0	68.00*[c]± 7.0	64.76*[c]±5.8	61.28*[c]± 5.6	8.92*[d]± 1.1	**2.00**	**0.3**
Nickel	BDL	BDL	BDL	BDL	BDL	BDL	BDL	**27.00**	**67.9**
Cadmium	BDL	0.10*[a]± 0.1	BDL	BDL	BDL	BDL	BDL	**0,20**	**0.2**
Chromium	3.60*[a]± 0.3	10.53*[b]± 3.1	13.51*[c]± 2.3	BDL	193.87*[d]± 12.6	BDL	BDL	**2.00**	**1.3**

BDL: Below detectable limit

* Statistical significant difference from the reference values

[a,b,c] Statistical difference within groups

Table 2: Estimated Daily Intake of Metals (DIM) (mg/kg/person/day) from Consumption of the vegetables in adults

Heavy metals	Cucumber (mg/kg)	Cabbage (mg/kg)	Banana (mg/kg)	Lettuce (mg/kg)	Green pea (mg/kg)	Carrot (mg/kg)	Onion (mg/kg)	USEPA oral reference dose (mg/kg) [19]
Copper	1220	1050	1580	1750	1690	1940	1270	**0.3**
Manganese	960	3850	600	4240	3460	2600	1010	**0.7**
Lead	850	0.00	9820	6660	6350	6010	870	**0.0035**
Nickel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.5**
Cadmium	0.00	10	0.00	0.00	0.00	0.00	0.00	**0.001**
Chromium	350	1030	1320	0.00	19000	0.00	0.00	**0.04**

Table 3: Health risk index of the heavy metals

Heavy metals	Cucumber (mg/kg)	Cabbage (mg/kg)	Banana (mg/kg)	Lettuce (mg/kg)	Green peas (mg/kg)	Carrot (mg/kg)	Onion (mg/kg)	USEPA oral reference dose (mg/kg) [19]
Copper	67.7	58.3	87.7	97.2	93.8	107.7	70.6	**0.3**
Manganese	20	80.2	12.5	88.3	72.1	54.1	21.0	**0.7**
Lead	4047	0.00	46761	31714	30238	28619	4142	**0.0035**
Nickel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.5**
Cadmium	0.00	166.6	0.00	0.00	0.00	0.00	0.00	**0.001**
Chromium	145.8	429.2	550	0.00	7916.7	0.00	0.00	**0.04**

Table 4: Hazard Index (HI) for the individual heavy metals in different vegetables

Heavy metals	Cucumber	Cabbage	Banana	Lettuce	Green pea	Carrot	Onion	Mean HI
Copper	67.7	58.3	87.7	97.2	93.8	107.7	70.6	**83.3**
Manganese	20	80.2	12.5	88.3	72.1	54.1	21.0	**49.7**
Lead	4047	00.00	46761	31714	30238	28619	4142	**20788**
Nickel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0**
Cadmium	0.00	166.6	0.00	0.00	0.00	0.00	0.00	**23.8**
Chromium	145.8	429.2	550	0.00	7916.7	0.00	0.00	**1291.7**
							$\sum$ HI	**22,236.5**

DISCUSSION

In the current study, there were variations in the heavy metal concentrations of the different vegetables sampled from Gwagwalada market, Abuja, Nigeria. These variations may be attributed to differences in the morphology and physiology of the plants for heavy metal uptake, exclusion, accumulation and retention [23]. The observed high Cr concentration in green peas may be attributable to the plant's high bioaccumulation capacity for this metal [24]. The high Pb concentration in bananas are similar to those reported by Zhou *et al*. [25] who carried out studies in selected markets in Abuja, Nigeria. Moreover, the concentrations of Ni and Cd in the vegetable types were below the maximum permissible limit [26]. The significant elevations observed in the Cu and Mn levels may be ascribed to anthropogenic activities around the farmlands or vehicular activities surrounding the market [27].

The toxicity of heavy metals in humans exposed through the consumption of food, depends on the daily intake [28]. It was observed in the present investigation that the heavy metals intake through the consumption of different vegetables grown and sold in Gwagwalada varies. The permissible reference dose [18] of FAO/WHO has established a daily intake level. Our findings suggest that the heavy metals assessed were all above this estimated daily intake reference values. This finding is similar to previous reports by Orisakwe [28].

The hazard index of the heavy metals through the intake of vegetables in this study were all above the USEPA oral reference dose values. This could be an indication of a high risk from consumption of vegetables sold in this area, in agreement with the investigation conducted by Ametepey [29]. Also, the hazard index was above 1 for all the vegetables. Consequently, there is a need for serious concern and appropriate actions regarding the continuous consumption of the vegetables in view of the potential health risks posed.

Conclusion

This study showed that heavy metals were present in some vegetables sold in Gwagwalada market and the detected levels were higher than the FAO/WHO recommended standard except for Ni and Cd which were below detectable limit. Therefore, regular monitoring and enforcement of standard regulations regarding heavy metal levels in vegetables is recommended.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

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