Original Research Article

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

ABSTRACT

This study was conducted to determine the heavy metals (Cr, Cd, Fe, Ni, Mn, Pb, and Zn) pollution load and health risks to the population in some local fruit samples in Katsina state Nigeria. Results from this study have shown that except for the mean concentration of Pb (1.152-1.623) and Cd (0.053-0.092), the mean concentration (mg/kg) range values of Fe (1.728-1.954), Mn (0.321-0.502) and Zn (0.263-0.967 ppm) in the samples were generally lower than the regulatory agencies maximum permissive limits. The risk level of Target Hazard Quotient (< 1) was observed for all the evaluated heavy metals for both adults and children indicating no non-carcinogenic adverse health effect on the populace. The Incremental Lifetime Cancer Risk for the heavy metal Cd was at the threshold risk limit (>10−4) in all the studied fruits in adults, While Pb for adults and Pb and Cd for children were within the moderate risk limit (>10−3). The cumulative cancer risk (∑ILCR) of the studied fruits was within the moderate risk level (>10−3) in adults and above the level (>10−2) in children. The results of thestudy have suggested that the consumption of the studied local fruits in Katsina state is of apublic health concern as it may lead to an increase in the population cancer burden.

Keywords: Fruits, Nigeria, Katsina, health, cancer, heavy metals, pollution

1. INTRODUCTION

The beneficial effect of fruit consumption on human health is well documented. Fruits have become a part of people's daily diets more and more with the improvement of living conditions in many parts of the world (1). The quality and safety of fruits are compromised by their contamination with heavy metals (2; 3; 4; 5). Heavy metals, are known to be non-biodegradable, with long biological half-lives, and possess the ability to bioaccumulate in different body organs, resulting in unwanted side effects (6;7).

The absence of data on the heavy metals composition of locally consumed fruits in Katsina state and the health implication of consuming food with heavy metals above permissible limits necessitate this study. Studies on heavy metals in various food samples have been carried out in Katsina state Nigeria (8; 9; 10; 11; 12; 13; 14; 15; 16; 17), but no study has been carried out on the levels of heavy metals in local fruits in Katsina state. Data on heavy metals in the fruits generated will give an insight into the level of metal contamination and by extension the impact on food safety standards and risk to consumers.

2. MATERIAL AND METHODS

2.1 STUDY AREA

The study was conducted n Katsina State, with a location of between latitude 12015'N and longitude of 7030'E in the North West Zone of Nigeria, possessing a land area of 24,192km2 (9,341 sq meters). Rainy and dry seasons are the two observable seasons of Katsina State. The rainy season begins in April and ends in October, while the dry season starts in November and ends in March (18). 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.

2.2 SAMPLE COLLECTION

The fruits samples comprising of Aduwa (*Balanites aegyptica*), Dinya (*Vitex doniana*), Faru (*Lanneaacida*), Goruba (*Hyphaene thebaica*), Kadanya (*Vitellaria paradoxa*), and Kanya (*Diospyros mespiliformis*) were collected based on the method of Pehluvan*et al*.(1). In each sampling point, three fruit trees were selected in terms of the age and growing status. Fruit samples that were at the full maturity stage were taken about 1 to 4 kg depending on fruit species. The fresh fruit samples were placed into clean polyethylene bags and transported to the laboratory.

2.3 SAMPLE PREPARATION

The collected samples were cleaned, fragmented with aclean plastic spoon and knife, and dried at ambient temperature. After drying, the seeds were removed from the dried fruits.

2.4 HEAVY METALS DETERMINATION

About 0.5 g of each dried 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 aratio of3:1 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 (19) 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 from theconsumption of the local fruit sample was calculated using the following equation:

$$\mathrm{DIM} = \frac{C_{\mathrm{metal}} * C_{\mathrm{factor}} * D_{\mathrm{intak}}}{B_{\mathrm{weight}}}$$ ………………………… eqn. (1)

Where, Cmetal, Cfactor, Dintake, and Bweight represent the heavy metal concentrations in the samples, the conversion factor, the daily intake of the sample, and the average body weight, respectively. The conversion factor (CF) of 0.085 (20) was used for the conversion of the samples to dry weights. The average daily intake of the fruits was 300g kg^{-1} d^{-1}(21) and the average body weight for the adult and children population was taken from literature as 60 kg (22) and 24 kg (23) respectively.

