HEALTH RISK ASSESSMENT FOR CARCINOGENIC AND NON-CARCINOGENIC HEAVY METAL EXPOSURES FROM PEPPER FRUITS CULTIVATED IN KATSINA STATE, NORTH WEST NIGERIA

ABSTRACT

This study was conducted to determine the heavy metals concentration in pepper fruits cultivated in Katsina state Nigeria. The objectives were mainly to detect the presence of heavy metals in the cultivated pepper fruits in the study area, compare the concentration of heavy metals in samples in relation to the permissible limits specified by WHO/FAO/USEPA Standards. Samples of the pepper fruits were collected in the year 2017 from the selected area. Analysis for the concentration of these heavy metals; Cr, Cd, Fe, Ni, Mn, Pb and Zn was conducted by the use of AAS (by Atomic Absorption Spectrophotometry) method. The health risks to the local inhabitants from the consumption of the samples were evaluated based on the Target Hazard Quotient. The possibility of cancer risks in the samples through intake of carcinogenic heavy metals was estimated using the Incremental Lifetime Cancer Risk. Results from this study has shown that with the exception of the mean values for the heavy metal Pb (1.200-1.333 mg/kg), the mean concentration range (mg/kg) values of Fe (0.901-0.967), Zn (0.899-0.911), Mn (0.250-0.287), Cd (0.053-0.0556) in the samples were generally lower than the USEPA, WHO/FAO maximum permissive limits. With the heavy metals Cr and Ni being below detection level (BDL) The results have indicated that the estimated daily intake (EDI) of the heavy metals were lower than the tolerable daily intake limit set by the USEPA in all the 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 were in the decreasing order Mn>Zn>Pb>Fe>Cd, for all the pepper fruits respectively. The sequence of risk was the same for both adults and children although the children had higher THQ values in all cases. ILCR for Cd violated the threshold risk limit ($>10^{-4}$) and ILCR for Pb reached the moderate risk limit ($>10^{-3}$) in all the studied samples in adults, While in children ILCR for both Pb and Cd violated the risk. The sampling area trend of risk for developing cancer as a result of consuming the studied samples showed in decreasing order: Funtua senatorial zone > Daura senatorial zone> Katsina senatorial zone for both adult and children. The Cumulative cancer risk (∑ILCR) of all the studied pepper fruits reached the moderate risk limit ($>10^{-3}$) in adults, while in children it is above the moderate risk limit ($>10^{-2}$). Among all the studied samples, pepper sample from Funtua senatorial zone has the highest chances of cancer risks (ILCR 6.863273×10^{-3} in adults; ILCR 1.715815×10^{-2} in children) and pepper sample from Katsina senatorial zone has the lowest chances of cancer risk (ILCR 6.260100×10^{-3} in adults; ILCR 1.565025×10^{-2} in children). The study suggests that consumption of the studied pepper fruits in Katsina state is of public health concern as they may contribute to the population cancer burden.

Keywords: Pepper, Heavy metals, Nigeria, Health risk index, Cancer risk, Vegetables, Katsina

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 and vegetables 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 fruits and vegetables. This work therefore seeks to bridge that gap by providing information especially to the Katsina state populace on the levels of heavy metals of pepper fruit. Data on heavy metal in the cultivated pepper fruit 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 pepper in Katsina State, Nigeria.

2. MATERIAL AND METHODS

2.1 STUDY AREA AND SAMPLE COLLECTION

The study was carried out during 2017 in Katsina State, Nigeria located between latitude $12^0$15'N and longitude of $7^0$30'E in the North West Zone of Nigeria, with an area of 24,192km2 (9,341 sq meters). 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 dry season. The average annual rainfall, temperature, and relative humidity of Katsina State are 1,312 mm, 27.3ºC and 50.2%, respectively (5). The state has a population of 7.6 million with the growth rate of 3.0% per annum. Over 50% of this population is between the ages of 15-64 years and 80% of the population is involved in subsistence farming and livestock rearing (5). The study was conducted within some catchment areas that cultivate pepper 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 vegetables are cultivated was subdivided into twenty (20) sampling areas. Samples 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 4^0C 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 fruit samples were fragmented with clean plastic spoon and knife and dried at ambient temperature. After drying, the seeds were removed from the dried fruits. They were then stored in the refrigerator at 4^0c until ready for use.

