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Impact of Heavy Metals Toxicity on Children and Adults from Local Rice Varieties of Northern Nigeria

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Abstract

The current study aimed to investigate the levels of heavy metals [cadmium (Cd), zinc (Zn), arsenic (As), lead (Pb), and mercury (Hg)] in local rice varieties named Jamila (JM), Santana (STN), Kwandala (KW), and Sipi (SP) collected from Danbatta town of Kano State, Northwestern Nigeria. The samples of local rice varieties were digested using HNO_3 and HCl as digestion acids in a ratio of 2:1 (v/v). The digested samples were later analyzed for heavy metals using atomic absorption spectrophotometer. Moreover, the health risk assessment of heavy metals by the consumption of local rice varieties among local children and adults was also estimated based on estimated daily intake (EDI), target hazard quotient (THQ), hazard index (HI), and target cancer risk (TCR). The concentrations of Cd, Zn, and Pb dry weight basis observed in the range of 0.002-0.06, 0.02-20.0, and 1.16-14.2 mg/kg, respectively. Hg was detected only in the SP rice variety with a concentration of 0.022 mg/kg. Whereas, As was detected in STN (0.086 mg/kg), KW (0.006 mg/kg), and SP (0.028 mg/kg). The resulting data showed that Cd, Zn, Hg, and As were within the maximum permissible limits set by regulatory bodies. The EDI values ranged from 1.21E-5 -1.21E-1 and 5.0E-6 – 5.0E-2 for children (24 kg body weight) and adults (70 kg body weight), respectively. The data of the non-carcinogenic risk assessment indicated that the THQ values of Cd, Hg, and As were less than the maximum permissible limit of 1.0 for both children and adults. The HI data showed the potentially high possible health risk of the heavy metals by the consumption of the studied local rice varieties, with Pb being the major contributor. Similarly, resulting data of TCR for Cd and Pb showed high cancer risk upon the consumption of the studied local rice varieties over a long time.

Keywords: Local rice, Heavy metals, Target hazard quotient, Hazard index

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Introduction

Food safety is a significant challenge in most developing countries, especially in Africa. Most foods consumed in these countries are contaminated with a series of pollutants. Feeding on unwholesome food materials has severe health and economic impacts on the populace [1, 2]. Nigeria ranks second among the nations across the globe in rice importation, purchasing about two million metric tons in one year from countries like Thailand and China [3]. Due to their public health implications, exposure to heavy metals by humans has been the main focus of attention among researchers and health and nutrition experts [4]. These contaminants could occur naturally as constituents of the earth's crust and could also be distributed through various activities of human beings.

Pollution of the environment by heavy metals, even at low concentrations, and their long–term cumulative health effects are among the leading global health concerns. Heavy metals are non-biodegradable and remain in aquatic and terrestrial environments for long periods. They could be transported from soil to water bodies or absorbed by cereal crops and eventually gets to humans through their consumption. Undoubtedly, high traffic and industrial activities are the major contributors to high levels of heavy metals in the environment. Plants growing around these areas are likely to be contaminated by these heavy metals by the absorption from the soil, or the leaves may absorb atmospheric contaminants.

Soil contamination by heavy metals can transfer to food and accumulate in consumers. For instance, plants may be accumulating these heavy metals from contaminated soil without physical changes or visible indication, which could pose a potential risk for humans, and animals. Most of these heavy metals may have long last harmful effects due to their non-biodegradable nature, and long biological half-lives lead to accumulation in different body parts. Most of them are very toxic because they are soluble in water. These heavy metals may harm humans and animals even at low concentrations because the body finds it difficult to get rid of them [5, 6]. For example, continuous Cd consumption leads to respiratory system damage and lung cancer [7].

Hg is a potent neurotoxin found in a variety of products. It affects the brain, liver, and kidneys and can cause developmental disorders in children. Methyl mercury is an organic contaminant capable of damaging the central nervous system [8]. Heavy metals generally affect the physiological functions of plants and retard nitrogen fixation and plant growth [9]. Heavy metals usually combine with the thiol, amino, and imino groups of protein and form a metal complex. This makes the proteins lose their biological functions and cause the breakdown of the cells [9].

