

# Health Risk Assessment of Exposure to Heavy Metals in Rice Grown in Nigeria

Henrietta Ijeoma Kelle<sup>1</sup>; Emeka Chima Ogoko<sup>1</sup>; Prisca Ifeoma Udeozo<sup>2</sup>; Daniel Achem<sup>3</sup>; and John Odah Otumala<sup>1</sup>

<sup>1</sup>Department of Pure and Applied Science, Faculty of Sciences, National Open University of Nigeria, Jabi, Abuja, Nigeria.

<sup>2</sup>Department of Chemistry, Faculty of Science, University of Lagos, Akoka, Lagos State, Nigeria.

<sup>3</sup>Department of Industrial Chemistry, Faculty of Natural and Applied Sciences, Enugu State University of Technology, Enugu State, Nigeria.

E-mail: [hkelle@noun.edu.ng](mailto:hkelle@noun.edu.ng)

## ABSTRACT

Rice is a staple food in Nigeria and can be a source of exposure to heavy metals for the Nigeria people. Samples of Nigerian grown, processed and packaged rice commonly sold in Nigeria were collected from markets within the Federal Capital Territory (FCT), Abuja, Nigeria, prepared according to standard methods, and analyzed for heavy metals using inductively coupled plasma - optical emission spectrometry (ICP-OES). From the results of the study, the mean concentration of heavy metals; Cd, As, Ni, Pb, Cu, Co and Hg in the rice samples ranged from 0.0017 to 0.4099 mg/kg with the exception of Co which was below detectable limit. The mean concentrations of the heavy metals were below maximum permissible limit of the metals in rice by FAO/WHO.

The estimated daily intake (EDI) of each heavy metal through ingestion of rice samples ranged from 0.000011 to 0.0024 mg/kg/day and are within international acceptable limit of their daily intake (ADI) for both adult and children population. Hazard quotient (HQ) ranged from 0.04 to 1.83 (for adult population) and 0.05 to 3.20 (for children population), HQ was less than one for most of the metals. The hazard index (HI) ranged from 1.3 to 3.0 and 2.17 to 4.90 for adult and children population respectively, HI of the heavy metals was greater than one in all the rice samples. Incremental lifetime cancer risk (ILCR) value for carcinogenic heavy metals (Cd, Cr, As, Ni and Pb) ranged from 4E -7 to 1E -3 and these values were greater than safe limit for cancer risk.

Rice samples may not present adverse health effect in adult population, except from those rice samples with high cadmium content, possibility

exist of adverse health effect in children population due to high cadmium intake. There may be probability of potential health risk through consumption of some of the rice samples for both adult and children population due mainly to arsenic. Consumption of the heavy metals combined in the rice samples may lead to chronic health effects and probability of cancer risk exist from carcinogenic heavy metals except Pb.

(Keywords: rice, heavy metals, estimated daily intake, hazard quotient, incremental lifetime cancer risk).

## INTRODUCTION

Rice is a major staple food in Nigeria, and it is grown in large quantities. In sub-Saharan Africa, Nigeria is the largest producer and consumer of rice (FAO, 2019), with a population of over 198 million (Odunsi, 2018). Not until recently when rice production was intensified increasing the quantity of rice produced in the country, which led to the spring up of rice processing and packaging industries (most of which buy from farmers, process and bag rice to meet international standards), most rice consumed in Nigeria was imported from other rice producing countries. Presently the predominant rice sold in the Nigerian market is domestically grown rice with minimal presence of imported rice.

Rice is an important source of nutrition to the Nigerian people, providing dietary calorie intake. It contains carbohydrates, protein, fiber, vitamins E and B, zinc, and magnesium (Awika, 2014). According to Nayar, 2014 rice provides more energy to humans than all other cereal grains and crop plants, except oats (Juliano, *et al*, 2019). Proximate, mineral and toxicants

compositions of food can provide information about nutritional value of food (Abdul-Hamid, *et al*, 2007). The chemical composition of some fifteen different varieties of rice grown in Nigeria was studied by Oko, *et al* (2012) who reported that carbohydrates content ranged from 51.50 to 86.90 %, maximum ash content was 2.0 % while the energy value ranged from 262.94 to 398.82 %. Fat content (0.5 to 3.5 %), fiber content (1.0 to 2.5 %) and moisture content (5.00 to 9.60%) were found to be relatively low. Highest concentrations of calcium, magnesium, potassium and sodium ions were 0.13, 0.26, 0.55, 0.23, and 0.17 %, respectively. However, they did not investigate the toxicant (heavy metal) composition.

The presence of heavy metal ions in rice is one of the greatest health problems facing the nutritional benefits of rice. Many plant species are good absorbers of heavy metals from soil, and rice is a good example. Rice can easily absorb cadmium and arsenic from soils (Chi *et al*, 2018). Heavy metals absorbed by rice from soil can be eventually consumed by humans. Heavy metals occur naturally in trace amounts in the environment; however anthropogenic activities have made their presence in the environment more than their normal background concentrations, causing adverse effects to both plants and animals.

Heavy metals interact with cell components and organelles causing DNA damage, cell modulation, carcinogenesis and organ damage making them toxic (Chang, *et al.*, 1996; Wang and Shi, 2001, Beyersmann and Hartwig, 2008). Heavy metals such as iron, zinc, copper, manganese, cobalt, magnesium, chromium, molybdenum, nickel, and selenium are essential elements required for healthy development in both animals and plants; however, at elevated levels they exert adverse health effects (WHO/FAO/IAEA, 1996).

Metals such as arsenic, cadmium, chromium, lead, and mercury are priority pollutants because they are toxic at low concentrations causing multiple organ damage. Arsenic can cause nervous, respiratory, cardiovascular, gastrointestinal, and hematologic problems and is a carcinogen (ATSDR, 2009). Cadmium causes skeletal, urinary, reproductive, cardiovascular, central and peripheral nervous, and respiratory system problems and it is carcinogenic (Rafati, *et al*, 2017). Toxicity of chromium is associated with hexavalent chromium compounds; however, trivalent chromium compound which is an

essential trace element in humans and animals can exert little toxic effect at high concentrations. Hexavalent chromium compounds cause bronchial carcinomas, gastro enteritis, and hepatocellular deficiency (Deng, *et al.*, 2019) and are classified as a human carcinogen by the International Agency for Research on Cancer. Nickel can also cause contact dermatitis, cardiovascular disease, asthma, lung fibrosis, and respiratory tract cancer (Chen, *et al.*, 2017).

