International Journal of Current Research and Applied Studies, (IJCRAS)

ISSN: 2583-6781

available at https://ijcras.com/

Volume 1 Issue 2 May-June 2022

Page 01-16

HEALTH RISK ASSESSMENT OF SOME HEAVY METALS (CADMIUM, CHROMIUM AND LEAD) IN COMMONLY CONSUMED VEGETABLES, COLLECTED AT JANGUZA MARKET, KANO STATE, NIGERIA.

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ABSTRACT

Heavy metals contamination of commonly consumed vegetables is a major global concern to human health. The consumption of contaminated vegetables is a major route of heavy metals ingestion to human body system. This project research was to assess the health risk of some heavy metals (cadmium, chromium and lead) in commonly consumed vegetables; Bitter leaf (Vernonia amygdalina), Cucumber (Cucumis sativus), Tomato (Solanum lycopersicum), Lettuce (Lactuca sativa), Pumpkin (Cucurbita pepo), Okra (Abelmoschus esculentus), Spinach (Spinacia oleracea), and Cabbage (Brassica oleracea), collected at Janguza market, Kano state, Nigeria. The Samples of vegetables were collected, air dried, digested and analyzed for heavy metals concentrations through atomic absorption spectrophotometer. The result obtained revealed that Cadmium, chromium and lead concentrations in the sampled vegetables ranged from (0.012-0.077) mg/kg, (0.004-0.046) mg/kg, (0.008-0.018) mg/kg, respectively. spinach had the highest concentration for cadmium (0.077) mg/kg and chromium (0.046) mg/kg, while tomato had the highest concentration for lead (0.018) mg/kg. The mean concentration of heavy metals in all the investigated vegetables were below the permissible limits set by WHO, 2007. The computed health risk indices of hazard quotient, hazard index and Daily intake of metals through adult consumption of the investigated vegetables do not pose any potential risk to human health. It is recommended that researches should be carried out to ascertain the sources of contamination of these heavy metals in commonly consumed vegetables in Kano state so as to reduce the potential health risk through the consumption of these vegetables.

Keywords: Heavy metals, Health risk, Hazard Quotient, Hazard index.

1. INTRODUCTION

Heavy metals contamination is a globally recognized environmental issue, threatening human life seriously (Anwarzeb *et al*., 2015). Food crops are one of the important parts of our diet, and they may contain a number of essential and toxic metals (Yang *et al.,* 2011). Increasing population and high demand for food resulted in release of various contaminants into the environment that finally contaminate the food chain (Anwarzeb *et al.*, 2015. Edible plants are the major source of diet, and their contamination with toxic metals may result in catastrophic health hazards (Anwarzeb *et al,*. 2015). Vegetables are important edible crops and are essential part of the human diet, they are rich in nutrients required for human health, and are important source of carbohydrates, vitamins, minerals, and fibers (Yang *et al.*, 2009). Vegetables are source of essential nutrients, antioxidants and metabolites in food item (Ftsum and Abraha, 2018). They constitute an important part of the human diet since they contain carbohydrates, proteins, vitamins, minerals as well as trace elements (Nazemi, 2012).

Heavy metals are inorganic elements essential for plant growth in traces or very small quantities (Ftsum and Abraha, 2018). They are hazardous contaminants in food and the environment and they are non-biodegradable having long biological half-lives (Heidarieh et al., 2013). Soils may become contaminated by the accumulation of heavy metals through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric depositions (Modaihsh, 2004). Some heavy metals such as; Cu, Fe, Ni, Zn, Mn, etc., are essential for the growth and development of plants when present in trace amounts, but at excessive concentrations these become toxic as both the natural and anthropogenic sources are responsible for increasing the levels of heavy metals in the environment (Agrawal *et al.*, 2007). Natural sources include; parent geologic rock material, volcanic outcropping, spontaneous contributions or forest fires, whereas anthropogenic sources include; sewage sludge, pesticides, organic matter, composts, fertilizer supplements (Lopez *et al*., 2000), industrial waste, mining, smelting and metallurgical industries (Singh 2001), and use of treated or untreated industrial and municipal effluents for irrigation purposes (Barman *et al*., 2000). Both commercial and residential growing areas are also vulnerable to atmospheric pollution, in the form of metal containing aerosols, which can penetrate the soil and be absorbed by vegetables, or alternatively be deposited on leaves and absorbed (Tasrina *et al*,. 2015). Mineral fertilizers have higher heavy metal concentrations as compared to organic manure; therefore, the application of mineral fertilizers results in soil heavy metal pollution (Hu *et al*,. 2013).