2.6.2 NON-CANCER RISKS

The non-carcinogenic risks for the adult and children population of the evaluated heavy metals from possible consumption of the fruit samples were computed as the target hazard quotient (THQ) using the following equation (24).

THQ=CDI/RfD………………………………………eqn. (2)

Where, CDI is the representation of the chronic daily heavy metal intake (mg/kg/day) calculated in the previous section and RfDis the representation of the oral reference dose (mg/kg/day) which is a quantification of the maximum permissible risk on thehuman population through daily exposure, bearing in mind a sensitive group in the course of a lifetime (25). The following reference doses from the literature were used (Pb = 0.6, Cd = 0.5, Zn = 0.3, Fe = 0.7, Ni = 0.4, Mn = 0.014, Cr = 0.3) (26; 27).To evaluate the potential risk to human health through more than one heavy metal from consumption of the fruit samples in the adult and children population, thechronic hazard index (HI) is obtained as the sum of all hazard quotients (THQ) computed for individual heavy metals for a particular exposure pathway (28). This is calculated as follows:

$HI=THQ_1+THQ_2+\cdots+THQ_n$……………………eqn. (3)

Where, 1, 2…, n are the individual heavy metals for the fruit samples.

It is usually believed that the magnitude of the effect is proportional to the sum of the multiple metal exposures and that asimilar working mechanism linearly affects the target organ (29). The calculated HI is compared to standard levels: the population is assumed to be safe when HI < 1 and at a level of concern when 1 < HI < 5 (30).

2.7 CANCER RISKS

The possibility of cancer risks to the adult and children consumer population in the studied fruit samples through intake of carcinogenic heavy metals was estimated by the use of the Incremental Lifetime Cancer Risk (ILCR) (31).

$ILCR= CDI\times CSF$……………………………eqn. (4)

Where, CDI represents the chronic daily intake of chemical carcinogen, mg/kg BW/day which represents the lifetime average daily dose of exposure in theadult and children population to the chemical carcinogen.

The US EPA ILCR is obtained by the use of the cancer slope factor(CSF), which represents the risk produced by a lifetime average dose of 1 mg/kg BW/day and is specific to theindividual contaminant (24). The ILCR value in fruits signifies the probability of an individual's lifetime health risks from carcinogenic heavy metals exposure (31). For regulatory purposes, the level of acceptable cancer risks (ILCR) is considered within the range of 10^{-6} to 10^{-4}(25). The CDI value was calculated based on the following equation and CSF values for carcinogenic heavy metals were used according to the literature (32).

$CDI = (EDI \times EFr \times EDtot)/AT$…………………..eqn. (5)

where EDI represents the estimated daily intake of metal via consumption of the samples; EFr is the exposure frequency (365 days/year); EDtot is the exposure duration of 60 years, which is the average lifetime for Nigerians; AT is the period of exposure for non-carcinogenic effects ($EFr \times ED_{tot}$), and 60 years lifetime for carcinogenic effect (24). The cumulative cancer risk as a result of exposure to multiple carcinogenic heavy metals from intake of a particular type of food was taken to be the sum of the individual heavy metal increment risks and calculated by the following equation (32).

$\sum 1n=ILCR1+ILCR2+\cdots+ILCRn$…………….eqn. (6)

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 some local fruit samples in Katsina state, Nigeria. A total of 6 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 Fe (range: 1.728-1.954) followed by Pb (range: 1.152-1.623), Zn (range: 0.263-0.967) and Mn (range: 0.321-0.502). While Cd recorded the lowest concentration (range: 0.053-0.092) with the heavy metals Ni and Cr being below detection level (BDL).