2.5 HEAVY METALS DETERMINATION

5 g of each Sample was dried at 80^0C 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 550^0C 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 ($HN0_3$) 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 (6) and the results were given in (mg/kg).

2.6 HEAVY METAL HEALTH RISK ASSESSMENT

2.6.1 DAILY INTAKE OF METALS (DIM)

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

$$\mathrm{DIM} = \frac{C_{\mathrm{metal}} * C_{\mathrm{factor}} * D_{\mathrm{intak}}}{B_{\mathrm{weight}}}$$

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 food crops and the average body weight, respectively. The conversion factor (CF) of 0.085 (7) was used for the conversion of the samples to dry weights. The average daily intake of the samples was 0.527 kg $person^{-1}$ d^{-1} (8) and the average body weight for the adult and children population was 60 kg (9) and 24 kg (10) respectively; these values were used for the calculation of HRI as well.

2.6.2 NON-CANCER RISKS

Non-carcinogenic risks for individual heavy metal in vegetable were evaluated by computing the target hazard quotient (THQ) using the following equation (11).

$$THQ=CDI/R_fD$$

CDI is the chronic daily heavy metal intake (mg/kg/day) obtained from the previous section and R_fD 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 (12). 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) (13; 14).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 (15). It is calculated as follows:

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

Where, 1, 2…, n are the individual heavy metals in vegetable and fruit species.

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 (16). 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 (17).

2.7 CANCER RISKS

The possibility of cancer risks in the studied pepper fruit samples through intake of carcinogenic heavy metals was estimated using the Incremental Lifetime Cancer Risk (ILCR) (18).

$$ILCR= CDI\times CSF$$

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 (11). ILCR value in pepper fruit represents the probability of an individual's lifetime health risks from carcinogenic heavy metals' exposure (19). The level of acceptable cancer risk (ILCR) for regulatory purposes is considered within the range of 10^{-6} to 10^{-4} (12). 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 (18).

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

where EDI is the estimated daily intake of metal via consumption of the pepper fruit; 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 ($EFr \times ED_{tot}$), and 60 years life time for carcinogenic effect (11). 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 (18).

$$\sum ILCR_n=ILCR_1+ILCR_2+\cdots+ILCRn$$

Where, n = 1, 2…, n is the individual carcinogenic heavy metal.

3. RESULTS AND DISCUSSION

The present study investigated the presence of heavy metals in pepper fruits which is a major component of the diet among the population in Katsina state, Nigeria. A total of 3 pepper fruit 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 (mg/kg) was observed for Pb (range: 1.200000-1.333000), followed by Fe (range: 0.901000-0.967000), Zn (range: 0.899000-0.911000) and Mn (range: 0.250000-0.287000). While Cd has the lowest concentration (range: 0.053000-0.0556000) with the heavy metals Cr and Ni being below detection level (BDL) The result for the heavy metals analysed in the sampled pepper fruits is similar to that reported for heavy metals in beans and some beans products from some selected markets in Katsina state, Nigeria (20).

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 (21). 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 pepper fruit 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 (22), that reported for leafy vegetables from Kaduna state Nigeria (23) and that reported for beans samples from Italy, Mexico, India, Japan, Ghana and Ivory Coast with a Pb concentration range of 4.084- 14.475ppm (24) and homegrown vegetables near a former chemical manufacturing facility in Tarnaveni, Romania (25). But the results are higher than the values 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 in Egypt in 2005 (28) and the range (0.007 to 0.032 mg/kg) reported by Okoye et al., (29) in a study conducted in South east Nigeria in 2009 on heavy metals evaluation in cereals and the Pb concentrations reported for 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).
The concentration of Cd (mg/kg) range from 0.042 to 0.059 in the 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. The Cd concentration range for the samples in this study is also lower than that reported for various beans samples from Europe, Asia and parts of West Africa (24), for locust beans from Odo-Ori market Iwo, Nigeria (33). The values are still lower than those obtained by Okoye et al., (29) in Cereals in South eastern Nigeria (0.007 to 0.23mg/kg) in 2009, Ahmed and Mohammed (28) in Cereal products (0.091-0.143mg/kg) in 2005, Orisakwe et al., (34) in Owerri (0.00 to 0.24mg/kg) in 2012 and Dahiru et al., (26) in Kano (0.11 to 0.28mg/kg) in 2013. But the values are similar to the values reported in a study for the Cadmium concentration range for both unprocessed and processed bean samples from Katsina state Nigeria (20) and for cucumber from Awka, Anambra state Nigeria (30), but higher than the value reported for cabbage and carrot from Awka, Anambra state Nigeria (30). These differences could be due to differences in the concentration of the metal in the soils where these vegetables were grown. These values are however, below the WHO (35) safe limit for Cd (0.3 mg/kg) in spices.