Rice is a common staple food produced in northern Nigeria. Zamfara, Jigawa, and Borno states are the major contributors to rice production because of the application of specialized processing equipment [10]. Statistical data indicated that the annual rice consumption in Nigeria is about 5.5 million tons, while the local production of rice is about 1.8 million tons [11]. Rice farmers in Nigeria account for nearly three million out of about sixty million rural dwellers, and approximately five million hectares of arable land are suitable for rice production [10].

Rice is an important cereal food that fulfilled the potential nutrition effectively for the poor population in remote areas of emerging countries [12]. Orisakwe et al. [13] and Otitoju et al. [4] reported high levels of Pb and Hg in pumpkin leaves obtained from a construction site in Uyo in the eastern part of Nigeria. Consumption of local rice is increasing in Nigeria because rice is one of the major staple foods available in the country.

Local rice is currently being eaten by more than one million people daily. Therefore, there is a need to investigate local rice varieties being consumed for their toxic effects. Uddin et al. [14] reported that many countries have assessed and monitored heavy metals in foods and vegetables. However, information about the toxicity and health risk parameters of the heavy metals in locally grown rice in Nigeria is scarce. Therefore, this study investigates the levels of heavy metals in locally produced rice varieties in Northern Nigeria, followed by the heavy metals' possible carcinogenic and non-carcinogenic risks assessment based on their consumption by children and adults.

Materials and Methods

Location of the Rice Cultivation

The local rice varieties were grown at Danbarta town in Danbarta local government area of Kano State, Nigeria. Danbarta is located about forty-nine miles north of Kano city at the northern border of Kano State, northwestern Nigeria. It has an area of 932 square kilometers with a latitude of $12^{o}25^{'}12^{''}$ and a longitude of $8^{o}38^{'}4^{''}$. Danbatta is bordered north, east, south, and west by Kazaure, Babura, Minjibir, and Makoda local government areas, respectively. The average temperature is 33^{o}C with a humidity level of 14%. The zonal office of Kano State Agricultural and Rural Development Agency is located in this area, where agriculture is a major economic activity. Residents of this region are recognised for their farming endeavours. Because they adhere to the philosophy of eating what they create, they consume a lot of local cuisines, particularly rice.

Samples Collection and Preparation

The local rice varieties were purchased in the Shuwarin market in Dutse, Jigawa State, from retailers who had earlier obtained them from the Danbarta local government area of Kano State, Nigeria. The samples were washed with distilled water in the Department of Chemistry, Federal University Dutse, and spread on a clean stainless steel tray to allow the water to drain off. The samples were separately packaged inside labeled envelopes and dried in the Gallenhkamp oven at 65 ^{o}C for two days, pulverized into a fine powder using electric stainless steel Excella Mixer grinder. The pulverized samples were sieved by a 2 mm sieve to obtain fine particles.

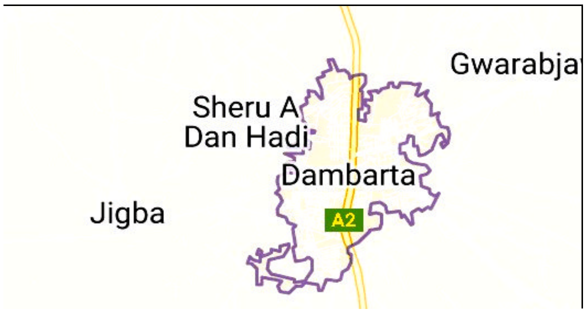

Figure 1. **Map of the study area, Danbarta area of Kano State, Nigeria**

Materials, Chemicals and Reagents

All the materials and chemicals used for the analysis were of Analytical Grade. They include ceramic mortar and pestle, analytical balance (Mettler Toledo, Switzerland), digital timer hotplate (Thermo Scientific, USA), Vortex shaker, different sizes of volumetric flasks (Pyrex, USA), different sizes of the beaker (Pyrex, USA), Whatman filter paper (150 mm diameter, GE Healthcare, USA), HNO_3 and HCl (Sigma Aldrich product of United States of America), distilled water and stock solutions of the metals obtained from Physical and Chemical Laboratories, N.I.M.G, Jos, Nigeria.