Results from the study have pointed out that the mean Fe concentration in the fruit samples was lower than that reported by (33) in a study on heavy metals in fruits from Bangladesh, in a similar study in Turkey (1), and that recorded in a study conducted in Pakistan (34) and the results for the study conducted byKrejpcio*et al.*(35) in Poland. All the samples' Fe concentrations were below the maximum permissible limit of 425 mg/kg for Fe in fruits (36).

In this study, the Pb content of all samples exceeded the permissible limit of regulatory bodies (37) that recommended Pb concentration limits for berries and other small fruits as 0.2 mg/kg and foods as 0.5 mg/kg. These results for the mean Pb in the samples were lower than the results reported by Rahman and Islam (38) in a study on heavy metals in fruits from

Bangladesh, Pehluvan*et al*. (1) for asweet cherry, apple, plum, and apricot in a study conducted in Turkey and the study of Ali *et al*. (39) that reported between 2.1 and 7.0 mg/kg of Pb in apricot. The result obtained in the present study was also lower than the values reported by Hamurcu*et al.*(40) in apple (2.21 mg/kg), plum (2.82 mg/kg), and rosehip (1.54-2.86 mg/kg). Likewise, the values reported for Pb in the present study are higher than the values reported by Nawab et al. (41) in fruits from Pakistan and Elbagermi*et al*. (42) in orange and banana, and the results of Uroko*et al*. (43) that reported non-detection of Pb in fruit samples from Umuahia market, Nigeria. The differences in the reported mean Pb concentration in the current study as compared to the above-cited literature may likely arise from the nature of the studied fruits, as plants have different absorptive capacities for heavy metals, another likely assumption is the nature of the heavy metal contamination source.

All the fruit samples have an excessive amount of Cd compared to the permissible limit (0.05 mg/kg) proposed by the FAO/WHO (37). As the sampling locations were located near the highway the above permissible mean values can be attributed to vehicular exhaust and the use of Cd-containing fertilizers. The concentration of Cd (mg/kg) in this study was much higher than those reported by Krejpcio*et al*. (35) in sweet cherry (0.021 mg/kg) in Poland, Pehluvan*et al*. (1) and Duran *et al*. (44) in white mulberry (0.015 and 0.63 mg/kg, respectively) in Turkey, Radwan and Salama (2006(45) in apple (0.05 mg/kg) in Egypt, Hamurcu*et al.* (2010(40) in plum (0.14 mg/kg) in Turkey and the result reported by Elbagermi*et al*. (42) in Orange (0.03) in Libya. But the results are similar to those reported by *Pehluvan et al*. (1) for sweet cherry and plum and that reported by Elbagermi*et al*. (42) for banana and the Cd mean concentration range of various fruits from Anambra state, Nigeria (5). However, the results obtained in the present study for Cd concentration were lower than those detected in some fruit and vegetable with a 25 mg/kg average value (46) and the reported Cd in fruits from Bangladesh (38).

The mean Zn values in the studied fruits fall below the WHO permissible limit of 5.00 mg/kg for Zn in fruits (47). But the values are similar to those reported by Elbagermi et al. (42) and the results of a study conducted in fruit samples from some markets in Anambra state Nigeria (5), but far below the range reported by Pehluvan*et al*. (1)in 2015 (10.24-30.24 mg/kg) in fruits and that reported in a study conducted by Mahfuza*et al*. (33). Manufacturing concerns such as galvanization, paint, batteries, smelting, fertilizer, and pesticides, fossil fuel combustion, pigment, polymer stabilizer have been reported to emit the heavy metal Zn to the environment (48), which may explain to observed values in the present study as Katsina state is mostly an agrarian state with a handful of industries mainly located in the state capital.

In the present work, theMn content of fruit samples is lower than that reported in fruits from Turkey (1) and Poland (35).