In the present study, the mean Fe concentration in the samples is higher than that reported in a study that evaluate heavy metals in millet from Kaduna, Nigeria (27) and the values reported for carrot cabbage and cucumber from Awka, Anambra state Nigeria (30). The result is similar to that reported for market sold beans from Katsina, Nigeria (20), but is lower to that reported in a study in eastern Nigeria (29) and that recorded by Zahir et al., (36) in a study conducted in Pakistan and the results for the study conducted by Di Bella et al., (24). These values are also too low to provide for the Recommended Daily allowance for Fe in both adult male (10mg/day) and female (15mg/day) from a nutritional point of view (27).

The heavy metal Zn values obtain in this study is similar to that reported in Zn levels in various foods in some studies (20; 26; 37), but are higher than the range (0.04 to 0.19mg/kg) reported by Edem et al., (32) in 2009 in wheat flours, the study conducted on heavy metals in tomato by Fatoba et al., (38) 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., (39) and the Zn range reported by Ahmed and Mohammed (28) in 2005 (4.893 to 15.450 mg/kg) in foodstuff from Egyptian markets and that reported in a study conducted by Sulyman et al., (40) in cereals from Kaduna state. These values also falls below the WHO permissible limit (100 mg/kg) for Zn in spices (35) and can also not provide for the required daily allowance for Zn which is 11mg/day for men and 8mg/day for women (27).

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., (39) in their study conducted in Chittagong Metropolitan City, Bangladesh to evaluate heavy metals in spices and results of evaluation of heavy metals in various foods reported in other studies (24; 29), but is similar to that reported by Yaradua et al,. (20) in a study on Mn levels in beans from Katsina states Nigeria.

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.

Table 1 Heavy Metal Concentration (mg/kg) In Pepper Fruit Cultivated in the Three Senatorial Zones of Katsina State

Zone	Pb	Cr	Zn	Ni	Fe	Mn	Cd
Katsina	1.200000± 0.000100	BDL	0.899000± 0.008000	BDL	0.901000± 0.001700	0.287000± 0.000800	0.055000± 0.000300
Funtua	1.333000± 0.000200	BDL	0.911000± 0.001700	BDL	0.967000± 0.001400	0.25000± 0.000900	0.053000± 0.000300
Daura	1.241000± 0.000300	BDL	0.904000± 0.000100	BDL	0.935000± 0.000300	0.274000± 0.001200	0.056000± 0.000200

Values are expressed as Mean ± SD
Key; BDL (Below detection level)

The degree for heavy metal toxicity to humans depends on daily consumption rate (41). The results for the estimated daily intake (EDI) of the heavy metals on consumption of the cultivated millet 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) were lower than the tolerable daily intake limit set by the USEPA (42) in all the samples.

Table 2 Daily Metal intake, Target Hazard Quotient and Health Risk Index in Children from Consumption of Pepper Fruit 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	0.000536	0.000467	0.000511	0.038262	0.033330	0.036529
Zn	0.001678	0.001700	0.001687	0.005593	0.005668	0.005624
Pb	0.002240	0.002489	0.002316	0.003733	0.004147	0.003861
Cd	0.000103	0.00099	0.000105	0.000205	0.000198	0.000209
Ni	BDL	BDL	BDL	BDL	BDL	BDL
Fe	0.001682	0.001805	0.001745	0.002402	0.002578	0.002493
Cr	BDL	BDL	BDL	BDL	BDL	BDL
Health Risk Index				0.050196	0.045920	0.044716

Key: BDL (Below detection level)

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 (43). THQ is interpreted as either greater than 1 (>1) or less than 1 (<1), where THQ >1 shows human health risk concern (44). Bhalkhair and Ashraf (8) 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 pepper fruits 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 pepper fruits respectively. The sequence of risk was the same for both adults and children although the children had higher THQ values in all cases. Similar observations have been reported previously by Mahfuza et al., (45), Micheal et al. (11) and Liu et al. (18).