Samples Digestion and Analysis

Five grams of each dried sample of local rice varieties was weighed into digestion flasks, and add 8.0 mL of HNO_3 and 4.0 mL HCl (2:1; v/v). The digestion flasks were placed on a hot plate and heated at 80 ^{o}C. The temperature was gradually increased up to 120 ^{o}C until there was complete digestion. The digested samples were diluted with distilled water and made up to 100 mL, as reported elsewhere [15]. Heavy metal concentrations in the samples (Pb, As, Zn, Cd and Hg) were determined using a Perkin Elmer AS 3100 Flame Atomic Absorption Spectrophotometer (FAAS) facility from Physical and Chemical Laboratories, N.I.M.G, Jos, Nigeria.

Quality Control and Assurance

The instrument used for the analysis was well calibrated to check the accuracy of the instrument and traceability of the measurement with certified reference standard solutions covering the desired concentration of the analytes in the samples. The reference standard stock solution (1000 mg/L) of each heavy metal was obtained from N.I.M.G, Jos, Nigeria. The stock solution was later diluted for calibration by AAS. Purification of the reagents blanks (acids) was carried out by sub-boiling distillation to remove the trace amounts of the metals in the acids, thereby removing background contamination of heavy metals. The spike recovery technique was used for the analytical procedure. This was achieved by introducing a known standard of the metals into already analyzed samples and re-analyzing it again. There was more than 96% recovery for all the metals. The relative standard deviation, a measure of the precision of results, was less than 5.0%. The limit of quantification (LOQ) for Zn and Cd was 0.005 mg/L, whereas that of As, Pb, and Hg was 0.007 mg/L.

Health Risk Assessment

The following parameters were used to assess the non-carcinogenic and carcinogenic health risk, such as estimated daily intake, target hazard quotient, and chronic hazard index.

Estimated Daily Intake (EDI) of the Heavy Metals

EDI of heavy metals was calculated using the equation [14]:

$$E = \frac{Cm \times Rf}{Bw}$$

Where C_m is the concentration of heavy metals (mg kg^{-1} dry weight), R_f represents the daily intake of food in kg per person per day, and B_w is the average body weight in kg (24 kg for children; 70 kg for adults).

Non-carcinogenic Risk
Target hazard quotient (THQ)

THQ was calculated using the following formula [14]:

$$THQ = \frac{EDI \times Ef \times De}{Df \times Tavncar}$$

Where THQ denotes non-cancer risks, Ef represents the exposure frequency (365 days/year), De represents exposure duration (65 years), and D_f denotes reference dose. D_f of Zn, Pb, Cd, Hg, and As are 0.03, 0.0035, 0.003, 0.0001, and 0.0003 mg/kg/day, respectively [16, 14], and Tavncar represents the average time for non-carcinogens is 365 days/year x De [17].

Chronic Hazard Index (HI)

The chronic hazard index is the sum of more than one hazard quotient for multiple toxicants or multiple exposure pathways [18]. This was calculated using the equation:

$$HI = \sum THQ \qquad (3)$$

Carcinogenic Risk
Target cancer risk (TCR)

TCR was estimated by using the formula [16]:

$$TCR = THQ \times S_{epo} \qquad (4)$$

S_{epo} = carcinogenic potency slope. The reference values for Cd and Pb (1) are 6.1 and 0.0085 mg/kg bw/day, respectively [16].

Data analysis

The data analysis was carried out using the Microsoft Excel package.