Plant contamination with heavy metals may occur through soil–plant, water–plant, and air–plant interfaces; however, soil–plant interface is the major source of plant metal accumulation (Khan *et al*,. 2015). The bioaccumulation of heavy metal is different for different plant species reflected by their growth, reproduction, occurrence, and survival in the metal-contaminated soil (Garty, 2001). Heavy metals can be readily taken up by vegetable roots, and can be accumulated at high levels in the edible parts of vegetables, even heavy metal in soil at low levels (Jolly *et al.*, 2013). Based on heavy metal uptake, the plants are classified as accumulator, hyperaccumulator, and excluders (Khan *et al,*. 2015). Heavy metal accumulation in food plants depends on metal concentrations as well as phyto-availability and phytovariety, as different plants have different uptake rates (Medina, *et al* 2005). Generally, the leafy vegetable metal uptake rates are higher and more contaminated than nonleafy vegetables (Yu *et al*, 2006). Leafy vegetables are good accumulators of toxic heavy metals due to their higher capacity of absorption both from contaminated soil and aerial deposits (Agrawal *et al.*, 2007). Leafy vegetables like lettuce are considered as potential hyperaccumulators of heavy metals (Ramos *et al,*. 2002). In nonleafy vegetables, the bioaccumulation pattern was leaf > root ≈ stem > tuber (Khan *et al,*. 2015). Heavy metals are first absorbed by the roots and are transported further into other parts of the cells (Agrawal *et al.*, 2007). Heavy metals are translocated to different plant parts through various pathways and result into reductions in growth by altering the physiological, biochemical and metabolic activities of the plants (Agrawal *et al.*, 2007). Plants are able to take up heavy metals available in air, water, soil and sediments, depending on their concentrations (Agrawal *et al.*, 2007). It is notable that different plant species show different toxicity to the same pollutant and in the same environmental condition, because the mechanisms of elemental uptake by plants are not the same for all plant species (Garty, 2001). The soil has a tendency to accumulate heavy metals, but the concentrations do not reach high levels due to continuous removal of heavy metals by plants (Sharma *et al.*, 2007). Heavy metals bioavailability to plants is strongly related to the concentration and specification of the element in the soil solution because this is where the plants get the heavy metals that they take up, this is because, plants only take up one or two forms of heavy metals from the soil solution (Tasrina *et al,*. 2015). The contamination of vegetables with heavy metals due to soil and atmospheric contamination poses a threat to its quality and safety (Nazemi, 2012).

Dietary intake of heavy metals also poses risk to animals and human health (Nazemi, 2012). High concentrations of heavy metals (Cu, Cd and Pb) in fruits and vegetables were related to high prevalence of upper gastrointestinal cancer (Turkdogan *et al.*, 2003). However, their consumption by humans and animals can pose serious health hazards, because they are potential carcinogens or cause human organ dysfunction (Ftsum and Abraha, 2018). Although, some heavy metals such as Cu, Zn and Fe are essential in plant nutrition, many of them do not play significant role in the plant physiology, for instance, Pb and Cd are among the most abundant heavy metals and are particularly toxic (Ftsum and Abraha, 2018). The uptake of these heavy metals by plants especially leafy vegetables is the path of their entry into human food chain which ends with harmful effects on health (Akan *et al*., 2009).