Sources of heavy metals include discharge of industrial heavy metal containing waste, fertilizers used in intensive farming (containing Cd and Pb as impurities), livestock manure (containing Cu, Zn and As) (Shi, *et al.*, 2011), crude oil and petroleum products, pesticides, stack or duct emissions of air, gas or vapor streams and fugitive dust emissions (Wuana and Okiemen, 2011), mining and milling processes (DeVolder, 2003) exhausts fumes, electronic/communication and domestic waste dumps, and paint dust (Nduka. *et al.*, 2019).

Though Nigeria is not an industrialized nation, it is one of the major oil-producing countries and ranks first in oil production in Africa (USEIA, 2020). Oil exploration and production as well as refinery activities release crude into the environment (soil and water) which contaminates the surrounding soils with heavy metals. Gas flaring phenomenon cannot be over emphasized in Nigeria; since the inception of production of crude oil in the country, Nigeria has been flaring natural gas associated with crude oil. According to World Bank, Nigeria is the seventh largest natural gas flaring country in the world (World bank, 2020). Gas flaring releases semi-volatile and volatile heavy metals in the environment (Ogbenejoboh, 2005; Alani, *et al.*, 2020), such as arsenic, cadmium, lead and mercury (Ogbenejoboh, 2005).

Heavy metals in the atmosphere can be distributed over a wide area and other regions of the country by natural air currents unless they are removed from the gas stream by dry and/ or wet precipitation mechanisms. In the atmosphere, the volatilized metals will convert to oxides and condense as fine particulate, by atmospheric deposition they get into soil and water.

Fertilizers, livestock manure and pesticides are extensively used in farming practices which is the main occupation of about 36.5 % of Nigeria population (FAO, 2018). Application of fertilizers,

livestock manures and pesticides over prolong period of time can greatly add to the heavy metal burden of soil.

Automobile and auto-panel workshops which are unregulated and indiscriminately sited in most parts of Nigeria can release heavy metals into soil through car repair activities. Car repair activities utilizes petrol, diesel, and lubricating oils, it includes re-painting of cars which involves scraping off old paint (releasing paint dust) from the vehicle, and body work before application of new paint. Decomposition of abandoned vehicles at automobile and auto-panel workshops also releases heavy metals. Components of automobiles such as connecting rods, power supply boxes, vehicular crankshafts, batteries, engine blocks, switches, head lamp bulbs, break lights, and other components may contain chromium, nickel, titanium, and copper (Kalpakjian and Schmidt, 2006), so when vehicles are abandoned over long periods of time these heavy metals are released. Car paint dust contains cadmium, chromium and nickel which are released into the environment during scraping off of old paint from a vehicle before repainting (Nduka. *et al.*, 2019).

Solid waste is improperly managed in Nigeria; indiscriminate disposal of solid wastes such as electronic/communication and domestic waste can contaminate the soil with heavy metals.

Though there has been research done on assessments of heavy metals in rice grown in some parts of Nigeria, there is still limited information as the work done does not cover most of the locally produced rice in Nigerian market. Determining the level of heavy metals in various rice samples of different rice companies from different parts of the country will help to provide better information on the heavy metal content of rice grown in Nigeria, and its health implication on the entire populace. In addition, the result of the study can help arouse interest in the wider research community on assessing heavy metals in rice grown in other rice producing nations, and its health risk, so as to ensure food safety while talking about food security.

This study is aimed at determining the concentration of heavy metals (Cd, Cr, As, Ni, Hg, Pb, Co, and Cu) in rice grown, processed, and package in Nigeria and health risk assessments of these heavy metals in the rice samples. The study can yield results that can help relevant authorities

form baseline information on policy formulation, monitoring and control to safeguard public health.

## **MATERIALS AND METHODS**

### **Standard and Reagents**

The following reagents were used in the study; Ultrapure HNO<sub>3</sub> and HCl from Merck, Darmstadt, Germany, Accustandard QCSTD – 27 multi – element stock standard solution (New Haven, USA), deionized water and ultrapure Merck LichCrosov water from Merck, Darmstadt, Germany. All standards and reagents were stored according to manufacturer's recommendation until use.

### **Sample Collection**

Nine (9) rice brands grown, processed and packaged in Nigeria by different rice processing and packaging industries located in different regions of the country, commonly sold and eaten in Nigeria were purchased in January, 2020 from Mpape and Wuse markets both located in the Federal Capital Territory (FCT), Abuja, Nigeria. The samples were stored in properly labelled polyethene bags and taken immediately to the laboratory, sieved through a ThermoFisher scientific sieve of 100 mesh to remove impurities and stored again in well labelled polyethene bags prior to analysis. The samples are limited to nine (9) brands because the number of rice processing and packaging industries are few presently.

### **Sample Preparation**

Each rice sample was ground using an electric milling machine and sieved through a 0.5 mm ThermoFisher scientific sieve. 2 g of sieved rice sample of particle size less than 0.5 mm (< 0.5 mm) was weighed into a beaker and 15 ml mixture of freshly prepared HNO<sub>3</sub> and HCl (aqua regia) in a ratio of 1.3 was added to the sample and heated on a hot plate inside a fume cupboard at a temperature of 110°C until volume reduced to about 2 ml. The mixture was allowed to cool and filtered through a Whatman 110 mm filter paper into a beaker and transferred into a 50 ml standard volumetric flask and made to mark with deionized water. The digest was analyzed

for heavy metals (Cd, Cr, As, Co, Hg, Pb, Ni, and Cu) at the respective wavelengths of the metals and limits of detection (0.0001 mg/L, 0.0004 mg/L, 0.003 mg/L, 0.0004 mg/L, 0.00006 mg/L, 0.001 mg/L, 0.0005 mg/L, and 0.0008 mg/L, respectively) and limits of quantification mg/kg (3 x LOD of each metal)) using inductively coupled plasma - optical emission spectrometry (ICP-OES) Agilent 720 ICP-OES (Agilent Technology, Inc, USA).