Table 1 Heavy Metal Concentration (mg/kg) in Local Fruit Samples from Katsina State

Location	Heavy Metal						
	Mn	Zn	Pb	Cd	Ni	Fe	Cr
Kanya	0.351±0.0004	0.952±0.0012	1.362±0.0001	0.078±0.0003	BDL	1.728±0.0004	BDL
Kadanya	0.423±0.0012	0.263±0.0006	1.520±0.0002	0.065±0.0008	BDL	1.825±0.0012	BDL
Faru	0.368±0.0003	0.967±0.0002	1.623±0.0003	0.053±0.0002	BDL	1.936±0.0008	BDL
Dinya	0.502±0.0001	0.925±0.0016	1.152±0.0002	0.092±0.0001	BDL	1.932±0.0025	BDL
Goruba	0.321±0.0003	0.958±0.0006	1.274±0.0002	0.074±0.0006	BDL	1.951±0.0001	BDL
Aduwa	0.357±0.0003	0.941±0.0006	1.331±0.0002	0.085±0.0003	BDL	1.748±0.0006	BDL

Values are expressed as Mean ± Standard Deviation

The results for the estimated daily intake (EDI) of the heavy metals in the consumption of the fruits were given in Figures 1 and 2. From the Figures, the estimated daily intake of the heavy metals (Pb, Zn, Cd, Fe, and Mn) was lower than the tolerable daily intake limit set by the USEPA (49) in both samples for both the adult and children consumer population.

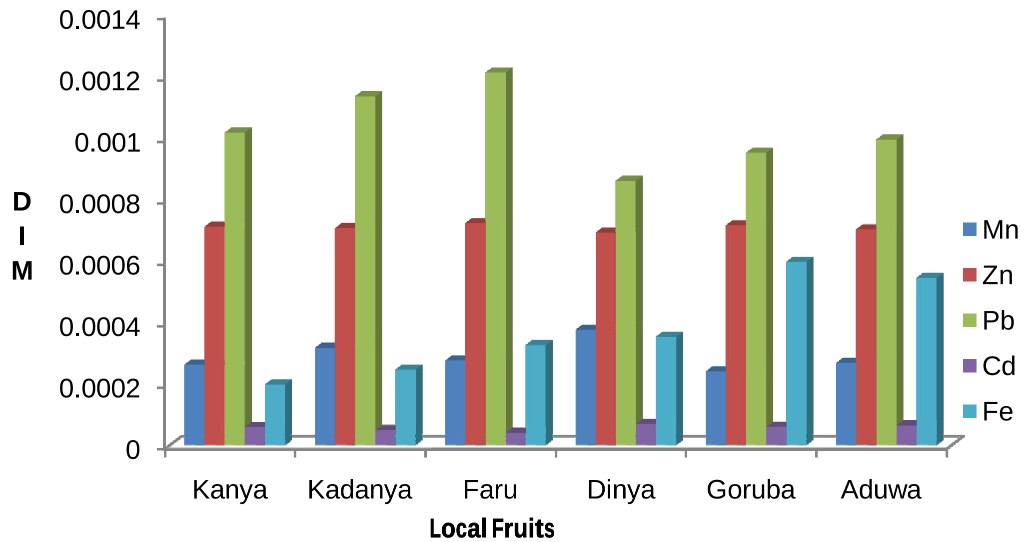

Fig 1 Daily Intake of Heavy Metal (DIM) in Adults from Consuming Local Fruit Samples from Katsina State

