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Heavy Metal Status and Health Risks Assessment of Some Local Alcoholic and Non-Alcoholic Beverages Consumed in Aba, Nigeria

Emeka Chima Ogoko*, Aletan Uduak I, Osu Charles Ikenna, Henrietta Ijeoma Kelle and Nnamdi Ibezim Ogoko

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Abstract: *The study was carried out to evaluate the levels heavy metals and health risk assessment in some local alcoholic (local gin, palm wine and herbal gin) and non-alcoholic beverages (zobo drink, kunu aya, and smoothies) consumed in Aba, Nigeria. Heavy metal concentrations were determined using atomic absorption spectrophotometer. The concentrations of Cr, Cd and Pb exceeded their respective standard maximum permissible limits. Computed hazard quotient was within safe limit (HQ<1) in all the studied samples, indicating that there were no potential non-carcinogenic health risks associated with consumption of these beverages with respect to Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb. The incremental life cancer risk for Pb were within safe limit while the cancer risks of Cd in children exceeded the safe limit. The incremental life cancer risk for ingestion of Cr through alcoholic and non-alcoholic beverages were higher than the safe limit (<1.0 x 10^{-4}). The unacceptable high values of incremental life cancer risk for Cd and Cr demonstrated high prospect of potential life carcinogenic health risks in Nigerian child and adult population.*

Keywords*: Hazard quotient, hazard index, incremental lifetime cancer risks, heavy metal*

Emeka Chima Ogoko
Department of Chemistry, National Open University of Nigeria, Abuja, Nigeria
Email: eogoko@noun.edu.ng
Orcid id: 0000-0002-0409-4708

Aletan, Uduak Irene
Department of Biological Sciences, National Open University of Nigeria, Abuja, Nigeria
Email: ualetan@noun.edu.ng
Orcid id: 0000-0003-0071-9632

Osu Charles Ikenna
Department of Pure and Chemistry, University of Port Harcourt, Port Harcourt, Nigeria
Email: charsike@yahoo.com
Orcid id: 0000-0003-0256-3299

Henrietta Ijeoma Kelle
Department of Chemistry, National Open University of Nigeria, Abuja, Nigeria
Email: hkelle@noun.edu.ng
Orcid id: 0000-0003-3701-4652

Nnamdi Ibezim Ogoko
Department of Biological Sciences, Federal University of Technology, Minna, Nigeria
Email: ogokonnamdiibe@gmail.com

1.0 Introduction

The consumption of alcoholic beverages such as palm wine and local gin is widespread in various cultures, including Nigeria. These beverages are traditionally prepared and consumed during social and ceremonial occasions (Etim, *et al*., 2018). Palm wine is a popular fermented drink tapped from the sap of various palm trees, while local gin, also known as "ogogoro" or "kai-kai," is a distilled spirit derived from palm wine (Okeke & Nwaogazie, 2019). Quality and acceptability of these beverages can be significantly affected by their metal content, as certain heavy metals pose serious health risks (Dada & Ojoawo, 2017). The heavy metals include zinc (Zn), cobalt (Co), lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), and iron (Fe), each playing different roles in environmental and biological contexts (Abiola & Adegoke, 2016; Eddy *et* al., 2024; Ogoko & Donald, 2018; Okwunodulu & Eddy, 2014; Omada *et al*., 2024a; Osu & Ogoko, 2014;).

Exposure to heavy metals such as copper and iron in excessive amounts can lead to various health issues, including oxidative stress, which is linked to a range of chronic diseases (Valko, Morris, & Cronin, 2005; Gaetke & Chow, 2003; Nduka *et. al.*, 2020). Lead toxicity is particularly concerning, as it can affect almost every organ and system in the human body, especially the nervous system (Needleman, 2004). Similarly, cadmium and chromium are known carcinogens, adding to the potential health risks associated with their presence in beverages (Bernard, 2008; International Agency for Research on Cancer (IARC, 2012).

To assess the safety of these beverages, digestion procedures for non-alcoholic drinks are often employed to prepare samples for heavy metal analysis (Association of Official Analytical Chemists (AOAC, 2017). Methods such as those outlined by the Association of Official Analytical Chemists (AOAC) provide standardized protocols to ensure accurate and reliable results (World Health Organization (WHO, 2017).