Results and Discussion

The concentrations of rice samples in mg/kg are presented in Table 1. This study showed that Cd was present in very low concentrations in all the local rice varieties, with STN (0.064 mg/kg) having the highest concentration and KW, and SP having the lowest concentration. The levels of Cd in this study were lower than 0.07 mg/kg, as reported by Wang et al. [19] for irrigated rice samples and Rezaei et al. [20] for rice samples from various countries (mg/kg): Korea (0.08), Brazil (1.60), Saudi Arabia (6.16) and China (0.23). The samples Cd were also lower than the 0.2 mg/kg permissible limit set by European Union [12], the Chinese regulatory agency [21] and WHO/FAO [22]. Also, it was reported that entering the food chain could cause damage to the lungs and bones, leading to anemia and sometimes high blood pressure [23]. Hg was not detected in JM, STN, and KW. This shows that the environment where they were grown was not contaminated with Hg. However, Hg was in SP with a value of 0.022 mg/kg. The permissible limit set European Union Commission, Chinese regulation and WHO/FAO is 0.02 mg/kg. The result of this study compares well with 0.022 mg/kg for irrigated rice, as reported by Wang et al. [19] but is comparatively lower than 0.041-0.798 mg/kg local and imported rice samples available in Iraq [24]. Hg is toxic and inimical to human health, even at low concentrations. Zn had concentrations ranging from 0.02 – 20.0 mg/kg. Zn is one of the trace metals that are needed in our diets in small amounts. The maximum permissible limit for Zn is 6.0 mg/kg [22]. Two of the samples under consideration STN (20.0 mg/kg) and KW (8.06 mg/kg), were higher than this critical level; others (0.02 – 0.028 mk/kg) were comparatively lower. However, the present finding showed that the samples' Zn levels were all lower than the 50 mg/kg and 60 mg/kg permissible limits by the Chinese regulatory agency and WHO/FAO, respectively. Excess Zn interacts with Cu and Fe, decreasing their absorption. Excess Zn also decreases the functioning of the immune system [25]. This study revealed that levels of As in the local rice samples ranged from 0.006-0.086 mg/kg. It was, however, not detected in JM. This finding indicated that the local rice varieties are low in As as compared with Chinese standard (0.15 mg/kg) [21], EU commission standard (0.10 mg/kg) [12] and WHO/FAO standard (0.15 mg/kg) [22]. According to Mousavi et al. [26], negative effects of As include general weakness in the muscle, loss of appetite, nausea, diarrhea, vomiting, inflammation of the mucous membrane of the eyes, skin lesions, anemia and reduced white blood cells and malignant tumors. This study shows that consumers of the local rice varieties may not be vulnerable to these diseases following their consumption.

***Table 1*. Levels of heavy metals (mg/kg) in four varieties of locally consumed rice in Nigeria.**

Metals	JM	STN	KW	SP	Mean	SD	CV%
Cd	0.038	0.064	0.002	0.002	0.027	0.030	112
Hg	ND	ND	ND	0.022	NC	NC	NC
Zn	0.020	20.0	8.06	0.028	7.03	9.44	134
As	ND	0.086	0.006	0.028	NC	NC	NC
Pb	2.30	6.84	1.16	14.2	6.13	5.92	96.5

JM = Jamila local rice; STN = Santana local rice; KW = Kwandala local rice; SP = Sipi local rice; SD = standard deviation; CV% = coefficient of variation percent; ND = Not detected; NC = Not computed

The concentration of Pb in the samples followed the sequence SP > STN > JM > KW with Pb values of 14.2, 6.80, 2.30 and 1.16 mg/kg, respectively. The Pb concentrations in this study were higher than 0.3 mg/kg which is the maximum limit set by FAO/WHO [22] and 0.2 mg/kg limit set by Chinese Department of Preventive Medicine [21]. These findings should arouse the attention of researchers and the government; since, on average, it has been revealed that locally produced rice from the northern region is contaminated with high levels of heavy metals and that rice is one of the commonest staples produced in the northern region [27]. A comparison of the findings of this work with research carried out on local rice grown in Kaduna by Umar and Wunzani [28] revealed the Pb content found in the literature (0.183 mg/kg) was lower than the Pb content of the present study. The variation could be due to variations in the species under consideration, total heavy metal contents of the soil, and physical and chemical properties, which could affect heavy metals' bioavailability [29, 30]. The Pb content of rice in this research was higher than 0.01 mg/kg of Pb in rice from Taiwan [31] but well below 61.17 mg/kg of local rice from Owerri, Imo state [13].