Further, the non-cancer risks for each sample of pepper fruit were expressed as the cumulative HI, which is the sum of individual metal THQ. All the studied pepper fruits showed the risk level (HI < 1) with highest in the sample from Katsina senatorial zone and lowest in the 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.

Table 3 Daily Metal intake, Target Hazard Quotient and Health Risk Index in Adults from Consumption of Pepper Fruit 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	0.000214	0.000187	0.000185	0.015305	0.013332	0.013172
Zn	0.000671	0.000680	0.000675	0.002237	0.002267	0.002249
Pb	0.000896	0.000995	0.000927	0.001493	0.001659	0.001544
Cd	0.000041	0.000040	0.000042	0.000082	0.000079	0.000084
Ni	BDL	BDL	BDL	BDL	BDL	BDL
Fe	0.000674	0.000729	0.000699	0.000961	0.001031	0.000997
Cr	BDL	BDL	BDL	BDL	BDL	BDL
Health Risk Index				0.019214	0.018368	0.018047

Key: BDL (Below detection level)

Cd and Pb are classified by the IARC as being carcinogenic agents (46; 47). Chronic exposure to low doses of Cd, and Pb could therefore result into many types of cancers (48). 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 (19; 49). ILCR for Cd violated the threshold risk limit (>10^{-4}) and ILCR for Pb reached the moderate risk limit (>10^{-3}) in all the studied samples in adults, While in children ILCR for both Pb and Cd violated the risk. The sampling area trend of risk for developing cancer as a result of consuming the studied samples showed: Funtua senatorial zone > Daura senatorial zone> Katsina senatorial zone for both adult and children (Tables 4 and 5).

Moreover, Cumulative cancer risk (∑ILCR) of all the studied pepper fruits 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, pepper sample from Funtua senatorial zone has the highest chances of cancer risks (ILCR 6.863273 × 10^{-3} in adults; ILCR 1.715815 × 10^{-2} in children) and pepper sample from Katsina senatorial zone has the lowest chances of cancer risk (ILCR 6.260100 × 10^{-3} in adults; ILCR 1.565025 × 10^{-2} in children). These risk values indicate that consumption of the pepper sample from Katsina senatorial would result in an excess of 69 cancer cases per 10,000 people exposure in adults and 17 cancer cases per 1,000 people exposure in children, while consumption of the pepper sample from Katsina senatorial zone would result in an excess of 63 cancer cases per 10,000 people exposure in adults and 16 cancer cases in children per 1,000 people exposure (US-EPA,). Prompt action should be needed to control the excess 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.

Table 4 Incremental Life Time Cancer Risk from Consuming of Pepper Fruit Cultivated in the Three Senatorial Zones of Katsina State

Zone	ILCR		∑ILCR
	Pb	Cd	
Katsina	5.644170E-03	6.159300E-04	6.260100E-03
Funtua	6.269753E-03	5.935200E-04	6.863273E-03
Daura	5.837006E-03	6.271200E-04	6.464128E-03

Table 5 Incremental Life Time Cancer Risk in Children from Consuming of Pepper Fruit Cultivated in the Three Senatorial Zones of Katsina State

Zone	ILCR		∑ILCR
	Pb	Cd	
Katsina	1.411043E-02	1.539825E-03	1.565025E-02
Funtua	1.567432E-02	1.483830E-03	1.715815E-02
Daura	1.459253E-02	1.567815E-03	1.616034E-02

