



Human Health Risk Assessment of Heavy Metals in Onion Bulbs Cultivated in Katsina State, North West Nigeria

**A. I. Yaradua^{1*}, A. J. Alhassan², A. Nasir¹, S. S. Matazu¹, A. Usman¹,
A. Idi², I. U. Muhammad³, S. A. Yaro⁴ and R. Nasir¹**

¹*Department of Biochemistry, Faculty of Natural and Applied Sciences, Umaru Musa Yar'adua University, P.M.B. 2218, Katsina, Nigeria.*

²*Department of Biochemistry, Faculty of Basic Medical Sciences, Bayero University Kano, P.M.B. 3011, Kano, Nigeria.*

³*Department of Biochemistry, Faculty of Basic Medical Sciences, Yusuf Maitama Sule University, P.M.B. 3220, Kano, Nigeria.*

⁴*Department of Biological Sciences, Faculty of Sciences, Federal University, P.M.B. 5007, Dutsinma, Katsina State, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. Author AIY designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors AJA, AN, SSM, AU and AI performed the statistical analysis and manage the analysis of the study. Author IUM, SAY and RN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Vegetable fields in Katsina State are increasingly being loaded with heavy metals through various pollution sources such as agricultural activities mining and traffic. Onion bulb samples from the three senatorial zones that constitute to make up Katsina state in the North West of Nigeria were collected and the concentrations of seven heavy metals (Pb, Cd, Cr, Fe, Zn, Mn and Ni) in all the samples were determined by atomic absorption spectrometry. The health risk assessment

*Corresponding author: Email: aliyuyaradua5@gmail.com;

methods developed by the United States Environmental Protection Agency (US EPA) were employed to explore the potential health hazards of heavy metals in the samples on the children and adult population. The highest mean concentration (mg/kg) was observed for Fe, followed by Pb, Zn and Mn. While Cd has the lowest concentration with the heavy metals Cr and Ni being below detection level (BDL). Overall hazard index (Hi) for the heavy metals were within the safety limit. The overall cancer risk to the adults based on pseudo-total metal concentrations exceeded the target value, mainly contributed by Pb. Mn and Zn were the primary heavy metals posing non-cancer risks while Pb caused the greatest cancer risk. It was concluded that consumption of the onion samples from Katsina State may contribute to the population cancer burden.

Keywords: Onion; heavy metals; Katsina; health risk index; cancer risk.

1. INTRODUCTION

Vegetables play important roles in human nutrition and health, particularly as sources of vitamin C, thiamine, niacin, pyridoxine, folic acid, minerals, and dietary fiber [1]. Heavy metals are environmental contaminants capable of causing human health problems if excess amount is ingested through food they are non biodegradable and persistent, have a long biological half lives and can be bio-accumulated through biological chains [2]. Heavy metal toxicity may occur due to contamination of irrigation water, the application of fertilizer and metal based pesticides, industrial emission, harvesting process, transportation, storage or sale. Crops grown in soils contaminated with heavy metals have greater accumulation than those grown in uncontaminated soils [3]. The toxicity of heavy metals most commonly involves the brain and kidney but other manifestations can occur in some other parts of the body for example arsenic is clearly capable of causing cancer, hypertension can result in individuals exposed to lead and renal toxicity in individual exposed to cadmium [4]. In Katsina State Nigeria, there is limited information on the levels of heavy metals in locally cultivated onions. This work therefore seeks to bridge that gap by providing information especially to the Katsina State populace on the levels of heavy metals of this most consumed vegetable. Information will further be provided on the heavy metals composition, sources of this vegetable and the extent to which they are contaminated with these heavy metals for future studies and effective comparative analysis. Data on heavy metal in the cultivated onion bulb generated will give an insight on the level of metal contamination and by extension the impact on food safety standard and risk to consumers. The objective of this study therefore was to evaluate human exposure to some heavy metals through consumption of some locally cultivated vegetables in Katsina State, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area and Sample Collection