Acute effects of heavy metals may not be common like the chronic effects of accumulated metallic elements in tissues which could pose health issues. Research has indicated that contaminated foods happened to be the major sources of heavy metals for humans, and rice was the major route of Cd and Pb accumulation for Asians [32]. Otitoju et al. [4] reported high levels of heavy metals in vegetables planted along a construction site in Uyo. This could be due to the waste coming from the various industries in the area. Consumers of locally produced rice from the northern region are at greater risk of lead toxicity. Otitoju et al. [4] reported that it is important to monitor and gather information systemically on the level of heavy metals in the environment to have effective pollution control and mitigate the contamination of food stuffs by heavy metals.

***Table 2*. Comparison of sample results with standard permissible limits.**

Pb	**JM**	**D (%D)**	**STN**	**D (%D)**	**KW**	**D (%D)**	**SP**	**D (%D)**
WHO/FAO (5.00)	2.30	+2.70 (54.0)	6.84	-1.84 (36.8)	1.16	+3.84 (76.8)	142	-9.20 (184)
EU standard (0.20)	2.30	-2.10 (1050)	6.84	-6.64 (3320)	1.16	-0.96 (480)	142	-14.0 (7000)
Chinese Standard (0.20)	2.30	-2.10 (1050)	6.84	-6.64 (3320)	1.16	-0.96 (480)	142	-14.0 (7000)
Cd	**JM**	**D (%D)**	**STN**	**D (%D)**	**KW**	**D (%D)**	**SP**	**D (%D)**
WHO/FAO (0.20)	0.038	+0.162 (81.0)	0.064	+0.136 (68.0)	0.002	+0.198 (99.0)	0.002	+0.198 (99.0)
EU standard (0.20)	0.038	+0.162 (81.0)	0.064	+0.136 (68.0)	0.002	+0.198 (99.0)	0.002	+0.198 (99.0)
Chinese Standard (0.20)	0.038	+0.162 (81.0)	0.064	+0.136 (68.0)	0.002	+0.198 (99.0)	0.002	+0.198 (99.0)
Zn	**JM**	**D (%D)**	**STN**	**D (%D)**	**KW**	**D (%D)**	**SP**	**D (%D)**
WHO/FAO (60.0)	0.02	+59.98 (99.9)	20.0	+40.0 (66.7)	8.06	+51.9 (86.6)	0.028	+59.9 (99.9)
EU standard (NA)	0.02	NC	20.0	NC	8.06	NC	0.028	NC
Chinese Standard (50.0)	0.02	+49.98 (99.9	20.0	+30.0 (60.0)	8.06	+41.94 (83.9)	0.028	+49.97 (99.9)
Hg	JM	**D (%D)**	**STN**	**D (%D)**	**KW**	**D (%D)**	**SP**	**D (%D)**
WHO/FAO (0.02)	ND	NC	ND	NC	ND	NC	0.022	-0.002 (10.0)
EU standard (0.02)	ND	NC	ND	NC	ND	NC	0.022	-0.002 (10.0)
Chinese Standard (0.02)	ND	NC	ND	NC	ND	NC	0.022	-0.002 (10.0)
As	JM	**D (%D)**	**STN**	**D (%D)**	**KW**	**D (%D)**	**SP**	**D (%D)**
WHO/FAO (0.15)	ND	NC	0.086	+0.064 (42.7)	0.006	+0.144 (96.0)	0.028	+0.122 (81.3)
EU standard (0.10)	ND	NC	0.086	+0.014 (14.0)	0.006	+0.094 (94.0)	0.028	+0.072 (72.0)
Chinese Standard (0.15)	ND	NC	0.086	+0.064 (42.7)	0.006	+0.144 (96.0)	+0.144 (96.0)	+0.122 (81.3)

Table 3 showed the estimated daily intake of the selected heavy metals by the consumption of local rice varieties by children (24 kg bw) and adults (70 kg bw). The EDI for children were (mg/kg/day): Cd (1.21E-5- 3.87 E-4); Zn (1.21 E-4 – 1.21 E-1); Pb (7.01 E-3 – 8.58 E-2); As (3.63 E-5 – 5.20E-4) and Hg (1.33 E-4 for SP only). For adults (70 kg bw), EDI levels were Cd (5.0E-6- 1.60 E-6); Zn (5.0 E-5 – 5.0 E-2); Pb (2.90 E-3 – 3.55 E-2); As (1.50 E-5 – 2.150E-4) and Hg (5.50 E-5 for SP rice variety only). The highest EDI values of Cd, Zn, and As were observed by the consumption of STN rice variety in the children and adults, whilst the high EDI of Pb and Hg was calculated by the consumption of SP rice variety. Awareness about dietary intake is fundamental to assess the risk of heavy metals to human health.