Vegetables (leafy and nonleafy) grown on contaminated soil are considered as the major source of heavy metals (Khan *et al,*. 2015). The advantage of high biomass production and easy disposal, makes vegetables useful to remediate heavy metals from a contaminated environment, but the excessive intake and consequent accumulation in human beings through long-term consumption of contaminated food may result in negative effects on human health (Agrawal *et al.*, 2007). Heavy metals have strong influence on nutritional values; therefore, plants grown on metal-contaminated soil were nutrient deficient and consumption of such vegetables may lead to nutritional deficiency in the population particularly living in developing countries which are already facing the malnutrition problems (Khan *et al*,. 2015). Food crop irrigated with industrial effluents and wastewater is the major source of soil and crop contamination with heavy metals and metalloids (Lee *et al*,. 2008). According to (Türkdoğan *et al*,. 2003), the consumption of heavy metal-contaminated food can seriously deplete some essential nutrients in the body that are further responsible for decreasing immunological defenses, such as; intrauterine growth retardation, impaired psycho-social facilities, disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates. This research is to assess the health risk of some heavy metals (cadmium, chromium and lead) in commonly consumed vegetables; Bitter leaf (*Vernonia amygdalina)*, Cucumber (*Cucumis sativus*), Tomato (*Solanum lycopersicum*), Lettuce (*Lactuca sativa*), Pumpkin (*Cucurbita pepo*), Okra (*Abelmoschus esculentus*), Spinach (*Spinacia oleracea*), and Cabbage (*Brassica oleracea*), collected at Janguza market, Kano state, Nigeria. To meet the following objectives; (i) To determine the concentration of heavy metals in some commonly consumed vegetables. (ii)To determine the non-cancer health risk assessment (daily intake rate of the metals, Health index and Hazard Quotient), associated with the consumption of these vegetables.

2. Materials and Methods

2.1. Study Area

Janguza market is a commercial place where different varieties of food crops are found, located at Kano state, Nigeria. It is located between longitude 8^0 22’ 52E and latitude 11^0 57’ 30N. It is among one of the most visited market place in kano state. This site was selected to collect some commonly consumed vegetables found which include; Bitter leaf (*Vernonia amygdalina)*, Cucumber (*Cucumis sativus*), Tomato (*Solanum lycopersicum*), Lettuce (*Lactuca sativa*), Pumpkin (*Cucurbita pepo*), Okra (*Abelmoschus esculentus*), Spinach (*Spinacia oleracea*), and Cabbage (*Brassica oleracea*).

2.2. Sample Collection

The vegetables were collected from the selected site in Kano state, Nigeria. The samples were kept in a polythene bag which were immediately transported to the laboratory. The samples were washed using distilled water in other to remove the dust particles. The samples were sliced separately and were allowed to be air dried at room temperature. The dried samples were crushed using pestle and mortar and was passed through a sieve of 10mm mesh size to obtain a powdered sample. Finally, the powdered sample was stored in a tightly closed clean and labelled sample bottles until analysis (Abbasi *et al.*, 2014).

2.3. Procedure for Digestion of Samples

1.0g each of the powdered sample was placed separately into labelled 100ml washed and dried beakers. 30ml of an aqua regia acid was poured into the sample using calibrated syringe. The mixture was heated at 160^{o}C for 1 hour on a hot plate until a clear solution was obtained. The sample was then allowed to cool to room temperature. The mixtures were filtered and transferred to a 50 mL volumetric flask, diluted to the mark with distilled water and was allowed to settle. The sample solution was later transferred into a screw capped polyethylene bottle (Ftsum and Abraha, 2018).

2.4. Heavy Metal Analysis

Heavy metals concentrations (mg/kg) in the digested sampled vegetables were analyzed using atomic absorption spectrophotometer (AAS). duplicate readings were noted to avoid error in the results (Hafiza *et al*., 2016).