The samples were introduced into the ICP – OES machine using Agilent SPS3 autosampler. Reagent blanks were analyzed with each batch of samples to ensure reliability of the results. Calibration and quality control (QC) solutions were prepared from AccuStandard QCSTD-27 multi-element solution. Ultrapure Merck Lichrosolv water was used for dilution of standards and quality control (QC) solutions. These were also stabilized in high purity 2% v/v concentrated nitric acid (HNO<sub>3</sub>). The linearity of the calibration curves of the heavy metals was evaluated by determining the coefficient of correlation (r<sup>2</sup>). The analysis was performed in triplicate n equals 3 and results presented as mean ± standard deviation. The accuracy of determinations was verified by spiking samples with 0.4 mg/L of the standard solutions of the metals prior to digestion; both samples for accuracy determination and the test samples were subjected to the same analytical conditions. The percentage recovery was obtained from the equation:

% Recovery =

$$\frac{\text{Concentration of the spiked sample} - \text{Concentration of un-spiked sample}}{\text{Actual spike concentration}} \quad (1)$$

The percentage recoveries ranged from 91% to 107%.

## HUMAN HEALTH RISK ASSESSMENT

### Estimation of Daily Heavy Metal Intake

The health risk posed to consumers of the rice samples was determined by dietary intake of heavy metals and compared with their established acceptable daily intake (ADI, mg/kg bw)). The estimated daily intake (EDI, mg/kg/day)) of heavy metals through the rice consumption was

calculated by using the equation given below (USEPA, 2000):

$$EDI = \frac{C_R \times IR}{BW} \quad (2)$$

Where, C<sub>R</sub> is the average concentration of heavy metals in the rice samples (mg/kg), and IR is the daily rice consumption rate.

The daily ingestion of cereals for children is 190 g/day (0.19 kg/day) and 409.7 g/day (0.4097 kg/day) for an adult Nigerian (WHO, 2017), while the average body weight BW for an adult Nigerian used in this study is 63 kg (Kelle, *et al.*, 2020) and 16.7 kg for children as suggested by USEPA.

### Non – Carcinogenic Risk

Non – carcinogenic risks for individual heavy metal in rice samples were evaluated by computing the hazard quotient using the following equation: (USEPA, 2014; Gerba, 2019).

$$HQ = \frac{EDI}{RfD} \quad (3)$$

Where *RfD* is the oral reference dose (mg/kg/day) which is an estimation of the maximum permissible risk on human population through daily exposure, taking into consideration a sensitive group that is likely to be without an appreciable risk of deleterious (non-cancer) effects during lifetime.

Non-cancer risks are expressed in terms of a hazard quotient (HQ) for a single substance, or hazard index (HI) for multiple substances (Gerba, 2019) that affect the same target organ or organ system (USEPA, 2005). HQ < 1 indicates no significant risk or systematic toxicity, HQ > 1 could represent a potential risk (Gerba, 2019).

To evaluate the potential risk to human health through more than one heavy metal, the hazard index was calculated. Hazard index (HI) is the sum of all hazard quotients (HQ) calculated for individual heavy metal for a particular exposure pathway.

$$HI = \sum HQ \quad (4)$$

It is assumed that the magnitude of the effect is proportional to the sum of the multiple heavy metals and that the heavy metals affect the same

target organ or organ system. The population is assumed to be safe when  $HI < 1$ , chronic risks may happen if  $HI > 1$  (USEPA, 2014; Gerba, 2019; USEPA, 2005).

### **Carcinogenic Risk**

The possibility of developing cancer through intake of carcinogenic heavy metals in the rice samples was estimated using the Incremental Lifetime Cancer Risk (ILCR) equation (USEPA, 2014; Gerba, 2019):

$$ILCR = CDI \times CSF \quad (5)$$

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, CSF is 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.

$$CDI = \frac{EDI \cdot EF \cdot ED}{AT} \quad (6)$$

Where, EF is exposure frequency (days/ year), according to USEPA 365 days/year, ED is exposure duration (years), 70 years (American adult) for carcinogenic (Gerba, 2019; USEPA, 2005). According to World Bank the life expectancy of an adult Nigerian is 54 years (World Bank, 2018). AT is average time – the period over which exposure is averaged (days); for carcinogens the average time is 25,550 days (365 days/year x 70 years) based on a lifetime exposure of 70 years, for the Nigerian people is 365days/year x 54 years.

Cancer risk of  $1 \times 10^{-4}$  to  $1 \times 10^{-6}$  are considered acceptable (USEPA, 2014). Cancer risk of  $1 \times 10^{-4}$  and  $1 \times 10^{-6}$  indicates a probability of 1 in 10,000 individuals and 1 in 1,000,000 individuals developing cancer during a lifetime.

Estimation of cancer risk was computed for only those heavy metals with evidence of probability or possibility of causing cancer.

## **RESULTS AND DISCUSSION**

The concentration of heavy metals in the rice samples is presented in Table 1. Abbreviations of

the name of the rice samples are presented in Table 1 alongside the name of the rice samples and would be used throughout this section.

The concentration of cadmium ranged from 0.0682 to 0.1414 mg/kg, while chromium ranged from 0.0996 to 0.1875 mg/kg and arsenic 0.006 to 0.0841 mg/kg. Nickel, lead, copper, and mercury ranged from 0.1646 to 0.2959 mg/kg, 0.0068 to 0.0394 mg/kg, 0.2437 to 0.4099 mg/kg and 0.0017 to 0.0083 mg/kg respectively. Cobalt was not detected at 0.001 mg/kg detection limit ( $< 0.001$  mg/kg) in all the rice samples.

Rice sample with highest cadmium concentration is TB while UC had the least cadmium content. The concentrations of cadmium in all the rice samples are below the maximum permissible level (MPL) of the Food and Agricultural Organization/ World Health Organization (FAO/WHO, 2017) for cadmium in polished rice which is 0.4 mg/kg.