The study was carried out in 2017 in Katsina State, Nigeria located between latitude 12°15'N and longitude of 7°30'E in the North West Zone of Nigeria, with an area of 24,192 km² (9,341 m²). Katsina State has two distinct seasons: rainy and dry. The rainy season begins in April and ends in October, while the dry season starts in November and ends in March. This study was undertaken during the rainy season. The average annual rainfall, temperature, and relative humidity of Katsina State are 1,312 mm, 27.3°C and 50.2%, respectively [5]. The study was conducted within some catchment areas that cultivate onions located within the 3 senatorial zones that constitute to make up the state (Katsina senatorial zone: Funtua senatorial zone; Daura senatorial zone). Sampling for this work was carried out by dividing the catchment areas into five [5] locations. In each of the locations, the plot where the onions are cultivated was subdivided into twenty [6] sampling areas. Samples of onions were collected from each of the areas and combined to form bulk sample, from which a representative sample was obtained. The samples were code-named and stored in glass bottles with tight covers to protect them from moisture and contamination. They were then stored in the refrigerator at 4°C until ready for use.

2.2 Identification of Sample

The samples were identified in the herbarium of the Department of Biology of Umaru Musa Yar'adua University Katsina.

2.3 Sample Preparation

The collected samples were cleaned by using dry air to remove the air borne pollutants, and the samples fragmented with a clean plastic spoon

and knife and dried at ambient temperature and stored in the refrigerator at 4°C until ready for used.

2.4 Heavy Metals Determination

5 g of each sample was dried at 80°C for 2 hours in a Gallenkamp hotbox oven (CHF097XX2.5) and then blended in an electric blender. 0.5 g of each sample was weighed and ashed at 550°C for 24 hours in an electric muffle furnace (Thermolyne FB131DM Fisher Scientific). The ash was diluted with 4.5 ml concentrated hydrochloric acid (HCl) and concentrated nitric acid (HNO₃) mixed at ratio 3:1 the diluent is left for some minutes for proper digestion in a beaker. 50 ml of distilled water was added to the diluents to make up to 100 ml in a volumetric flask. The levels of heavy metals (Pb, Zn, Ni, Cd, Cr, Mn and Fe) were determined using AA210RAP BUCK Atomic Absorption Spectrometer flame emission spectrometer filter GLA-4B Graphite furnace (East Norwalk USA), according to standard methods [7] and the results were given in (ug/g).

2.5 Heavy Metal Health Risk Assessment

2.5.1 Daily intake of metals (DIM)

The daily intake of metals was calculated using the following equation:

$$DIM = \frac{C_{metal} \times C_{factor} \times D_{intake}}{B_{weight}}$$

Where, C_{metal} , C_{factor} , D_{intake} and B_{weight} represent the heavy metal concentrations in the samples, the conversion factor, the daily intake of the onion bulbs and the average body weight, respectively. The conversion factor (CF) of 0.085 [8] was used for the conversion of the samples to dry weights. The average daily intake of the sample was 0.527 kg person⁻¹ d⁻¹ [9] and the average body weight for the adult and children population was 60 kg [10] and 24 kg [11] respectively; these values were used for the calculation of HRI as well.

2.5.2 Non-cancer risks

Non-carcinogenic risks for individual heavy metal in the onion bulb samples were evaluated by computing the target hazard quotient (THQ) using the following equation [12].

$$THQ = CDI / RfD$$

CDI is the chronic daily heavy metal intake (mg/kg/day) obtained from the previous section

and RfD is the oral reference dose (mg/kg/day) which is an estimation of the maximum permissible risk on human population through daily exposure, taking into consideration a sensitive group during a lifetime [13]. The following reference doses were used (Pb = 0.6, Cd = 0.5, Zn = 0.3, Fe = 0.7, Ni = 0.4, Mn = 0.014, Cr = 0.3) [14,15]. To evaluate the potential risk to human health through more than one heavy metal, chronic hazard index (HI) is obtained as the sum of all hazard quotients (THQ) calculated for individual heavy metals for a particular exposure pathway [16]. It is calculated as follows:

$$HI = THQ_1 + THQ_2 + \dots + THQ_n$$

Where, 1, 2, ..., n are the individual heavy metals in the samples.