2.5. Determination of Daily Intake of Metals

The following formula was used to calculate the daily intake of metals in human body.

$$DIM = \frac{M \times K \times I}{W} \quad (1)$$

Where M represents concentration of heavy metals in plant tissue (mg/kg), I represent the amount of intake of vegetables on daily basis, W is average body weight and K is conversion factor. To convert fresh weight of vegetables into dry weight, 0.085 will be used as conversion factor (Rattan *et al*., 2005). The average adult body weight was considered as 55.9kg, whereas average intake of vegetables in adult was considered as 0.345kg/person/day; all estimated values stated were obtained from (Chen *et al*., 2005).

2.6. Determination of Hazard Quotient

Hazard (HQ) refers to the ratio of the daily intake of metals in the vegetables to the Oral reference dose and was calculated using the following equation;

$$\mathrm{HQ} = \frac{\mathrm{DIM}}{Rf_D} \quad (2)$$

Where; HQ is the hazard quotient, DIM is daily intake metal and Rf_D is the oral reference dose.
Oral reference dose; Reference oral dose (Rf_D) is an estimated exposure of metal to the human body per day that has no hazardous effect during life time (Yang and Liu 2012). The values of oral reference dose for the selected metals that were used are; Pb (0.3mgkg^{-1}), Cd (0.1 mgkg^{-1}), and Cr (2.3 mgkg^{-1}) given by USEPA IRIS, 2006 (Hafiza *et al*., 2016).

2.7. Determination of Health Index

$HI = HQ_1 + HQ_2 \ldots + HQ_n$. (Isa *et al.*, 2015). (3)

HI > 1 for any metal in the vegetable means that the consumer population faces a health risk (Chioma *et al.*, 2016).

3. RESULTS

The mean concentration of heavy metals in the investigated vegetables revealed that chromium had the highest concentration of 0.046mg/kg in spinach (*Spinacia oleracea*), followed by lead which was also found in spinach (*Spinacia oleracea*). The mean concentration of heavy metals with the least concentration of 0.004mg/kg was chromium seen in pumpkin (*Cucurbita pepo*), (Table 4.1). In all the studied vegetables, spinach (*Spinacia oleracea*) had the highest concentration of cadmium and chromium (0.077, 0.046) mg/kg respectively, while tomato (*Solanum lycopersicum*), had the highest concentration of lead (0.018 mg/kg). The mean result showed that the concentration ranged from (0.012-0.077, 0.004-0.046, 0.008-0.018) mg/kg for cadmium, chromium and lead respectively (Table 4.1). The mean concentration of heavy metals in the studied vegetables were below the permissible limit set by (W.H.O, 2007).

Table 3.1 Mean Values of Heavy Metals (mg/kg) in Vegetables

Vegetables	Part of plant used	Heavy metals		
		Cd	Cr	Pb
Cabbage	Leaf	0.017 ± 0.002	0.010 ± 0.002	0.008 ± 0.00
Bitter Leaf	Leaf	0.012 ± 0.002	0.012 ± 0.00	0.010 ± 0.002
Cucumber	Fruit	0.032 ± 0.010	0.014 ±0.002	0.012 ± 0.00
Okra	Fruit	0.015 ± 0.002	0.014 ± 0.00	0.012 ± 0.002
Lettuce	Leaf	0.047 ± 0.004	0.008 ± 0.00	0.010 ± 0.002
Pumpkin	Fruit	0.035 ± 0.004	0.004 ± 0.00	0.010 ± 0.002
Spinach	Leaf	**0.077** ± 0.014	**0.046** ± 0.002	0.016 ± 0.002
Tomato	Fruit	0.052 ± 0.002	0.022 ± 0.011	**0.018** ± 0.002
Permissible limits (WHO, 2007)		0.02	5.0	0.3

The computed daily intake metal (DIM) values through adult consumption of the vegetables in the study area revealed the trends of the heavy metals in the following order; (Cd > Cr > Pb) in cabbage (*Brassica oleracea*), bitter leaf (*Vernonia amygdalina)*, cucumber (*Cucumis sativus*), okra (*Abelmoschus esculentus*), spinach (*Spinacia oleracea*), and tomato (*Solanum lycopersicum*) (Table 4.2). The order of (Cd > Pb > Cr) was found in lettuce (*Lactuca sativa*) and pumpkin (*Cucurbita pepo*). The highest daily intake rate was recorded in cadmium (4.0E-5mg/kg/day) followed by chromium (2.4E-5 mg/kg) in spinach (*Spinacia oleracea*), while the highest concentration for lead showed (9.4E-6 mg/kg) in tomato (*Solanum lycopersicum*), (Table 3.2).