The target hazard quotient, hazard index and target cancer risk of heavy metals for the consumption of the local rice varieties in children and adults are presented in Table 4. For the children category, the THQ values of Cd, Zn, Pb, and As ranged from 0.004 – 0.129, 0.004 – 4.03, 2.00 – 16.6, and 0.12 – 1.73, respectively. Whereas THQ value of Hg was found to be 1.33 for SP rice variety only. In the adult's category, THQ values ranged from Cd (0.002 – 0.053); Zn (0.002 – 1.67); Pb (0.830 – 10.1); As (0.05 – 0.72); Hg (0.55 for SP only). THQ is a measure of the non-carcinogenic risk of heavy metals. It is a measure of developing non-carcinogenic health challenges. The maximum limit for THQ is 1. If the THQ is less than 1, it is considered safe for the exposed consumers but if it is equal or greater than 1, it could be dangerous to the health of the consumers [33]. Results of this study showed that THQ for Cd, As and Hg ha values less than 1. This suggests that consumption of the samples would pose no health risk due to these metals in all the samples for both children and adults. However, for Zn, the THQ was greater than 1.0 by the consumption of STN rice variety by children and adults, respectively. The THQ for Pb were less than 1 in KW (0.830) for childern and greater than 1 (2.00 – 16.6) by the consumption of local rice varieties by adults. This implies that long term exposure to the rice samples could pose health risk as a result of Pb poisoning. The levels of hazard index ranged from 3.74 – 18.5 (for 24kg bw) and 1.69 – 10.9 (for 70kg bw). Hazard index is the addition of all THQ values in any given sample. A value of HI less than 1 in any food sample indicates that the exposed consumers would not have any adverse lifetime health effects due to consumption of that sample. HI above 1.0 implies that the combined effects of heavy metals could cause long-term non-carcinogenic health problems to the consumers. Hazard index reported for root, fruit, and leafy vegetables were 11.24, 8.35, and 13.16, respectively [14]. In this study, HI levels were higher than 1.0 in children and adults, and Pb is the major contributor to these high levels of HI.

***Table 3*. Estimated daily intake of the rice varieties for 24 kg and 70 kg body weight.**

Samples	Children (24 kg body weight)					Adults (70 kg body weight)				
	Cd	*Hg*	*Zn*	*As*	*Pb*	*Cd*	*Hg*	*Zn*	*As*	*Pb*
JM	2.30 E-4	ND	1.21E-4	ND	1.39E-2	9.5E-5	ND	5.00E-5	ND	5.75 E-3
STN	3.87 E-4	ND	1.21 E-1	5.20 E-4	4.13 E-4	1.60 E-4	ND	5.0 E-5	2.15 E-4	1.71 E-2
KW	1.21 E-5	ND	4.87 E-2	3.63 E-5	7.01 E-3	5.0 E-6	ND	2.02 E-2	1.50 E-5	2.90 E-3
SP	1.21 E-5	1.33 E-4	1.69 E-4	1.69 E-4	8.58 E-2	6.0 E-6	5.50 E-5	7.00 E-5	7.0 E-5	3.55 E-2
Mean	1.60 E-4	NC	4.25 E-2	NC	3.70 E-2	6.63 E-6	NC	1.80 E-2	NC	1.50 E-2
SD	1.83 E-4	NC	5.71 E-2	NC	3.57 E-2	7.55 E-5	NC	2.40 E-2	NC	1.50 E-2
CV%	114	NC	134	NC	96.6	114	NC	131	NC	100

JM = Jamila local rice; STN = Santana local rice; KW = Kwandala local rice; SP = Sipi local rice; SD = standard deviation;
CV% = coefficient of variation percent; ND = Not detected; NC = Not computed