It is assumed that the magnitude of the effect is proportional to the sum of the multiple metal exposures and that similar working mechanism linearly affects the target organ [17]. The calculated HI is compared to standard levels: the population is assumed to be safe when $HI < 1$ and in a level of concern when $1 < HI < 5$ [18].

2.6 Cancer Risks

The possibility of cancer risks in the studied onion bulb samples through intake of carcinogenic heavy metals were estimated using the Incremental Lifetime Cancer Risk (ILCR) [19].

$$ILCR = CDI \times CSF$$

Where, CDI is chronic daily intake of chemical carcinogen, mg/kg BW/day which represents the lifetime average daily dose of exposure to the chemical carcinogen.

The US EPA ILCR is obtained using the cancer slope factor (CSF), which is the risk produced by a lifetime average dose of 1 mg/kg BW/day and is contaminant specific [12]. ILCR value in onion bulb represents the probability of an individual's lifetime health risks from carcinogenic heavy metals exposure [20]. The level of acceptable cancer risk (ILCR) for regulatory purposes is considered within the range of 10^{-6} to 10^{-4} [13]. The CDI value was calculated on the basis of the following equation and CSF values for carcinogenic heavy metals were used according to the literature [19].

$$CDI = (EDI \times EFr \times ED_{tot}) / AT$$

where EDI is the estimated daily intake of metal via consumption of the onion bulb; EFr is the

exposure frequency (365 days/year); ED_{tot} is the exposure duration of 60 years, average lifetime for Nigerians; AT is the period of exposure for non-carcinogenic effects ($E_{Fr} \times ED_{tot}$) and 60 years life time for carcinogenic effect [12]. The cumulative cancer risk as a result of exposure to multiple carcinogenic heavy metals due to consumption of a particular type of food was assumed to be the sum of the individual heavy metal increment risks and calculated by the following equation [19].

$$\sum ILCR_n = ILCR_1 + ILCR_2 + \dots + ILCR_n$$

Where, $n = 1, 2, \dots, n$ is the individual carcinogenic heavy metal.

3. RESULTS AND DISCUSSION

Contamination of dietary substances by chemicals and non-essential elements such as heavy metals is known to have a series of adverse effects on the body of humans and animals [6]. The present study investigated the presence of heavy metals in onion bulb which is a major component of the diet among the population in Katsina state, Nigeria. A total of 3 composite samples were analyzed for the presence of heavy metals in this study. As shown in Table 1, among the heavy metals evaluated, the highest concentration (ug/g) was Fe (range: 0.935-1.796), followed by Pb (range: 1.276-1.305), Zn (range: 0.503-0.978) and Mn (range: 0.215-0.250). While Cd has the lowest concentration (range: 0.057-0.058) with Cr and Ni being below detection level (BDL). The results for the heavy metals analysed in the sampled onion bulbs is similar to that reported for heavy metals in beans and some beans products from some selected markets in Katsina state, Nigeria [21].