Table 3.2: DIM (Daily Intake of Metal) Values (mg/kg/day) for the Vegetable Samples

Vegetables	Heavy metals		
	Cd	Cr	Pb
Cabbage	9.1E-06	5.3E-06	4.2E-06
Bitter Leaf	6.5E-06	6.3E-06	5.2E-06
Cucumber	1.7E-05	7.4E-06	6.2E-06
Okra	7.8E-06	7.4E-06	6.2E-06
Lettuce	2.5E-05	4.2E-06	5.2E-06
Pumpkin	1.8E-05	2.1E-06	5.2E-06
Spinach	**4.0E-05**	**2.4E-05**	8.3E-06
Tomato	2.7E-05	1.2E-05	**9.4E-06**

The computed hazard quotient through the consumption of each vegetable in the study area revealed that; the highest HQ value for the heavy metals was observed in cadmium (4.0E-2) and Chromium (1.6E-5) in spinach (*Spinacia oleracea*), while tomato (*Solanum lycopersicum*) has the highest value of heavy metal for lead (2.3E-3). Spinach (*Spinacia oleracea*) showed the highest value of hazard index (HI) (4.2E-2), and Bitter leaf (*Vernonia amygdalina*) showed the lowest value of hazard index, through adult consumption (Table 3.3). All the values of the computed hazard index were less than one (HI<1) which indicate that all the vegetables are within the safe limit for adult consumption.

Vegetables	Hazard Quotient			Hazard Index
	Cd	Cr	Pb	
Cabbage	9.1E-03	3.5E-06	1.0E-03	1.0E-02
Bitter Leaf	6.5E-03	4.2E-06	1.3E-03	7.8E-03
Cucumber	1.7E-02	4.9E-06	1.6E-03	1.8E-02
Okra	7.8E-03	4.9E-06	1.6E-03	9.4E-03
Lettuce	2.5E-02	2.8E-06	1.3E-03	2.6E-02
Pumpkin	1.8E-02	1.4E-06	1.3E-03	1.9E-02
Spinach	4.0E-02	1.6E-05	2.1E-03	4.2E-02
Tomato	2.7E-02	7.7E-06	2.3E-03	3.0E-02

Table 3.3: Hazard Quotient (HQ) and Hazard Index (HI) Values for the Vegetable Samples

4. DISCUSSION

In this study, the result revealed that the mean concentration of the heavy metals in the investigated vegetables ranges between (0.012-0.077) mg/kg, (0.004-0.046) mg/kg, (0.008-0.018) mg/kg, for cadmium, chromium and lead respectively. The heavy metal concentrations for the investigated vegetables were in the following order; for cadmium (spinach > tomato > lettuce > pumpkin > cucumber > cabbage > okra > bitter leaf), for chromium (spinach>tomato>cucumber>okra>bitterleaf>cabbage>lettuce>pumpkin), and for lead (tomato>spinach>okra>cucumber> (bitter leaf, lettuce, pumpkin)>cabbage). This result showed variability in the mean concentration of heavy metals in the investigated vegetables. Spinach had the highest mean concentration for Cadmium and Chromium while Tomato had the highest mean concentration for lead. This variation in the mean concentration of heavy metals among different vegetables may be attributed to the different in heavy metal uptake capabilities, growth rate, bioavailability of heavy metals, plant type among others. The heavy metal concentration in this project research were lower than the ones reported in vegetables collected in Lagos market and in Tamale Metropolis, Ghana, by (Adedokun *et al.*, 2016) and (Samuel *et al.*, 2018) respectively. The heavy metals content in vegetables across the markets reported by (Adedokun *et al.*, 2016), ranged as follow; Cd (0.05 –0.20 mg/kg); Pb (0.34 – 5.44 mg/kg), Zn (4.21 – 20.80 mg/kg), Cr (0.25 – 1.51 mg/kg), Ni (0.13 –2.91 mg/kg) and Cu (2.34 –