The level of chromium was highest in BB and lowest in ER. There are no set standard for chromium by international bodies, national standards for food safety limits of contaminants in foods for China was used to compare chromium level in the rice samples. The concentrations of chromium in all rice samples are below the maximum permissible level (MPL) of the National Standards of the People's Republic of China GB 2762 – 2017 for chromium (1.0 mg/kg) in grains and brown rice (NSPRC, 2012).

UC had the highest concentration of arsenic and AW the least. The concentrations of arsenic in the rice samples are below the MPL of FAO/WHO and National Standards of the People's Republic of China GB 2762 – 2017 for arsenic (0.2 mg/kg).

There are no set standards for concentration of nickel in polished, paddy or brown rice by international regulatory bodies. The maximum permissible level (MPL) of nickel in hydrogenated vegetable oils and hydrogenated vegetable-based products (1.0 mg/kg) of FAO/WHO was used to compare the nickel concentrations in the rice samples. The concentrations of nickel in the various rice samples are below the aforementioned permissible level.

**Table 1: Heavy Metal Levels in Rice Samples.**

S/N	Rice	Rice ID	Heavy metals (mg/kg)							
			Cd	Cr	As	Ni	Pb	Cu	Co	Hg
1	Ebony rice	ER	0.1358 ± 0.015	0.1875 ± 0.009	0.0333 ± 0.05	0.2959 ± 0.007	0.0384 ± 0.003	0.3748 ± 0.001	BDL	0.0075 ± 0.002
2	Big big	BB	0.0936 ± 0.012	0.0996 ± 0.001	0.0101 ± 0.003	0.1669 ± 0.003	0.021 ± 0.015	0.3197 ± 0.0006	BDL	0.007 ± 0.002
3	Fursa crown	FC	0.1247 ± 0.0016	0.1058 ± 0.012	0.0166 ± 0.03	0.1697 ± 0.001	0.0295 ± 0.006	0.4099 ± 0.001	BDL	0.018 ± 0.007
4	Ali waibi	AW	0.0889 ± 0.01	0.1330 ± 0.007	0.006 ± 0.06	0.1711 ± 0.001	0.0102 ± 0.006	0.2437 ± 0.001	BDL	0.0077 ± 0.05
5	Three brothers	TB	0.1414 ± 0.05	0.1533 ± 0.001	0.0698 ± 0.04	0.207 ± 0.002	0.0394 ± 0.006	0.3165 ± 0.003	BDL	0.0083 ± 0.006
6	Mama pride	MP	0.1302 ± 0.005	0.1272 ± 0.008	0.0783 ± 0.053	0.1853 ± 0.003	0.0134 ± 0.012	0.3372 ± 0.038	BDL	0.0058 ± 0.002
7	Lake rice	LR	0.0864 ± 0.005	0.1223 ± 0.004	0.0272 ± 0.05	0.1684 ± 0.003	0.0299 ± 0.003	0.2396 ± 0.018	BDL	0.0038 ± 0.002
8	Mama choice	MC	0.1135 ± 0.016	0.1281 ± 0.002	0.0506 ± 0.12	0.1852 ± 0.002	0.0376 ± 0.005	0.2556 ± 0.003	BDL	0.0064 ± 0.002
9	Umza Classic	UC	0.0682 ± 0.013	0.1080 ± 0.06	0.0841 ± 0.04	0.1646 ± 0.002	0.0068 ± 0.01	0.2846 ± 0.011	BDL	0.0017 ± 0.0007

Mean ± standard deviation.

Lead concentration was highest in TB rice and lowest in UC rice. FAO/WHO and National Standards of the People's Republic of China GB 2762 – 2017 maximum permissible limit for lead in cereals, grains and grain products is 0.2 mg/kg, all the rice samples had lead concentration below this limit.

FC and TB rice had the highest concentrations of copper and mercury while LR and UC had the least concentrations of copper and mercury, respectively. The concentrations of copper and mercury in all the rice samples are below the maximum permissible limit of 10 mg/kg and 0.002 mg/kg for copper and mercury in rice by National Standards of the People's Republic of China GB 2762 – 2017.

Maximum permissible level (MPL) is the level, usually a combination of time and concentration beyond which any exposure of humans to a chemical or physical agent in their immediate environment is unsafe (IUPAC Compendium, 1997). Since the concentrations of the heavy metals in all the rice samples are below their maximum permissible levels it indicates that they are not contaminated with these heavy metals and are safe for consumption.

Table 2a and 2b shows the estimated daily intake (EDI) mg/kg/day of Cd, Cr, As, Ni, Pb, Cu, and Hg through consumption of the rice samples for adult

and child population of Nigeria. The estimated daily intake (EDI) of cadmium through consumption of the rice samples for the adult population range from 0.00044 to 0.00092 mg/kg/day, 0.00065 to 0.0012 mg/kg/day, 0.000039 to 0.00055 mg/kg/day, 0.0011 to 0.002 mg/kg/day, 0.000044 to 0.00026 mg/kg/day, 0.0016 to 0.0027 mg/kg/day and 0.000011 to 0.00012 mg/kg/day for the respective metals.

For the child population it ranged from 0.00098 to 0.0016 mg/kg/day, 0.0011 to 0.0021 mg/kg/day, 0.000068 to 0.00096 mg/kg/day, 0.0019 to 0.0073 mg/kg/day, 0.000077 to 0.00094 mg/kg/day, 0.0027 to 0.0047 mg/kg/day and 0.000019 to 0.0002 mg/kg/day for the metals, respectively.

The acceptable daily intake (ADI) mg/kgBW of cadmium 0.00083 mg/kgBW/ derived from the provisional tolerable monthly intake of 25 µg/kgBW/month for cadmium, that is 0.83 µg/kgBW/day when calculated for a daily basis (FAO/WHO, 2011) is higher than the estimated daily intake (EDI) of cadmium through consumption of the rice samples except the estimated daily intake of cadmium through TB (0.00092 mg/kg), ER (0.00088 mg/kg), and MP (0.00085 mg/kg) rice samples for the adult population which is slightly above the acceptable daily intake (ADI) for cadmium in food substances.