Hypertension can result in individuals exposed to lead [4]. Lead was detected in all the samples, with 100% of samples seen to be higher than 0.01 mg/kg which is the maximum permissible limit set by WHO/FAO and also the maximum allowable concentration of 0.02 mg/kg by EU and 0.05 mg/kg limit set by USEPA [22]. The violation of the maximum permissible limits of Pb set by the WHO, EU, and US EPA is a cause for public health concern considering the frequency of exposure. The Pb concentration range for the onion bulb samples in this study is lower than that reported for ginger 22 mg/kg and in Negro pepper (5 mg/kg) in a study on the heavy metal content of spices in Abuja, Nigeria [23], leafy vegetables from Kaduna state Nigeria [24],

beans samples from Italy, Mexico, India, Japan, Ghana and Ivory Coast with a Pb concentration range of 4.084- 14.475ppm [25]. However the results are higher than those reported for the concentration of Pb in cereals from Kano and Kaduna states, Nigeria [26,27]. The value was still higher than the range (0.116 to 0.390) reported by Ahmed and Mohammed [28] in Egypt (0.116 to 0.390) in 2005 and the range (0.007 to 0.032 mg/kg) reported by Okoye et al. [29] in a study conducted in South east of Nigeria in 2009, the result for Pb concentration in carrot and cucumber from Awka, Anambra state Nigeria [30] and the results of Gomaa et al., [31] for Pb in potato (0.96 mg/kg), tomato (0.25 mg/kg) and cucumber (0.58 mg/kg) in a study conducted in Egypt. This difference has earlier been attributed to differences in anthropogenic activities that introduce metals into the soil in the areas where these vegetables were grown or even deposition of Pb on the surface of these vegetables during production, transport and marketing or by emissions from Vehicles and industries [4].

Renal toxicity can result in individual exposed to cadmium [4]. The concentration of Cd (ug/g) range from 0.057 to 0.058 in the onion bulb samples, these values are higher than the range (0.002 to 0.004 mg/kg) reported by Edem et al. [32] in Wheat flours in 2009, but the results are similar to the study conducted by Bedassa et al. [33] that reported values of 0.05 and 0.06 mg/kg Cd for onion bulbs in Mojo and Ziwey areas of Oromia region in Ethiopia and the result for Cd concentration in cucumber from Awka, Anambra state Nigeria [30]. Likewise the Cd concentration range for the samples in this study is lower than that reported for various beans samples from Europe, Asia and parts of West Africa [25] and for the cadmium content of natural spice samples ranged from 0.45 mg/kg, in garlic, locust beans and onion and 0.3 mg/ kg in ginger, from Odo-Ori market Iwo, Nigeria [34]. The values are also lower than those obtained by Okoye et al. [29] in Cereals in South eastern Nigeria (0.007 to 0.23 mg/kg) in 2009, Ahmed and Mohammed in Cereal products (0.091-0.143 mg/kg) in 2005 (28), Orisakwe et al. [35] in Owerri (0.00 to 0.24 mg/kg) in 2012 and Dahiru et al. [26] in Kano (0.11 to 0.28 mg/kg) in 2013. These differences could be due to differences in the concentration of the metal in the soils where these vegetables were grown. But the results for Cd concentration in the onion bulb samples in the present study are similar to values reported in a study for the Cadmium concentration range for both unprocessed and processed bean samples from

Katsina state Nigeria [21]. These values are however, below the WHO [36] safe limit for Cd (0.3 mg/kg) in spices.

In the present study, the mean Fe concentration in the onion bulb samples is higher than that reported in a study that evaluate heavy metals in millet from Kaduna, Nigeria [27], the Fe range in wheat flours in Calabar (0.002 to 0.004 mg/kg) reported by Edem et al. [32] and Fe values reported for carrot, cabbage and cucumber from Awka, Anambra state Nigeria [30]. These values are also too low to provide for the Recommended Daily allowance for Fe in both adult male (10 mg/day) and female (15 mg/day) from a nutritional point of view [27]. But the result is similar to that reported for market sold beans from Katsina, Nigeria [21], but is lower to that reported in onion bulbs from Mojo and Meki areas of Oromia region, Ethiopia [33], a study in eastern Nigeria [29] and that recorded by Zahir et al., [37] in a study conducted in Pakistan and the results for the study conducted by Di Bella et al., [25] and the Fe value of 33.5 mg/kg in onion from Odo-Ori market Iwo, Nigeria reported by Olusakin et al., [34].