The assessment of heavy metal content in beverages involves calculating the Estimated Daily Intake (EDI) and the Hazard Index (HI) based on standard formulas and references (United States Environmental Protection Agency (USEPA, 2014). The average body weight of Nigerian adults is used in these calculations to provide a more accurate risk assessment for the local population (Etim et al., 2018). To ensure the safety of these beverages, it is crucial to compare the obtained heavy metal concentrations with Provisional Tolerable Daily Intake (PTDI) standards set by international bodies such as the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA) (WHO, 2017; USEPA, 2014). Furthermore, HI values less than one are typically considered acceptable, indicating no significant risk of adverse health effects (Nriagu & Pacyna, 1988). By adhering to these standards and utilizing established methods, the quality and safety of palm wine local gin, zobo drink, kunu and smoothies can be monitored, ensuring they remain safe for consumption (WHO, 2017).

2.0 Materials and Methods

2.1 Study area

Aba metropolis is one of the main commercial cities in Abia State located in south eastern Nigeria. Aba metropolis is geolocated within the coordinates of 5°07’ N and 7°22’ E. The city has several large markets, supermarket outfits, vast fertile agricultural lands and small to medium scale industries. Thirty samples of alcoholic and non-alcoholic beverages were procured from supermarket outlets in Aba, and its environs labelled appropriately and stored in refrigerator at 4 ^{o}C prior to analysis.

2.2 Digestion of the samples

Triacid wet digestion procedures was used in the digestion of non-alcoholic drinks for heavy metal analysis. 5 ml of sample was accurately measured into digestive tube and 20 ml of a mixture of HNO_3 + HCl + $HClO_4$ in volume ratio of 3:1:1 was added and transferred into a FOSS TECATOR digester (Model 210) at 250 ^{o}C for 120 minutes in a fume chamber. The digestion process is continued until a clear solution was obtained. The clear solution was then filtered in a 100 ml volumetric flask using Whatman filter paper. The filtrate was made up to the standard volumetric mark by addition of deionized water (AOAC, 2019).

2.3 Heavy metal analysis

Non-alcoholic beverage samples were subjected to laboratory analysis for metals (Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb) according to method described by the Association of Official Analytical Chemists (USEPA, 2014). Heavy metal analysis was performed with the aid of Flame Atomic Absorption Spectrophotometer (AAS) Agilent 280 AA model. The concentrations of Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb were measured at 279.5, 357.9, 228.8, 213.9, 240.7, 324.8, 248.3 and 217 nm respectively. Calibration blanks were used to establish the calibration curve while rinse blanks were used intermittently between samples and standards to flush the Atomic Absorption Spectrophotometer (AAS). Preparation of the blanks were done under the same laboratory preparation procedure as the samples. The AAS instrument was adjusted to automatically recalibrate after each five sets of samples were analysed. Triplicate measurements were done and the mean value of each metal was recorded for enhanced reliability and reproducibility of measurements. All reagents used were of analytical grade. The atomic absorption spectrophotometer was operated under optimal conditions; measurement mode (integrated), Slit with (0.5 nm), gain (57%), lamp current (10.0 mA), flame type (air/acetylene), air flow (13.5 l/min), acetylene flow (2.0 l/min), burner height (13.5mm), measurement time (10.0 seconds), while the detection limit is 0.001 ppm for all the metals analysed.

2.4 Risk assessment

2.4.1 Method of determination of estimated daily intake (EDI)

Estimated daily intake (EDI) of heavy metals for a 64 kg adult was evaluated based on average consumption rate of 300 ml per day. The mean weight of 16.7 kg and average consumption rate of 250 ml per day were used for calculating the EDI for child population. EDI (mg/kg/day) is calculated using the formula in equation 1 (Gibb and O'Leary, 2014; Omada *et al*., 2024b).

$$EDI = \frac{CR}{BW} \text{ x IR} \tag{1}$$

where CR is the metal concentration found in the alcoholic sample, IR is daily consumption rate, BW is the mean body weight of Nigerian adult (NPS, 2010).

2.4.2 Method of determination of hazard quotient (HQ)

Non-carcinogenic health risk of heavy metals was estimated using an index known as the Hazard quotient (HQ). HQ is therefore evaluated using the following the formular in equation 2 (USEPA, 2001).

$$HQ = \frac{EDI}{RfD} \tag{2}$$

where RfD is the oral reference dose (mg/kg/day) which refers to the estimated maximum permissible health risk related to daily human consumption heavy metals ((USEPA, 2014).

2.4.3 Method of determination of hazard index (HI)

The combined effects of two or more heavy metals on the potential human health risk is appropriately described as hazard index (HI). HI is calculated using the following formula in equation 3.

$$\text{HI} = \sum \text{HQ} \tag{3}$$

If HI <1, then no potential health risk, but HI >1 indicates potential chronic health risk (Gibb and O'Leary, 2014; Kelle et al., 2022; Ogoko et al., 2023).