4. CONCLUSION

This study determines the heavy metals concentration in pepper fruits in 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 in both samples. Risk level of Target Hazard Quotient (THQ < 1) was observed for all the evaluated heavy metals for both adults and children. ILCR for Cd violated the threshold risk limit ($>10^{-4}$) and ILCR for Pb reached the moderate risk limit ($>10^{-3}$) in all the studied samples in adults, While in children ILCR for both Pb and Cd violated the risk. The sampling area trend of risk for developing cancer as a result of consuming the studied samples showed: Funtua senatorial zone > Daura senatorial zone> Katsina senatorial zone for both adult and children. Cumulative cancer risk (∑ILCR) of all the studied pepper fruits reached the moderate risk limit ($>10^{-3}$) in adults, while in children it is above the moderate risk limit ($>10^{-2}$). Among all the studied samples, pepper sample from Funtua senatorial zone has the highest chances of cancer risks (ILCR 6.863273×10^{-3} in adults; ILCR 1.715815×10^{-2} in children) and pepper sample from Katsina senatorial zone has the lowest chances of cancer risk (ILCR 6.260100×10^{-3} in adults; ILCR 1.565025×10^{-2} in children). The study suggests that consumption of the studied pepper fruits 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.

REFERENCES

1. Siegel KR, Ali MK, Srinivasiah A, Nugent RA, Narayan KMV. Do we produce enough fruits and vegetables to meet global health need? PloS one, 2014; 9, e104059

2. Haware DJ, Pramod HP, Determination of specific heavy metals in fruit juices using Atomic Absorption Spectrophotometer (AAS), Int. J. Res. Chem. Environ., 2011; 4(3)163-168

3. Bempah CK, Kwofie AB, Tutu AO, Danutsui D, Bentil N. Assessing the potential dietary intake of heavy metals in some selected fruits and vegetables from Ghanaian markets, Elixir Pollut. 2011; 39: 4921-4926

4. Gottipolu RR, Flora SJ, Riyaz B. Environmental Pollution-Ecology and human health: P. Narosa publishing house, 2012; New Delhi India.110 002, 166-223

5. Katsina State investor’s handbook, Yaliam Press Ltd 2016: 12-15

6. A.O.A.C Official Methods of Analysis 18th Edition, Association of Official Analytical Chemists, 1995U.S.A

7. Jan FA, Ishaq M, Khan S, Ihsanullah I, Ahmad I, Shakirullah M, A comparative study of human health risks via consumption of food crops grown on wastewater irrigated soil (Peshawar) and relatively clean water irrigated soil (lower Dir). J. Hazard. Mater, 2010; 179: 612–6219.

8. Balkhaira KS, Ashraf MA, Field accumulation risks of heavy metals in soil and vegetable crop irrigated with sewage water in western region of Saudi Arabia. Saudi Journal of Biological Sciences 2015; 23 (1): S32-S44

9. Orisakwe OE, Mbagwu HOC, Ajaezi GC, Edet UW, Patrick U, Uwana PU. Heavy metals in sea food and farm produce from Uyo, Nigeria Levels and health implications. Sultan Qaboos Univ Med J. 2015; 15(2): e275–e282.

10. Ekhator OC, Udowelle NA, Igbiri S, Asomugha RN, Igweze ZN, Orisakwe OE. Safety Evaluation of Potential Toxic Metals Exposure from Street Foods Consumed in Mid-West Nigeria. Journal of Environmental and Public Health Volume 2017, Article ID 8458057

11. Micheal B, Patrick O, Vivian T. Cancer and non-cancer risks associated with heavy metal exposures from street foods: Evaluation of roasted meats in an urban setting. Journal of Environment Pollution and Human Health, 2015; 3, 24–30

12. Li S, Zhang Q. Risk assessment and seasonal variations of dissolved trace elements and heavy metals in the Upper Han River, China. Journal of Hazardous Materials, 2010; 181, 1051–1058

13. Li PH, Kong S, Geng CM, Han B, Sun RF, Zhao RJ, Bai ZP, Assessing the hazardous risks of vehicle inspection workers’ exposure to particulate heavy metals in their work places. Aerosol and Air Quality Research, 2013; 13, 255–265

14. United States Environmental Protection Agency. EPA Human Health Related Guidance, OSWER, 2002; 9355 (pp. 4–24). Washington, DC: United States Environmental Protection Agency

15. NFPCSP Nutrition Fact Sheet; Joint report of Food Planning and Nutrition Unit (FMPU) of the ministry of Food of Government of Bangladesh and Food and Agricultural Organization of the United Nation (FAO) September 14, 2011; 1–2, National Food Policy Plan of Action and Country Investment Plan, Government of the People’s Republic of Bangladesh