The result for the heavy metal Mn concentrations in the present study is lower than the result of Mn levels in tumeric (76 mg/kg), red chilli (74.02 mg/kg) and coriander (52.91 mg/kg) reported by Das et al., [38] in their study conducted in Chittagong Metropolitan City, Bangladesh to evaluate heavy metals in spices, the result of Mn in homegrown vegetables near a former chemical manufacturing facility in Tarnaveni, Romania [39] and results of evaluation of heavy metals in various foods reported in other studies (25; 29). But the result is similar to that reported by Yaradua et al., in a study on Mn levels in beans from Katsina state, Nigeria [21].

Zinc is required for the growth and repair of body tissues, as well as an important element of ligaments and tendons [40]. The heavy metal Zn values obtain in this study is similar to that reported in Zn levels in various foods in some studies [21,26,41], but are higher than the range (0.04 to 0.19 mg/kg) reported by Edem et al., [32] in 2009 in wheat flours, the study conducted on heavy metals in tomato by Fatoba et al., [42] in Ilorin, but far below the Zn values reported for tumeric (75.5 mg/kg), red chilli (68.78 mg/kg) and coriander (87.89 mg/kg) by Das et al., [38] and the Zn range reported by Ahmed and Mohammed in 2005 (4.893 to 15.450 mg/kg) in foodstuff from Egyptian markets [28] and that reported in a study conducted by

Sulyman et al., [43] in cereals from Kaduna state. These values also falls below the WHO permissible limit (100 mg/kg) for Zn in spices [36] and can also not provide for the required daily allowance for Zn which is 11mg/day for men and 8mg/day for women [27].

In the present study, an important finding was the absence of Cr and Ni in all the analyzed samples. There are several possible explanations for this result; e.g., low level of Cr and Ni in agricultural soil, limitation of Cr and Ni contamination sources and no intake or accumulation of Cr and Ni by the studied vegetables.

The degree for heavy metal toxicity to humans depends on daily consumption rate [44]. The results for the estimated daily intake (EDI) of the heavy metals on consumption of the onion bulbs were given in Tables 2 and 3. From the table the estimated daily intake of the heavy metals (Pb, Zn, Cd, Cr, Fe and Mn) in adult and children were lower than the tolerable daily intake limit set by the USEPA [45] in all the samples.

The non-cancer risks (THQ) of the investigated heavy metals through the consumption of the samples for both adults and children inhabitants of the study area were determined and presented in Tables 4 and 5. The THQ has been recognized as a useful parameter for evaluating the risk associated with the consumption of metal-contaminated foods [46]. THQ is interpreted as either greater than 1 (>1) or less than 1 (<1), where THQ >1 shows human health risk concern [47]. Bhalkhair and Ashraf [9] in their study have put forward the suggestion that the ingested dose of heavy metals is not equal to the absorbed pollutant dose in reality because a fraction of the ingested heavy metals may be excreted, with the remainder being accumulated in body tissues where they can affect human health. Risk level of Target Hazard Quotient (THQ < 1) was observed for all the evaluated heavy metals for both adults and children. It indicates that intake of these heavy metals through consumption of the onion bulbs does not poses a considerable non-cancer risk. The THQ for the samples was in the decreasing order Mn>Zn>Pb>Fe>Cd, for all the samples respectively. The sequence of risk was the same for both adults and children although the children had higher THQ values in all cases (Tables 2 and 3). Similar observations have been reported previously by Mahfuza et al., [48], Micheal et al. [12] and Liu et al. [19].