2.4.4 Determination of Incremental lifetime cancer risk

Incremental lifetime cancer risk ($ILCR$) is expressed with the formula in equation 4.

$$ILCR = CDI \times CSF \tag{4}$$

where CDI is the chronic daily intake of carcinogenic chemical substances (mg/kgbw/day), CSF is cancer slope factor. CSF is estimated using the formula in equation 5 (USEPA, 2001).

$$\text{CDI} = \frac{EDI \times EF \times ED}{AT} \tag{5}$$

where EF is the exposure frequency in days/year (365 days per year), ED is exposure duration in years or life expectancy. The life expectancy for adult Nigerians is 54 years (De Miguel, *et al*., 2007). AT is the average time or period of exposure. AT is 365 days per year multiplied by 54 years (19,710 days).

3.0 Results and Discussion

3.1 Heavy metal concentrations

The mean manganese concentration in alcoholic beverages ranged from 0.001±0.001 – 0.091±0.005 mg/l while manganese concentration varied between 0.061±0.010 - 0.312±0.022 mg/l in non-alcoholic beverages. These values were below the base line value (0.50 mg/l) recommended by world health organisation. The concentrations levels of Cr in alcoholic and non-alcoholic beverages ranged from 0.001±0.00 - 0.239±0.050 mg/l and 0.056±0.005- 0.130±0.020 mg/l respectively. Chromium concentrations in 73.34% of alcoholic samples and 100% of non-alcoholic samples exceeded the standard permissible limit of 0.050 mg/l (NSDWQ, 2007; WHO, 2004). This implies that most of the samples were polluted with respect to chromium. The mean concentrations range of Cd in alcoholic and non-alcoholic beverages were 0.001±0.000 - 0.045±0.002 mg/l and 0.002±0.001- 0.024±0.010 mg/l respectively. The permissible limit of 0.003 mg/l was recommended for cadmium in drinking water (NSDWQ, 2007; WHO, 2004). Most of the samples of alcoholic beverages (73.34%) and non-alcoholic beverages (93.3%) were above the standard permissible limit for Cd, indicating potential health risks associated with ingestion of this metal through beverage drinks. The mean concentrations of Zn ranged from 0.003±0.001 - 0.072±0.005 mg/l in alcoholic drinks but varied between 0.010±0.001 - 0.084±0.010 mg/l in non-alcoholic drinks. The zinc content in both alcoholic and non-alcoholic beverages were lower than the standard maximum permissible limit of 3.00 mg/l (NSDWQ, 2007; WHO, 2004). The mean cobalt content in alcoholic and non-alcoholic beverages were 0.004±0.001- 0.075±0.001mg/l and 0.002±0.001 - 0.040±0.012 mg/l respectively. Copper had concentrations which ranged from 0.003±0.001 - 0.115±0.003 mg/l and 0.010±0.001 - 0.097±0.010 mg/l in alcoholic and non-alcoholic beverages respectively. These concentrations of copper were lower than the 2.0 mg/l and 1.0 mg/l maximum permissible limits proposed by world health organisation and Nigeria standard drinking water quality for potable drinking water respectively ((NSDWQ, 2007; WHO, 2004). The mean concentrations range of iron in alcoholic and non-alcoholic beverages were 0.018±0.001 - 1.392±0.045 mg/l and 0.011±0.005 - 0.902±0.040 mg/l respectively. Iron content appeared to be slightly higher in the alcoholic beverages than in the non-alcoholic drinks. Iron contents in 53.4% alcoholic beverages and 46.7% non-alcoholic drinks investigated in the present study were above the recommended standard permissible limits of 0.3 mg/l (NSDWQ, 2007; WHO, 2004). Lead contents ranged from 0.002±0.001 - 0.199±0.041 mg/l and 0.040±0.010 - 0.122±0.020 mg/l alcoholic and non-alcoholic beverages respectively. Lead concentration exceeded the maximum permissible limit in drinking water across almost all the alcoholic and non-alcoholic samples evaluated, indicating possible lead pollution of samples.

The estimated daily intake (EDI) for consumption of alcoholic drinks in adult population are presented in Table 3, while the EDI for ingestion of heavy metals through non-alcoholic beverages in both adult and children population are presented in Tables 4 and 5. In adult population, the estimated daily intake of Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb through alcoholic beverages consumption ranged from 4.69E-06 - 4.27E-04, 4.69E-06 - 1.12E-03, 4.69E-06 - 2.11E-04, 1.41E-05 - 3.38E-04, 1.88E-05 - 3.52E-04, 1.41E-05- 5.39E-04, 8.44E-05-6.53E-03 and 9.38E-06- 9.33E-04 mg/kg/day respectively. In adult population, the estimated daily intake of Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb through non-alcoholic beverages consumption ranged from 2.19E-04 - 5.55E-04, 2.19E-04 - 5.55E-04, 7.81E-06 - 9.38E-05, 3.91E-05 - 3.28E-04, 7.81E-06 - 2.38E-04, 3.91E-05 - 3.79E-04, 4.30E-05 - 3.52E-03 and 3.91E-48 - 4.77E-04 mg/kg/day respectively.