16. The Risk Information System, 2007; Retrieved from http://rais.oml.govt/tox/rap_toxp.shtml

17. Guerra F, Trevizam AR, Muraoka T, Marcante NC, Canniatti-Brazaca SG, Heavy metals in vegetables and potential risk for human health. Scientia Agricola, 2012; 69, 54–60.10.1590/S0103-90162012000100008

18. Liu X, Song Q, Tang Y, Li, W, Xu J, Wu J, Wang F, Brookes, PC. Human health risk assessment of heavy metals in soil–vegetable system: A multi-medium analysis. Science of the Total Environment, 2013; 463–464, 530–540

19. Pepper IL, Gerba CP, Brusseau ML. Environmental and pollution Science: Pollution Science Series, 2012; pp. 212–232. Academic Press

20. Yaradua AI, Alhassan AJ, Shagumba AA, Nasir A, Idi A, Muhammad IU, Kanadi AM. Evaluation of heavy metals in beans and some beans product from some selected markets in Katsina state Nigeria. Bayero Journal of Pure and Applied sciences.2017http://dx.doi.org/10.4314/bajopas.v10i1.1S

21. Landrigan PJ, Fuller R, Acosta NJR, Adeyi O, Arnold R, Basu N, Zhong M, The Lancet Commission on pollution and health. The Lancet, 2017; https://doi.org/10.1016/S0140-6736 (17)32345-0

22. Salihu ZO, Umar MA, Heavy metal of some spices available within FCT Abuja Nigeria, Journal of Agricultural and Food Science, 2014; 2:66-74

23. Mohammed SA, Folorunsho JO, Heavy metals concentration in soil and Amaranthus retroflexus grown on irrigated farmlands in Makera Area, Kaduna, Nigeria. Journal of Geography and Regional Planning, 2015; Vol. 8(8), pp. 210 - 217

24. Di Bella G, Clara N, Giuseppe D B, Luca R, Vincenzo L T, Angela G P, Giacomo D, Mineral composition of some varieties of beans from Mediterranean and Tropical areas. International Journal of Food Sciences and Nutrition 2016; vol. 67, no. 3, 239–248

25. Mihaileanu RG, Neamtiu IA, Fleming M, Pop C, Bloom MS, Roba C, Surcel M, Stamatian F, Gurzau E. Assessment of heavy metals (total chromium, lead, and manganese) contamination of residential soil and homegrown vegetables near a former chemical manufacturing facility in Tarnaveni, Romania. Environmental Monitoring Assessment, 2019; 191:8 https://doi.org/10.1007/s10661-018-7142-0

26. Dahiru MF, Umar AB, Sani MD. Cadmium, Copper, Lead and Zinc Levels In Sorghum And Millet Grown In The City Of Kano And Its Environs. Global Advanced Research Journal of Environmental Science and Toxicology (ISSN: 2315-5140). 2013; Vol 2(3), 082-085

27. Babatunde OA, Uche E. A comparative evaluation of the heavy metals content of some cereals sold in Kaduna, North west Nigeria. International Journal of Scientific & Engineering Research, 2015; Volume 6, Issue 10, October-2015 485ISSN 2229-5518

28. Ahmed KS, and Mohammed AR. Heavy Metals (Cd, Pb) and Trace Elements (Cu, Zn) Contents Of Some Food Stuffs from Egyptian Markets. Emir J. Agric.sci, 2005; 17(1):34-42.

29. Okoye COB, Odo IS, Odika IM. Heavy metals content of grains commonly sold in markets in south-east Nigeria. Plant Products Research Journal, 2009; vol. 13, SSN 1119-2283

30. Sab-Udeh SS, Okerulu IO, Determination of Heavy Metal Levels of some Cereals and Vegetables sold in Eke-Awka Market Awka, Anambra State, Nigeria. Journal of Natural Sciences and Research, 2017; Vol 7, No 4

31. Gomaa NA, Mohamed BMA, Essam MS, Ahmed SMF, Estimated heavy metal residues in Egyptian vegetables in comparison with previous studies and recommended tolerable limits. J. Biol. Sci., 2018; 18:135-143