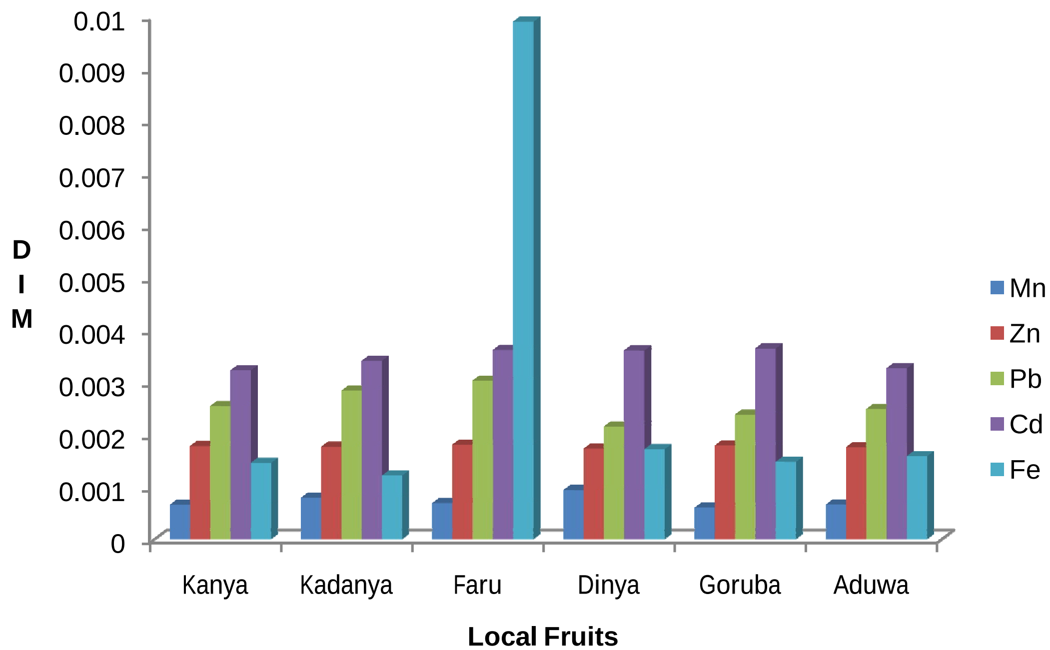

Fig 2 Daily Intake of Heavy Metal (DIM) in Children from Consuming Local Fruit Samples from Katsina State

The calculated THQ through the consumption of the present study fruit samples provides a measure of the evaluated metal contaminants although it does not measure the risk of exposure but rather gives an estimate of thelevel of concern (43).The consumption of the study local fruits pointed to an indication of no adverse health effects for both the children and adults population of the study area because the calculated fruit sampleTHQs are <1; hence, it may be assumed that the study fruit samples are safe for consumption(Tables 2 and 3).The THQ for the samples was in the decreasing order Mn>Zn>Fe>Pb>Cd, for all the samples respectively. Similar observations of THQs <1 have been reported previously in studies that have evaluated heavy metals in foods from Katsina state, Nigeria (10; 11; 12; 13; 14; 15; 16; 17).The cumulative HI to the population which is the representation of the non-cancer risk for all studied fruits showed the risk level (HI < 1) with the highest value in Dinya fruit and lowest in Goruba fruit(Tables 4 and 5).

Table 2 Heavy Metal Target Hazard Quotient and Health Risk Index in Adults from Consuming Local Fruit Samples from Katsina State

			Target Hazard Quotient			Health Risk Index (HRIs)
Location				Heavy Metal		
	Mn	Zn	Pb	Cd	Fe	
Kanya	0.023367	0.002475	0.001695	0.000117	0.001843	0.028794
Kadanya	0.032664	0.002352	0.001891	0.000097	0.001946	0.038950
Faru	0.025729	0.002552	0.002020	0.000079	0.002065	0.032445
Dinya	0.037836	0.002302	0.001433	0.000014	0.002061	0.043646
Goruba	0.021652	0.002454	0.001585	0.000012	0.002081	0.027784
Aduwa	0.023897	0.002342	0.001656	0.000127	0.001864	0.029886

Table 3 Heavy Metal Target Hazard Quotient and Health Risk Index in Children from Consuming Local Fruit Samples from Katsina State

			Target Hazard Quotient			Health Risk Index (HRIs)
Location				Heavy Metal		
	Mn	Zn	Pb	Cd	Fe	
Kanya	0.046795	0,005923	0.004202	0.002912	0.004608	0.064439
Kadanya	0.056394	0.005879	0.004728	0.002426	0.004866	0.074294
Faru	0.049061	0.006016	0.005049	0.000198	0.005162	0.065486
Dinya	0.066926	0.005755	0.003584	0.003435	0.005151	0.084851
Goruba	0.042795	0.005960	0.003963	0.002949	0.005202	0.060870
Aduwa	0.047375	0.005855	0.004140	0.003173	0.004661	0.065204