**Table 2a: EDI of Heavy Metals through Consumption of Rice (mg/kg/day) for Adult Population.**

S/N	Rice	Cd	Cr	As	Ni	Pb	Cu	Hg
1	Ebony rice	0.00088	0.0012	0.00022	0.002	0.00025	0.0024	0.000049
2	Big bull	0.00061	0.00065	0.000066	0.0011	0.00014	0.0021	0.000046
3	Fursa crown	0.00081	0.00069	0.00011	0.0011	0.00019	0.0027	0.00012
4	Ali waibi	0.00058	0.00086	0.000039	0.0011	0.000066	0.0016	0.00005
5	Three brothers	0.00092	0.001	0.00045	0.0013	0.00026	0.0021	0.000054
6	Mama pride	0.00085	0.00083	0.00051	0.0012	0.000087	0.0022	0.000038
7	Lake rice	0.00056	0.0008	0.00018	0.0011	0.00019	0.0016	0.000025
8	Mama choice	0.00074	0.00083	0.00033	0.0012	0.00024	0.0017	0.000042
9	Umza classic	0.00044	0.00070	0.00055	0.0011	0.000044	0.0019	0.000011

**Table 2b: EDI of Heavy Metals through Consumption of Rice (mg/kg/day) for Child Population.**

S/N	Rice	Cd	Cr	As	Ni	Pb	Cu	Hg
1	Ebony rice	0.0015	0.0021	0.00038	0.0073	0.00094	0.0043	0.000085
2	Big bull	0.0011	0.0011	0.00012	0.0019	0.00024	0.0036	0.00008
3	Fursa crown	0.0014	0.0012	0.00019	0.0019	0.00034	0.0047	0.00002
4	Ali waibi	0.0010	0.0015	0.000068	0.0019	0.00012	0.0028	0.000088
5	Three brothers	0.0016	0.0017	0.00079	0.0024	0.00045	0.0036	0.000094
6	Mama pride	0.0015	0.0014	0.00089	0.0021	0.00015	0.0038	0.000066
7	Lake rice	0.00098	0.0014	0.00031	0.0019	0.00034	0.0027	0.000043
8	Mama choice	0.0013	0.0015	0.00058	0.0021	0.00043	0.0029	0.000073
9	Umza	0.00078	0.0012	0.00096	0.0019	0.000077	0.0032	0.000019

For the child population, the EDI of cadmium through consumption of the rice samples are higher than the acceptable daily intake (ADI) of cadmium. Acceptable daily intake (ADI) mg/kgBW is the maximum amount of a chemical that can be ingested daily over a lifetime with no appreciable health risks and is based on the highest intake that does not give rise to observable adverse effects. The rice samples with estimated daily intake of cadmium above the acceptable daily intake of cadmium in food substances, for both adult and children population implies that there may be possibility of adverse health effect over a lifetime due to ingestion of high levels of cadmium in rice samples.

High cadmium content caused adverse health effect to consumers of unpolished rice contaminated with high levels of cadmium  $\geq 0.3$  mg in Japan in the 1950s (Fowler *et al*, 2015). The consumers came down with itai – itai disease, a disease associated with osteoporosis, and osteomalacia. Cadmium affects the kidney, the skeletal system and the respiratory system, causing renal dysfunction, osteoporosis, and is classified as a human carcinogen (WHO, 2010; Fowler *et al*, 2015).

Exposure to toxic chemicals during growth and development can lead to acute long-term effects on the health of children. They are more at risk of adverse health effect from exposure to toxic chemicals in food, because, as their bodies are

developing they consume more food on a body weight basis than adults; resulting to greater exposure and more harm health wise than in adults (ENHIS, 2007). Also, developing organs and tissue are more susceptible to the toxic effects of certain chemicals, for instance, exposure to lead or methyl mercury during gestation or early childhood will cause serious damage to the developing brain with consequent loss of intellectual potential while an adult experiencing the same exposure will suffer no considerable effects to his/her intellectual capacity (ENHIS, 2007).

The EDI of cadmium through consumption of rice samples is greater than the ADI of cadmium in food substances for the children population compared to the adult population with EDI of cadmium below ADI of cadmium in food substances despite exposure to the same concentration of cadmium. This is so because of the lesser body weight of children. The estimated daily intake of cadmium in TB,ER and MP rice samples are slightly above the acceptable daily intake for cadmium in food substances because, the concentration of cadmium in these rice samples are slightly more than that of the other rice samples (Tables 2).

Though the comparison of the concentration of cadmium in TB, ER and MP rice samples with the maximum permissible level of cadmium in rice shows that the concentration of cadmium is

within safety limit in the rice samples, whereas, the estimated daily intake of cadmium in TB, ER and MP rice samples compared with the acceptable daily intake of cadmium in food samples indicates possibility of cadmium in these rice samples causing adverse effect. This is attributed to the slightly higher concentration of cadmium in these rice samples to the body weight of an adult Nigeria.

The ADI mg/kgBW of arsenic is 0.0021 mg/kgBW based on provisional weekly tolerable intake (PTWI) of 15 µg/kg/week i.e 2.1 µg/kgBW/day, while that of lead is 0.00357 mg/kgBW (25 µg/kgBW/week i.e 3.57 µg/kgBW/day) and mercury 0.00057 mg/kgBW (4 µg/kgBW/week i.e., 0.57 µg/kgBW/day) (FAO/WHO, 2011).

The EDI of As, Pb and Hg in all the rice samples are below their established ADI for both the adult and children population. Currently there is no standard value for oral daily intake of chromium through food by WHO or FAO, adequate intakes (AI) derived by US Food and Nutrition Board for Cr 0.035 mg/day (35 µg/day) and 0.025 mg/kg (25 µg/day) for different age groups from 19 to 50

years old men and women was used to compare the EDI of Chromium through the rice samples (FBN, 2001).

The EDI of Cr through consumption of the rice samples are lower than the adequate intake values of Cr for both adult and child population.

The EDI of Ni and Cu are lower than established oral daily intake of Ni and Cu through food which are Ni < 300 µg/kg, i.e., < 0.3 mg/kg (WHO, 2000) and Cu 0.5 mg/kg bw per day (FAO/WHO, 1982). EDI of As, Pb, Hg, Cr, Cu. and Hg suggests that there may be no adverse health effects based on intake of these metals, except rice samples with high cadmium content. Ihedioha, *et al.* (2016) reported EDI of Pb and Cd from rice grown on fields in one of the states in south eastern Nigeria being above safety levels established by WHO and JECFA, respectively.