Table 4. **Target hazard quotient, hazard index and target cancer risk of the samples for children and adults.**

Metals	JM	STN	KW	SP	Mean	SD	CV%	JM	STN	KW	SP	Mean	SD	CV%
	Children (24 kg body weight)							*Adults (70 kg body weight)*						
Cd	0.077	0.129	0.004	0.004	0.063	0.053	85.3	0.032	0.053	0.002	0.002	0.022	0.025	102
Hg	ND	ND	ND	1.33	NC	NC	NC	ND	ND	ND	0.550	NC	NC	NC
Zn	0.004	4.03	1.62	0.006	1.41	1.90	135	0.002	1.67	0.670	0.002	0.586	0.788	135
As	ND	1.73	0.120	0.560	NC	NC	NC	ND	0.720	0.05	0.230	NC	NC	NC
Pb	3.97	11.8	2.00	16.6	8.59	6.81	9.3	1.64	4.89	0.830	10.1	4.37	4.21	96.3
HI	4.05	15.0	3.74	18.5	10.3	7.56	73.4	1.69	7.33	1.54	10.9	5.37	4.57	85.1
$TCR_{(Cd)}$	0.468	0.787	0.025	0.025	0.326	0.372	114	0.193	0.325	0.014	0.014	0.137	0.151	110
$TCR_{(Pb)}$	0.034	0.100	0.017	0.141	0.073	0.058	79.2	0.014	0.042	0.007	0.086	0.037	0.036	96.6

JM = Jamila local rice; STN = Santana local rice; KW = Kwandala local rice; SP = Sipi local rice; SD = standard deviation; CV% = coefficient of variation percent; ND = Not detected; NC = Not computed

The levels of TCR of Cd in children (24 kg bw) and adults (70 kg bw) were 0.025 – 0.787 and 0.014 – 0.325, respectively whilst the levels of TCR of Pb were 0.017 – 0.141 and 0.007 – 0.086, respectively. FAO/WHO [22] has shown that prolonged exposure to a specific carcinogen might lead to cancer, and the probability may increase with prolonged consumption contact time. The TCR levels of Cd and Pb by the consumption of the studied local rice varieties were within the range of 0.042 – 0.330 in vegetables in Satkhira, Bangladesh [14] but higher than 4.48E-6 – 1.74E-3 in fourteen leafy vegetables sold in Ekiti State, Nigeria [34]. The level of carcinogenic risk is linked to the TCR level of heavy metals in any food sample [34]. If the TCR value is less than 10^{-6}, the carcinogenic risk is low. But, the TCR values between 10^{-5} and 10^{-3} showed a moderate risk. Similarly, the TCR value between 10^{-3} and 10^{-1}, and equal or greater than $10^{-1,}$ indicated the high and very high risk, respectively. The levels of TCR in this study for Cd and Pb indicate a high risk of carcinogen upon consumption of the rice samples over a long period.

Conclusion

This study examined the toxicity levels of heavy metals in four varieties of local rice consumed in the Northwestern region of Nigeria. The results revealed that the studied heavy metals were found in very trace amounts in the samples of the local rice varieties, while some were not detected. The concentrations of Pb in the samples of the local rice varieties were more than the permissible limits set by most of the regulatory agencies. This is a significant concern as this might be due to the onset of environmental pollution. The target hazard quotient of Cd, As, and Hg showed that the consumption of the local rice varieties would not pose any health risk in children and adults. However, the Zn levels in local rice varieties were above the permissible limit in only one sample. Whereas, Pb was greater than the permissible limit in most of the samples of local rice varieties. The combined effects of heavy metals in the samples of the local rice varieties can pose a health risk for the consumers over a long period of time. The carcinogenic risk is high for the exposed populations over time due to high TCR values. High levels of heavy metallic elements in the local rice varieties, especially Pb, are undesirable. More research on soil and water samples from the region is recommended to determine whether the contamination is coming from irrigation water or the soil to the rice variety. Generally, there were high variations in the levels of the local rice varieties, as evident in the values of the coefficient of variation percent.

Conflict of Interest

Authors declare that there is no conflict of interest.

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