Table 1. Heavy metal concentration (ug/g) in onion bulb cultivated in the three senatorial zones of Katsina State

Zone	Pb	Cr	Zn	Ni	Fe	Mn	Cd
Katsina	1.31± 0.0001	BDL	0.98±0.0009	BDL	1.27± 0.0003	0.25± 0.0007	0.06± 0.0001
Funtua	1.28±0.0005	BDL	0.94±0.0003	BDL	1.80±0.0004	0.24±0.001	0.06±0.0002
Daura	1.28±0.0003	BDL	0.51±0.0002	BDL	0.94±0.0003	0.22±0.0012	0.06±0.0002

*Values are expressed as Mean ± SD***Table 2. Daily metal intake (ug/g), target hazard quotient and health risk index in adults from consumption of onion bulb cultivated in the three senatorial zones of Katsina State**

Heavy metal	Daily intake of metal			Target hazard quotient		
	Katsina	Funtua	Daura	Katsina	Funtua	Daura
Mn	0.000187	0.000178	0.000161	0.013332	0.012691	0.011465
Zn	0.000730	0.000699	0.000376	0.002501	0.002329	0.001252
Pb	0.000874	0.000955	0.000953	0.001624	0.001592	0.001588
Cd	0.000043	0.000043	0.000043	0.000085	0.000087	0.000085
Ni	BDL	BDL	BDL	BDL	BDL	BDL
Fe	0.000947	0.001341	0.000698	0.001352	0.001955	0.000997
Cr	BDL	BDL	BDL	BDL	BDL	BDL
Health Risk Index				0.018894	0.018654	0.015387

Table 3. Daily metal intake (ug/g), target hazard quotient and health risk index in children from consumption of onion bulb cultivated in the three senatorial zones of Katsina State

Heavy metal	Daily intake of metal			Target hazard quotient		
	Katsina	Funtua	Daura	Katsina	Funtua	Daura
Mn	0.000467	0.000444	0.000401	0.033330	0.031730	0.024931
Zn	0.001825	0.00174	0.000939	0.005823	0.005823	0.003129
Pb	0.002436	0.002387	0.00238	0.004060	0.003979	0.003969
Cd	0.000106	0.000108	0.000106	0.000213	0.000217	0.000213
Ni	BDL	BDL	BDL	BDL	BDL	BDL
Fe	0.002367	0.003352	0.00175	0.003381	0.004789	0.002493
Cr	BDL	BDL	BDL	BDL	BDL	BDL
Health Risk Index				0.047068	0.046537	0.038468

Table 4. Incremental life time cancer risk from consuming of onion bulb cultivated in the three senatorial zones of Katsina State

Zone	ILCR		Σ ILCR
	Pb	Cd	
Katsina	6.14E-03	6.38E-04	6.78E-03
Funtua	6.02E-03	6.50E-04	6.67E-03
Daura	6.00E-03	6.38E-04	6.64E-03

Table 5. Incremental life time cancer risk in children from consuming of onion bulb cultivated in the three senatorial zones of Katsina State

Zone	ILCR		Σ ILCR
	Pb	Cd	
Katsina	1.53E-02	1.60E-03	1.69E-02
Funtua	1.50E-02	1.62E-03	1.67E-02
Daura	1.50E-02	1.60E-03	1.66E-02

Furthermore, the non-cancer risks for each sample were expressed as the cumulative HI, which is the sum of individual metal THQ. All the studied samples showed the risk level ($HI < 1$) with highest in onion bulb sample from Katsina senatorial zone and lowest in the onion bulb sample from Daura senatorial zone. It suggests that the inhabitants of Katsina state might not be exposed to non-carcinogenic health risk through the intake of heavy metals.

Cd and Pb are classified by the IARC as being carcinogenic agents [49]. Chronic exposure to low doses of Cd, and Pb could therefore result into many types of cancers [50]. US-EPA recommended the safe limit for cancer risk is below about 1 chance in 1,000,000 lifetime exposure ($ILCR < 10^{-6}$) and threshold risk limit ($ILCR > 10^{-4}$) for chance of cancer is above 1 in 10,000 exposure where remedial measures are considerable and moderate risk level ($ILCR > 10^{-3}$) is above 1 in 1,000 where public health safety consideration is more important [20,51]. ILCR for Cd violated the threshold risk limit ($>10^{-4}$) while the ILCR for Pb has reached the moderate risk limit ($>10^{-3}$) in all the studied samples in adults. In children the ILCR for Cd has reached the moderate risk level ($>10^{-3}$) while the ILCR for Pb is above the moderate risk level ($>10^{-2}$). The sampling area trend of risk for developing cancer as a result of consuming the studied samples showed: Katsina senatorial zone > Funtua senatorial zone > Daura senatorial zone for both adult and children (Tables 4 and 5).