The result of the hazard quotient (HQ) and hazard index (HI) of Cd, Cr, As, Ni, Pb, Cu, and Hg for the adult and child populations through intake of rice samples is presented in Table 3a and 3b.

**Table 3a:** Hazard Quotient (HQ) and Hazard Index (HI) of Heavy Metals for Adult Population through Consumption of Rice.

S/N	Rice	HQ							HI = $\sum HQ$
		Cd	Cr	As	Ni	Pb	Cu	Hg	
1	Ebony rice	0.29	0.40	0.73	0.09	0.18	0.06	0.49	2.2
2	Big bull	0.20	0.22	0.22	0.05	0.09	0.05	0.46	1.3
3	Fursa crown	0.27	0.23	0.36	0.06	0.13	0.07	0.20	1.3
4	Ali waibi	0.19	0.28	0.13	0.05	0.04	0.04	0.50	1.2
5	Three brothers	0.31	0.33	1.50	0.06	0.18	0.05	0.54	3.0
6	Lake rice	0.18	0.26	0.60	0.05	0.13	0.04	0.25	1.5
7	Mama choice	0.25	0.27	1.10	0.06	0.16	0.04	0.42	2.3
8	Umza classic rice	0.14	0.23	1.83	0.05	0.03	0.48	0.11	2.8
9	Mama pride	0.28	0.27	1.70	0.06	0.06	0.05	0.38	2.8

RfD = Cd (0.001); Cr (0.003); As; (0.0003); Ni (0.02); As (0.0003); Hg (0.0001); Pb (0.00143); Cu (0.04)

**Table 3b:** Hazard Quotient (HQ) and Hazard Index (HI) of Heavy Metals for Child Population through Consumption of Rice.

S/N	Rice	HQ							HI = $\sum HQ$
		Cd	Cr	As	Ni	Pb	Cu	Hg	
1	Ebony rice	0.51	0.70	1.27	0.36	0.66	0.11	0.85	4.46
2	Big bull	0.38	0.38	0.38	0.09	0.17	0.09	0.80	2.30
3	Fursa crown	0.48	0.40	0.63	0.09	0.24	0.12	2.00	3.96
4	Ali waibi	0.33	0.50	0.22	0.09	0.08	0.07	0.88	2.17
5	Three brothers	0.53	0.58	2.63	0.12	0.32	0.09	0.94	5.21
6	Lake rice	0.33	0.48	1.03	0.09	0.24	0.06	0.43	2.66
7	Mama choice	0.43	0.50	1.93	0.11	0.30	0.07	0.73	4.07
8	Umza classic rice	0.26	0.40	3.20	0.09	0.05	0.08	0.19	4.27
9	Mama pride	0.50	0.48	2.96	0.11	0.10	0.09	0.66	4.90

RfD = Cd (0.001); Cr (0.003); As; (0.0003); Ni (0.02); As (0.0003); Hg (0.0001); Pb (0.00143); Cu (0.04)



**Table 4:** Incremental Lifetime Cancer Risk (ILCR) for Adult Population through Consumption of Rice.

S/N	Rice	ILCR					Σ ILCR
		Cd	Cr	As	Ni	Pb	
1	Ebony rice	3E-4	6E-4	3E-4	2E-4	2E-6	1E-3
2	Big bull	2E-4	3E-4	10E-6	1E-3	1E-6	1.5E-3
3	Fursa crown	3E-4	3E-4	2E-4	1E-3	1E-6	1.8E-3
4	Ali waibi	2E-4	4E-4	6E-5	1E-3	5E-7	1.6E-3
5	Three brothers	3E-4	5E-4	7E-4	1E-3	2E-5	2.5E-3
6	Lake rice	2E-4	4E-4	3E-4	1E-3	2E-6	1.9E-3
7	Mama choice	3E-4	4E-4	5E-4	1E-3	2E-6	2.2E-3
8	Umza classic rice	2E-4	4E-4	8E-4	9E-4	4E-7	2.3E-3
9	Mama pride	3E-4	4E-4	7E-4	1E-3	7E-7	2.4E-3

The hazard quotient (HQ) values are less than one for Cd, Cr, Ni, Pb, Cu, Hg, and As for both the adult and children population of Nigeria except for TB, MC, UC, and MP rice samples that has HQ of arsenic greater than one for the adult population and EB, TB, LR, MC, UC, and MP rice samples with HQ greater than one for arsenic for the children's population. This suggests probability of potential risk from arsenic in rice samples. Arsenic is associated with integumentary, nervous, respiratory, cardiovascular, hematopoietic, immune, endocrine, hepatic, renal, reproductive system and development health issues. The hazard index (HI) from the intake of the heavy metals is greater than one for both the adult and children population indicating probability of chronic health effects in both populations. Previous studies on some rice samples obtained from some regions of Nigeria indicated HQ and HI values in excess of one (Ihedioha *et al*, 2019; Ihedioha *et al*, 2016).

Table 4 presents the result of the incremental lifetime cancer risk (ILCR) of Cd, Cr, As, Ni, and Pb which are the carcinogenic metals among the other metals. These values ranges from 2E – 4 to 3E – 4, 3E – 4 to 6E-4, 10E –6 to 8E – 4, 2E -4 to 1E – 3, and 5E – 7 to 2E – 5 for Cd, Cr, As, Ni, and Pb, respectively, and are greater than the recommended acceptable limit of  $1 \times 10^{-4}$  (1E - 4) to  $1 \times 10^{-6}$  (1E- 6) of USEPA (USEPA, 2014), except for incremental lifetime cancer risk (ILCR) value for As in BB and AW rice samples as well as for Pb in all the rice samples.

ILCR values for Cd, Cr, Ni, and As indicates probability of developing cancer during a lifetime in Nigeria population through intake of the metals in the rice samples. The cumulative cancer risk (ΣILCR) of all the rice samples exceeded the recommended threshold risk limit (>10<sup>-4</sup>).