The International Agency for Research on Cancer (IARC) has listed the heavy metals Cd and Pb IARC as being carcinogenic agents (50; 51). Chronic exposure to low doses of Cd, and Pb could therefore manifest into various types of cancers (6). Tables4 and 5 are the representations of the total cancer risk of heavy metals to the children and adults consumer population in the study fruit samples. From the tables a deduction can be made that the cancer risks for the heavy metal Cd in the adults population were at the threshold of the risk limit (ILCR > 10^{-4}) for cancer, while the metal Pb in adults and the metals Pb and Cd in children were above the risk threshold (ILCR ≤ 10^{-3}) for cancer.The trend of risk for developing cancer as a result of consuming the studied fruits showed: Faru>Kadanya> Kanya >Goruba>Dinya> Aduwa.

Table 4 Incremental Life Time Cancer Risk in Adults Consuming Local Fruit Samples from Katsina State

Location	ILCR		∑ILCR
	Pb	Cd	
Kanya	6.406000E-03	8.730000E-04	7.280000E-03
Kadanya	7.149000E-03	7.280000E-04	7.877000E-03
Faru	7.634000E-03	5.930000E-04	8.227000E-03
Dinya	5.418000E-03	1.030000E-03	6.449000E-03
Goruba	5.992000E-03	8.850000E-04	6.877000E-03
Aduwa	6.260000E-03	9.520000E-04	6.260000E-03

Table 5 Incremental Life Time Cancer Risk in Children from Consuming Local Fruit Samples from Katsina State

Location	ILCR		∑ILCR
	Pb	Cd	
Kanya	1.601533E-02	2.183745E-03	1.819908E-02
Kadanya	1.787320E-02	1.819785E-03	1.969299E-02
Faru	1.908434E-02	1.483830E-03	2.056817E-02
Dinya	1.354601E-02	2.576100E-03	1.612211E-02
Goruba	1.498056E-02	2.211750E-03	1.719231E-02
Aduwa	1.365081E-02	2.379720E-03	1.603053E-02

4. CONCLUSION

Results from this study have shown that concentration values of Pb in the samples were generally above the USEPA, WHO/FAO maximum permissive limits. The results have indicated that the estimated daily intake of the heavy metals was lower than the tolerable daily intake limit set by the regulatory bodies in both samples. The risk level of Target Hazard Quotient (THQ < 1) was observed for all the evaluated heavy metals for both adults and children. ILCR for Cd is at the threshold risk limit ($>10^{-4}$) in all the studied fruits in adults, While Pb for adults and Cd for children lies within the moderate risk limit ($>10^{-3}$), and Pb in children is above the moderate risk limit ($>10^{-2}$) in children. Moreover, cumulative cancer risk (∑ILCR) of all the studied fruits reached the moderate risk level ($>10^{-3}$) in adults while in children it is above the level ($>10^{-2}$). The study suggests that consumption of the studied local fruits in Katsina state is of apublic health concern as they may contribute to the population's cancer burden.

REFERENCES

1 Pehluvan M, Turan M, Kaya T, Şimsek U. heavy metal and mineral levels of some fruit species grown at the road side in the east part of Turkey. *Fresenius Environmental Bulletin* 2015; 24 (4): 1302 – 1309

2 Kuno K. Effects of Heavy Metals on Photosynthetic Rates and Morphogenesis in Mulberry Leaves. *J. Seric. Sci* 1984; 53 (3): 198-204

3Fotakis G, Timbrell JA. Role of Trace Elements in Cadmium Chloride Uptake in Hepatoma Cell Lines. *Toxicol Lett*. 2006 164: 97-103

4 Sharma RK, Agrawal M, Marshall FN. Heavy Metals (Cu, Zn, Cd and Pb) Contamination of Vegetables in Urban India: A Case Study in Varanasi. *Environmental Pollution* 2008; 145: 254-263