32. Edem CA, Grace I, Vincent O, Rebecca E, Matilda O. A Comparative Evaluation Of Heavy Metals In Commercial Wheat Flours Sold In Calabar –Nigeria. Pakistan Journal of Nutrition, 2009; 8, 585-587

33. Olusakin PO, Olaoluwa DJ, Evaluation of Effects of Heavy Metal Contents of Some Common Spices Available in Odo-Ori Market, Iwo, Nigeria. J Environ Anal Chem., 2016; 3:174. doi:10.41722380-2391.1000174

34. Orisakwe EO, John KN, Cecilia NA, Daniel OD, Onyinyechi B. Heavy Metals Health Risk assessment for Population Consumption of Food Crops and Fruits in Owerre-Southern Nigeria. Chem. Cent., 2012; 6, 77

35. WHO Quality control methods for medicinal plant materials, World Health Organisation, 2005 Geneva.

36. Zahir E, Naqvi II, Mohi Uddin SH. Market basket survey of selected metals in fruits from Karachi city (Pakistan), Journal of Basic and Applied Sciences 2009; 5(2):47-52

37. Yahaya MY, Umar RA, Wasagu RSU, Gwandu HA, Evaluation of some heavy metals in food crops of Lead polluted sites of Zamfara State Nigeria, International Journal of Food Nutrition and Safety, 2015; 6(2): 67-73

38. Fatoba PO, Adepoju AO, Grace AO, Heavy Metal Accumulation in the Fruits of Tomato and Okra Irrigated with Industrial Waste Effluents. Jr. of Industrial Pollution Control 28(2) pp 103-107

39. Das PK, Halder M, Mujib ASM, Islam F, Mahmud ASM, Akhter S, Joardar JC. Heavy Metal Concentration in Some Common Spices Available at Local Market as Well as Branded Spicy in Chittagong Metropolitan City, Bangladesh. Curr World Environ. 2015;10(1). doi : http://dx.doi.org/10.12944/CWE.10.1.12

40. Sulyman YI, Abdulrazak S, Oniwapele, YA, Ahmad A, (2015) Concentration of heavy metals in some selected cereals sourced within Kaduna state, Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT), e-ISSN: 2319-2402,p- ISSN: 2319-2399. 2015; Volume 9, Issue 10 Ver. II (Oct. 2015), PP 17-19

41. Singh A, Sharma RK, Agrawal M, Marshall FM. Health risk assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India, Food Chem. Toxicol., 2010; 48, 611–619, doi:10.1016/j.fct.2009.11.041

42. SEPA limits of pollutants in food. State environmental protection administration, 2005 China GB2762

43. Agbenin JO, Danko M, Welp G. Soil and vegetable compositional relationships of eight potentially toxic metals in urban garden fields from northern Nigeria J. Sci. Food Agric., 2009; 89 (1), pp. 49–54

44. Bassey SC, Ofem OE, Essien NM, Eteng MU. Comparative Microbial Evaluation of Two Edible Seafood P. palludosa (Apple Snail) and E. radiata (Clam) to Ascertain their Consumption Safety. J Nutr Food Sci 2014; 4: 328. doi: 10.4172/2155-9600.1000328

45. Mahfuza SS, Rana S, Yamazaki S, Aono T, Yoshida S. Health risk assessment for carcinogenic and noncarcinogenic heavy metal exposures from vegetables and fruits of Bangladesh. Cogent Environmental Science, 2017; 3: 1291107 http://dx.doi.org/10.1080/23311843.2017.1291107

46. A review of human carcinogens. Part C: Arsenic, metals, fibres, and dusts/ IARC Working Group on the Evaluation of Carcinogenic Risks to Humans Publish by the International Agency for Research on Cancer, 150 cours Albert Thomas, 69372 Lyon Cedex 08, France ©International Agency for Research on Cancer, 2012

47. Lead and Lead compounds, International Agency for Research on Cancer IARC Monographs, vol. 23, suppl. 7 pp 230-232

48. Jarup L, Hazards of heavy metal contamination British Medical Bulletin, 2003; 68, 167–182

49. Tchounwou PB, Yedjou CG, Patlolla AK, Sutton DJ, Heavy metal toxicity and the environment. Molecular Clinical and Environmental Toxicology, 2014; 101, 133–164