## CONCLUSION

The concentration of each heavy metal in rice samples studied is below international standards for maximum permissible limit (MPL). Some estimated daily intake (EDI) of heavy metals through rice sample consumption are above established international acceptable daily intake (ADI) standards for adults. Hazard quotient (HQ) for each metal in rice samples is less than one for both adult and child populations, except HQ of arsenic in some rice samples. Hazard indices (HI) of heavy metals in rice samples are greater than one and incremental lifetime cancer risk (ILCR) value for each carcinogenic metal in rice samples is greater than safe limit for cancer risk, except Pb in the rice samples.

While rice samples may not present adverse health effect in adult populations with the daily consumption of rice samples except from those rice samples with high cadmium, the possibility exists of adverse health effects in children due to high cadmium intake. There may be a probability of potential health risks through consumption of some of the rice samples for both adult and children population due mainly to arsenic. Consumption of the heavy metals combined in the rice samples may lead to chronic health effects and, probability of cancer risk exists from carcinogenic heavy metals except Pb.

As a way of reducing heavy metal levels in rice grown in Nigeria, gas flaring should be reduced, proper disposal of waste by industries and households should be designed and implemented by the relevant authorities, reduction of oil spill is recommended and rice farmlands contaminated with heavy metals should be remediated by employing techniques such as phytoremediation of heavy metals as

part of the cycle of rice farming, soil washing and immobilization techniques (*in situ* and *ex situ* immobilization techniques), etc.

## AUTHOR STATEMENTS

Henrietta Ijeoma Kelle conceived and designed this work. Henrietta Ijeoma Kelle, Emeka Chima Ogoko, Daniel Achem, Ifeoma Prisca Udeozo, and John Otumala carried out the laboratory work. Ifeoma Udeozo and John Otumala sourced the literature. Henrietta Ijeoma Kelle and Daniel Achem performed the calculations presented in this paper. Emeka Chima Ogoko reviewed the entire manuscript. All the authors approved the final article and all of the authors contributed financially to this work.

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## DECLARATION OF COMPETING INTEREST

The authors declare no conflicts of interest related to this research.

## REFERENCES

1. Abdul-Hamid, A., R.R.R. Sulaiman, and O.N. Saari. 2007. "Preliminary Study of The Chemical Composition of Rice Milling Fractions Stabilized By Microwave Heating". *Journal of Food Composition and Analysis*. 20: 627-637.
2. Agency for Toxic Substances and Disease Registry (ATSDR). 2009. "Arsenic Toxicity".
3. Alani, R., D. Nwude, A. Joseph, and O. Akinrinnade. 2020. "Impact of Gas Flaring on Surface and Underground Water: A Case Study of Anieze and Okwuiborne Areas of Delta State, Nigeria". *Environmental Monitoring Assessment*. 192: 166.
4. Awika, J.M. 2011. "Major Cereal Grains Production and Use Around the World". In: *Advances In Cereal Science: Implication To Food Processing and Health Promotion*. ACS Symposium Series. 1089:1 – 13.

5. Beyersmann, D., and A. Hartwig. 2008. "Carcinogenic Metal Compounds: Recent Insight into Molecular and Cellular Mechanisms". *Archives of Toxicology*. 82: 493–512.
6. Chang, L.W., L. Magos, and T. Suzuki. 1996. *Toxicology of Metals. 1st Edition*. CRC Press: Boca Raton, FL.
7. Chen Q.Y., J. Brocato, F. Laulicht, and M. Costa. 2017. "Mechanisms of Nickel Carcinogenesis". In: A. Mudipalli and J.T. Zelikoff. *Essential and Non-Essential metals. 1ST Edition*. Springer International Publishing: New York, NY.
8. Chi, Y., P. Li, N.F. Tam, C. Liu, Y. Ouyang, X. Qi, W.C. Li, and Z. Ye. 2018. "Variation in Grain Cadmium and Arsenic Concentrations and Screening for Stable Low-Accumulating Rice Cultivars from Multienvironment Trials". *Science of the Total Environment*. 643: 1314 -1324.
9. Deng, Y., M. Wang, T. Tian, S. Lin, P. Xu, L. Zhou, C., Dai, Q. Hao, Q. Wu, Y. Zhai, Y. Zhu, G. Zhuang, and Z. Dai. 2019. "The Effect of Hexavalent Chromium on the Incidence and Mortality of Human Cancers: A Metal-Analysis Based on Published Epidemiological Cohort Studies". *Frontier in Oncology*. 9: 24.
10. Devolder, P.S., S.L. Brown, D. Hesterberg, and K. Pandya. 2003. "Metal Bioavailability and Speciation in a Wetland Tailings Repository Amended with Biosolids Compost, Wood Ash, and Sulfate". *Journal of Environmental Quality*. 32: 851–864.
11. European Environment and Health Information System (ENHIS). 2007. "Exposure of Children to Chemical Hazards in Food", Fact Sheet No. 44.
12. FAO. 2019. "FAO in Nigeria: Nigeria at a Glance". available online: <http://www.fao.org/nigeria/fao-in-nigeria/nigeria-at-a-glance/en/>. Accessed 15th April, 2020.
13. FAO/WHO. 1982. "Evaluations of the Joint FAO/WHO Committee on Food Additives (JECFA)". Twenty - six meeting of the joint FAO/WHO Expert committee on food additives. FAO: Rome, Italy.
14. FAO/WHO Food Standards Programme. 2017. "CODEX Committee on Contaminant in Foods". Eleventh Session. Rio de Janeiro, Brazil.
15. FAO/WHO Food Standards Programme. 2011. "CODEX Committee on Contaminants in Foods". Fifth Session. The Hague, The Netherlands. 21 - 25 March.