14.08 mg/kg). The concentrations of all the metals were quite generally lower than the permissible limits by FAO/WHO in the vegetables except for Pb. Similarly, (Samuel *et al.*, 2018), revealed that cadmium concentration in cabbage, carrot, green pepper, onion and tomato ranged from (0.04 to 0.07) mg kg^{-1}, (0.01 to 0.06) mg kg^{-1}, (0.04 to 0.06) mg kg^{-1}, (0.03 to 0.06) mg kg^{-1} and (0.03 to 0.07) mg kg^{-1}, respectively and the concentration of heavy metals in the various vegetables were below the World Health Organization (WHO) standards.

In this study, the computed daily intake metal values range between (6.5E-6 - 4.0E-5) mg/kg/day, (2.1E-6 - 2.4E-5) mg/kg/day and (4.2E-6 – 9.4E-6) mg/kg/day for cadmium, chromium and lead respectively. The hazard quotient for all the vegetables species ranges as follow; Cd (4.0E-2 – 6.5E-3), Cr (1.6E-5 – 1.4E-6)), and Pb (2.3E-3 – 1.0E-3) and the calculated HI for the investigated vegetables ranges from (4.2E-2 – 7.8E-3). The order in health index values for the vegetables was as follows; (spinach > tomato > lettuce > pumpkin > cucumber > cabbage > okra > bitter leaf). This indicates that among all the sampled vegetables, spinach had the highest health index value of 4.2E-2. All the health index values were less than 1 (HRI < 1). Generally, health risk index (HRI) < 1 means that the exposed population is safe of metals health risk while HRI > 1 means that the population is at a risk (Khan *et al.*, 2008). The Computed Hazard quotient and hazard index values in this study were lower than the HQ and HI values reported from the research conducted by Adedokun *et al*., (2016); Samuel *et al*., (2018). According to (Adedokun *et al.*, 2016), he found out that The HRI for all the vegetables species were far greater than 1 (HRI > 1) except Cr. Also, Samuel *et al.*, (2018), reported that Hazard index (HI) values of the heavy metals studied ranged from 6.51 to 29.30 which were above 1, indicating non-acceptable level of non-carcinogenic adverse health effect. Studies by (Hafiza *et al.*, 2016) in Bahawalpur, Pakistan showed that the health risk index (HRI) of vegetables irrigated with sewage water for adults and children were greater than 1 in 50 % vegetables in case of Cd, while those vegetables irrigated with turbine water were found to be less than one (<1) for both children and adults. This illustrate that vegetables irrigated with turbine water do not imparts any health risk theoretically, and the use of sewage water may be responsible for the HI values greater than one (>1), than the lower values less than one (<1) reported in this study.

5. CONCLUSION

In this research, it was revealed that the mean concentrations of heavy metals in the vegetables were within the permissible limits set by world health organization (2007), and the calculated hazard index (HI) and hazard quotient (HQ) values for the investigated vegetables were less than one (HI<1). Thus, this indicates that all the investigated vegetables were safe for adult consumption and will not pose a serious health hazard over a lifetime.

6. RECOMMENDATION

It is recommended that;

1. Researches should be carried out to ascertain the sources of contamination of these heavy metals in commonly consumed vegetables in Kano state.

2. Awareness should be raised about the dangers of heavy metal pollution in order for farmers to adopt best practices for cultivation of vegetables.
3. Further researches should be carried out to study the levels of heavy metals in vegetables in and around Kano state in order to maintain or improve measures to reduce their levels in vegetables and ultimately prevent this health problem.

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