5 Ezeilo CA, Okonkwo SI, Onuorah CC, Linu-Chibuezeh A, Ugwunnadi NE. Determination of Heavy Metals in Some Fruits and Vegetables from Selected Market's in Anambra State". *Acta Scientific Nutritional Health* 2020; 4 (4): 163-171

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

7 Sathawara NG, Parikh DJ, Agarwal YK. Essential heavy metals in environmental samples from Western India," *Bulletin of Environmental Contamination and Toxicology* 2004; 73 (4): 756–761

8 Yaradua AI, Alhassan AJ, Shagumba AA, Nasir A, Idi A, Muhammad IU, *et al*., 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* 2017; 10(1): 341-344

9 Yaradua AI, Alhassan AJ, Kurfi AU, Nasir A, Idi A, Muhammad IU, *et al*., (2018) Heavy metals health risk index (HRI) in human consumption of whole fish and water from some selected dams in Katsina State Nigeria. *Asian Journal of Fisheries and Aquatic Research* 2018; 1(1): 1-11

10 Yaradua AI, Alhassan AJ, Imam AA, Nasir A, Usman F, Shuaibu L, *et al*., Comparative Evaluation of the Heavy Metals Content of Sorghum Cultivated in Katsina State, North West Nigeria .*Acta Scientific Nutritional Health 2019a;* 3 (11): 188-196.

11 Yaradua AI, Alhassan AJ, Nasir A, Matazu KI, Usman A, Idi A,*et al*., Heavy Metals Health Risk Assessment through Consumption of Baobab Leaf Cultivated in Katsina State, North West Nigeria. *Asian Food Science Journal 2019b*; 13(1): 1-11

12 Yaradua AI, Alhassan AJ, Nasir A, Matazu SS, Usman A, Idi A, *et al*., Health Risk Assessment for Carcinogenic and Non-carcinogenic Heavy Metal Exposures from Pepper Fruits Cultivated In Katsina State, North West Nigeria. *Asian Journal of Advanced Research and Reports 2019c*; 6(4): 1-10

13 Yaradua AI, Alhassan AJ, Nasir A, MatazuKI, Usman A, Idi A,*et al*., Concentrations and Risk Evaluation of Selected Heavy Metals in Amaranthus (L.) Lea Cultivated in Katsina State, North West Nigeria. *Journal of Applied Life Sciences International 2019d*; 20(4): 1-12

14 Yaradua AI, Alhassan AJ, Matazu HK, Nasir A, Matazu KI, Idi, A, *et al*. ,Evaluation of Heavy Metals in some Locally Produced Food Seasonings in Katsina state Nigeria. *Sustainability, Agri, Food and Environmental Research 2019e;* 7 (4) 212-226

15 Yaradua AI, Alhassan AJ, Nasir A, Matazu KI, Usman A, Yau S, et al*., Health Risk Assessment for Carcinogenic and Non Carcinogenic Heavy Metal Exposure from Hibiscus Leaf Cultivated* in Katsina State, North West Nigeria. *Asian Journal of Agricultural and Horticultural Research 2019f*; 3 (4): 1-12

16 Yaradua AI, Alhassan AJ, Nasir A, Bala M, Usman A, Idi A, *et al*., Heavy Metal Burden and Evaluation of Human Health Risks in Tomato Fruits Cultivated in Katsina State, North West Nigeria. *Asian Food Science Journal 2019g*; 9 (1): 1-10

17 Yaradua AI, Alhassan AJ, Nasir I, Matazu SS, Usman A, Idi A, Human Health Risk Assessment of Heavy Metals in Onion Bulbs Cultivated in Katsina State, North West Nigeria. *Archives of Current Research International 2020*; 20(2): 30-39

18 Katsina State Government, Katsina State investor's handbook 2016, Yaliam Press Ltd, pp 12-15

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

20 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: 612–621

21 World Health Organization/Food and Agriculture Organization. Codex Alimentarius Commission. Food Additives and Contaminants. Joint FAO/WHO Food Standards Programme. No. ALINORM 01/12A; 2018; 1-289.