16. FAO/WHO. 2018. "Small Family Farms Country Factsheet". FAO: Rome, Italy.
17. Food and Nutrition Board (FNB). 2001. Institute of Medicine, National Academy of Sciences. "Dietary Reference Intakes: Vitamin A, Vitamin K, Arsenic, Boron, Chromium, 15 Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium and Zinc". National Academy Press: Washington D.C. Appendix C table C 14, pp 620.
18. Fowler, B.A., J. Alexander, and A. Oskersson. 2015. "Toxic Metals in Food". In: G.F. Nordberg, B.A. Fowler, and M. Nordberg. *Handbook of the Toxicology of Metals. 4th Edition*. Academic Press Elsevier: Amsterdam, The Netherlands.
19. Gerba, C.P. 2019. "Risk Assessment". In: M.L. Brusseau, I.L. Pepper, and C.P. Gerba. *Environmental and Pollution Science. 3rd Edition*. Elsevier Inc.: Amsterdam, The Netherlands.
20. Ihedioha, J.N., O.T. Ujam, N. Nwuche, and C. Chime. 2016. "Assessment of Heavy Metal Contamination of Rice Grains (*Oryza sativa*) and Soil from Ada field, Enugu, Nigeria: Estimating the Human Health Risk". *Human and Ecological Risk Assessment: An International Journal. 22*: 1665 – 1677.
21. IUPAC. 1997. *Compendium of Chemical Terminology 2nd Edition*. Blackwell Scientific Publications: Oxford, UK. <https://doi.org/10.1351/goldbook>.
22. Juliano, B.O., A. Paul, and P. Tuano. "Structure and Composition of the Rice Grain". 2018. In: B. Jinsong. *Rice Chemistry and Technology. 4th Edition*. Elsevier: Amsterdam, The Netherlands.
23. Kalpakjian, S. and S.R. Schmidt. 2006. *Manufacturing Engineering and Technology. 5th Edition*. Prentice Hall: Chicago, IL.
24. Kelle, H.I., E.C. Ogoko, D. Achem, and S.A. Ousherovich. 2020. "Health Risk Assessment of Heavy Metals in Some Rice Brands Imported into Nigeria". *Communication in Physical Science. 5*: 210 – 222.
25. National Standard of the People's Republic of China (NSPRC). 2012. G.B 2762 – 2012. "National Food Safety Standard, maximum levels of contaminants in Food". NSPRC: Beijing, China.
26. Nayar, N.M. 2014. *Origins and Phylogeny of Rice. 1st Edition*. Academic Press Elsevier: Amsterdam, The Netherlands.
27. Nduka, J.K., H.I. Kelle and J.O. Amuka. 2019. "Health Risk Assessment of Cadmium, Chromium and Nickel from Car Paint Fust from Used Automobiles at Auto-Panel Workshops in Nigeria". *Toxicology Report. 6*: 449-456.
28. Odunsi, W. 2018. "FG Reveals Nigeria's Current Population". Daily Post. April, 11. Available online: <https://dailypost.ng/2018/04/11/fg-reveals-nigerias-current-population/>. Accessed 15th March, 2020.
29. Oghenejoboh, K.M. 2005. "The Impact of Acid Rain Deposition Resulting from Natural Gas Flaring on the Socio – Economic Life of the People of Afiesere Community in Nigeria". *Journal of Industrial Pollution Control. 21*: 83 – 90.
30. Oko, A.O., B.E. Ubi, A.A. Efisue, and N. Dambaba. 2012. "Comparative Analysis of the Chemical Nutrient Composition of Selected Local and Newly Introduced Rice Varieties Grown in Ebonyi State of Nigeria". *Journal of Agriculture and Forestry. 2*: 16-23.
31. Rafati, R.M., M.R. Rahimzadeh, S. Kazem, and A.A. Moghadamnia. 2017. "Cadmium Toxicity and Treatment: An Update". *Caspian Journal of Internal Medicine. 8*: 135 – 145.
32. Shi, J.C., X.L. Yu, M.K. Zhang, S.G. Lu, W.H. Wu, J. Wu, and J. Xu. 2011. "Potential Risks of Copper, Zinc, and Cadmium Pollution Due to Pig Manure Application in a Soil- Rice System Under Intensive Farming: A Case Study of Nanhu, China". *Journal of Environmental Quality. 40*: 1695-1704.
33. US Energy Information Administration (USEIA). 2020. "Country Analysis Executive Summary: Nigeria". USEIA: Washington, D.C.
34. US Environmental Protection Agency (USEPA). 2005. "Human Health Risk Assessment Protocol, Chapter 6: Quantifying Exposure". Multimedia Planning and Permitting Division, Office of Solid waste, Center for Combustion Science and Engineering. USEPA: Washington, DC.
35. USEPA. 2014. "Overview of Human Health Risk Assessment". Office of Research and Development". National Center for Environmental Assessment, National Institute of Environmental Health Science Superfund Research Program. USEPA: Washington, DC.
36. USEPA. 2000. "Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures". Risk Assessment Forum Technical Panel [EPA/630/R-00/002]. USEPA: Washington, DC.
37. Wang, S. and X. Shi. 2001. "Molecular Mechanisms of Metal Toxicity and

Carcinogenesis". *Molecular and Cellular Biochemistry*. 222:3–9.

38. WHO. 2017. "Country Assignments to the 13 Proposed GEMS/ Food Consumption Cluster Diets". WHO: Geneva, Switzerland.
39. WHO. 2010. "Exposure to Cadmium: A Major Public Health Concern". Public Health and Environment. WHO: Geneva, Switzerland.
40. WHO/FAO/IAEA. 1996. "Trace Elements in Human Nutrition and Health". WHO: Geneva, Switzerland.
41. WHO 2000. *WHO Air Quality Guidelines for Europe. 2nd Edition*. WHO Regional Publication. European Series. No. 91.
42. World Bank. 2017. "Nigeria's Flaring Reduction Target: 2020". Available at <https://www.worldbank.org/en/news/feature/2017/03/10/nigerias-flaring-reduction-target2020#:~:text=With%20almost%20%20billion%20cubic,Nigerians%20lack%20access%20to%20electricity>. Accessed 24th August, 2020.
43. World Bank. 2018. "The World Bank, Life Expectancy at Birth, Total (years) – Nigeria". Available online: <https://data.worldbank.org/indicator/SP.DYN.LE00.I.N?locations=NG> Accessed 15th April, 2020.
44. Wuana, R.A. and F.E. Okieimen. 2011. "Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation". *International Scholarly Research Network*. doi:10.5402/2011/402647.

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