Moreover, cumulative cancer risk (Σ ILCR) of all the studied onion bulbs has reached the

moderate risk limit ($>10^{-3}$) in adults, while in children it is above the moderate risk limit ($>10^{-2}$). Further, among all the studied samples, the sample from Katsina senatorial zone has the highest chances of cancer risks ($ILCR 6.776000 \times 10^{-3}$ in adults; $ILCR 1.694091 \times 10^{-2}$ in children) and tomato sample from Daura senatorial zone has the lowest chances of cancer risk ($ILCR 6.64000 \times 10^{-3}$ in adults; $ILCR 1.659990 \times 10^{-2}$ in children). These risk values indicate that consumption of the sample from Katsina senatorial would result in an excess of 68 cancer cases per 10,000 people exposure in adults and 17 cancer cases per 1,000 people exposure in children, while consumption of the sample from Daura senatorial zone would result in an excess of 66 cancer cases per 10,000 people exposure in adults and 17 cancer cases in children per 1,000 people exposure (US-EPA). Prompt action should be needed to control the excessive use of heavy metal-based fertilizer and pesticides and also emission of heavy metal exhaust from automobiles should be checked to save the population from cancer risk.

4. CONCLUSION

This study determines the heavy metals concentration in onion bulbs from the 3 senatorial zones (Katsina, Funtua and Daura) of Katsina state Nigeria. Results from this study has shown that with the exception of the heavy metal Pb the concentration values of Mn, Zn, Cd and Fe in the samples were generally lower than the USEPA, WHO/FAO maximum permissive limits. The results have indicated that the estimated daily intake of the heavy metals were lower than the tolerable daily intake limit set by the USEPA (2013) in both samples. Risk level of Target Hazard Quotient ($THQ < 1$) was observed for all the evaluated heavy metals for both adults and children. The THQ for the samples was in the decreasing order $Mn > Zn > Pb > Fe > Cd$, for all the samples respectively. The sequence of risk was the same for both adults and children although the children had higher THQ values in all cases. All the studied samples showed the risk level ($HI < 1$) with highest in onion bulb sample from Katsina senatorial zone and lowest in the onion bulb sample from Daura senatorial zone. ILCR for Pb violated the threshold risk limit ($>10^{-4}$) while the ILCR for Pb has reached the moderate risk limit ($>10^{-3}$) in all the studied samples in adults. In children the ILCR for Cd has reached the moderate risk level ($>10^{-3}$) while the ILCR for Pb is above the moderate risk level ($>10^{-2}$). The sampling area trend of risk for developing cancer

as a result of consuming the studied samples showed: Katsina senatorial zone > Funtua senatorial zone> Daura senatorial zone for both adult and children. Cumulative cancer risk (Σ ILCR) of all the studied onion bulbs has reached the moderate risk limit ($>10^{-3}$) in adults, while in children it is above the moderate risk limit ($>10^{-2}$). Further, among all the studied samples, the sample from Katsina senatorial zone has the highest chances of cancer risks (ILCR 6.776000×10^{-3} in adults; ILCR 1.694091×10^{-2} in children) and the sample from Daura senatorial zone has the lowest chances of cancer risk (ILCR 6.64000×10^{-3} in adults; ILCR 1.659990×10^{-2} in children). The study suggests that consumption of the studied onion bulbs in Katsina state is of public health concern as they may contribute to the population cancer burden.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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