22 Orisakwe OE, MbagwuHOC, 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

23 Ekhator OC, UdowelleNA, 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* 2017; 4: 1-8 Article ID 8458057

24Micheal 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

25 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

26 Li PH, Kong SF, 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

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

28 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 2011; 14, 1–2, National Food Policy Plan of Action and Country Investment Plan, Government of the People's Republic of Bangladesh

29 RAIS The Risk Information System 2007. Retrieved from http://rais.oml.govt/tox/rap_toxp.shtml

30 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

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

32 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

33 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

34 Grembecka M, Szefer P. Comparative assessment of essential and heavy metals in fruits from different geographical origin. *Environ Monit Assess* 2013; 185:9139-9160

35 Krejpcio Z, Sionkowski S, Bartela J. Safety of fresh fruits and juices available on the Polish market as determined by heavy metal residues. *Polish journal of Environmental Studies* 2005; 14: 877-881

36 FAO/WHO. Codex Alimentarius Commission Food additives and contaminants: Joint FAO/WHO Food Standards Program 2011; ALINORM 01/12A:1-289

37 FAO/WHO (1995) Codex General Standard for Contaminants and Toxins in Food and Feed (193-1995) 1995; 31-32

38 Rahman M, Islam MA. Concentrations and Health Risk Assessment of Trace Elements in Cereals, Fruits, and Vegetables of Bangladesh. *Biological Trace Element Research* 2019; 1-11

39 Ali S, Masud T, Abbasi KS. Physico-chemical characteristics of apricot (*Prunus armenica* L.) grown in Northern Areas of Pakistan. *Scientia Horticulturae* 2011; 130: 386- 392

40 Hamurcu M, Özcan MM, Dursun N, Gezgin S. Mineral and Heavy Metal Levels of Some Fruits Grown at the Roadsides. *Food and Chemical Toxicology* 2010; 48: 1767-1770

41 Nawab J, Farooqi S, Xiaoping W, Khan S, Khan A. Levels, dietary intake, and health risk of potentially toxic metals in vegetables, fruits, and cereal crops in Pakistan. *Environmental Science and Pollution Research*2018; 25 (6): 5558–5571

42 Elbagermi MA, Edwards HGM, Alajtal AI. Monitoring of Heavy Metal Content in Fruits and Vegetables Collected from Production and Market Sites in the Misurata Area of Libya. *International Scholarly Research Network (ISRN) Analytical Chemistry* 2012; 1-5

43Uroko IR, Okpashi VE, Oluomachi UN, Paulinus NC, Nduka FO, Precious O. Evaluation of heavy metals in selected fruits in Umuahia market, - Nigeria: Associating toxicity to effect for improved metal risk assessment. *J App Biol Biotech2019;* 7(04):39-45. DOI: 10.7324/JABB.2019.70407

44 Duran, A., Tuzen, M. and Soylak, M. Trace Element Levels in Some Dried Fruit Samples from Turkey. *International Journal of Food Sciences and Nutrition* 2008; 59(7-8): 581-589

45 Radwan MA, Salama AK Market basket survey for heavy metals in Egyptian fruits and vegetables; *Food and Chemical Toxicology 2006;* 44: 1273-1278

46 Turkoglu MK, Kilicel F, Kara K, Tuncer I, Uygun I. Heavy metals in soil, vegetables and fruits in the endemic upper gastrointestinal cancer region of Turkey. *Environ Toxicol Pharmacol* 2002; 13: 175-179

47 WHO. Cadmium environmental health criteria World Health Organization, 1992: 134

48 Mukesh P, Lokendra Singh T. “Heavy Metal Cu, Ni and Zn: Toxicity, Health Hazard and their Removal Technique by Low Cost Adsorbents: A short Overview”. *International Journal of Plant, Animal and Environmental Sciences* 2013; 3 (3): 1-16

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

50 International Agency for Research on Cancer. Lead and Lead compounds, IARC Monographs 2005; 23(7):230-232

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