In child population, the estimated daily intake of Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb through non-alcoholic beverages consumption varied from 9.13E-04 - 4.67E-03, 8.38E-04 - 2.13E-03, 2.99E-05 - 3.59E-04, 1.23E-04 - 1.26E-03, 2.99E-05 - 9.13E-04, 1.50E-04 - 1.45E-03, 1.65E-04 - 1.35E-02 and 5.99E-04 - 1.83E-03 mg/kg/day respectively.

Table 1: Mean heavy metal concentrations (mg/l) in locally produced alcoholic drinks sold in Aba

Brand	Categories	Mn (mg/l)	Cr (mg/l)	Cd (mg/l)	Zn (mg/l)	Co (mg/l)	Cu (mg/l)	Fe (mg/l)	Pb (mg/l)
SG1	Local gin	0.003±0.001	0.011±0.001	0.001±0.000	0.009±0.001	0.014±0.005	0.115±0.003	0.462±0.001	0.002±0.001
SG2		0.001±0.000	0.012±0.005	0.001±0.000	0.017±0.002	0.004±0.001	0.074±0.002	0.047±0.002	0.019±0.003
SG3		0.007±0.001	0.001±0.000	0.003±0.001	0.010±0.001	0.032±0.003	0.061±0.005	0.246±0.005	0.009±0.001
SG4		0.002±0.001	0.001±0.001	0.002±0.001	0.018±0.003	0.052±0.001	0.050±0.003	0.038±0.003	0.023±0.001
SG5		0.001±0.000	0.118±0.004	0.007±0.002	0.003±0.001	0.026±0.002	0.051±0.001	0.658±0.001	0.007±0.001
PW1	Local Palm	0.081±0.002	0.208±0.010	0.033±0.003	0.015±0.003	0.013±0.001	0.014±0.001	0.541±0.062	0.128±0.010
PW2	wine	0.074±0.003	0.220±0.030	0.034±0.001	0.012±0.005	0.075±0.001	0.035±0.003	0.018±0.001	0.137±0.040
PW3		0.085±0.004	0.239±0.050	0.036±0.001	0.016±0.002	0.009±0.001	0.040±0.002	1.121±0.039	0.157±0.029
PW4		0.091±0.005	0.171±0.010	0.040±0.002	0.012±0.004	0.017±0.002	0.003±0.001	1.392±0.045	0.127±0.019
PW5		0.084±0.002	0.234±0.009	0.041±0.001	0.024±0.002	0.020±0.001	0.026±0.003	0.501±0.042	0.137±0.021
HPB	Local	0.013±0.001	0.212±0.031	0.040±0.003	0.023±0.001	0.017±0.010	0.042±0.005	0.308±0.025	0.148±0.024
PAB	herbal gin	0.016±0.004	0.203±0.051	0.041±0.001	0.072±0.005	0.020±0.001	0.014±0.001	0.329±0.010	0.171±0.019
SKB		0.001±0.001	0.212±0.020	0.044±0.005	0.017±0.004	0.014±0.001	0.026±0.003	0.528±0.023	0.194±0.050
KAB		0.029±0.003	0.205±0.006	0.043±0.003	0.018±0.001	0.017±0.001	0.010±0.004	0.827±0.013	0.199±0.041
IYB		0.029±0.006	0.144±0.010	0.045±0.002	0.021±0.001	0.020±0.001	0.012±0.002	0.133±0.015	0.178±0.055
	WHO	0.500	0.050	0.003	3.0		2.0	0.30	0.01
	NSDWQ	0.200	0.050	0.003	3.0		1.0	0.30	0.01

Table 2 : Mean heavy metal concentrations in some locally produced non-alcoholic drinks sold in Aba

Brand code	Categories	Mn (mg/l)	Cr (mg/l)	Cd (mg/l)	Zn (mg/l)	Co (mg/l)	Cu (mg/l)	Fe (mg/l)	Pb (mg/l)
ZB1	Zobo drink	0.143±0.010	0.107±0.015	0.020±0.010	0.031±0.006	0.009±0.010	0.042±0.005	0.745±0.015	0.040±0.010
ZB2		0.131±0.005	0.113±0.010	0.010±0.005	0.021±0.005	0.002±0.001	0.097±0.010	0.610±0.010	0.062±0.015
ZB3		0.158±0.012	0.080±0.005	0.015±0.010	0.043±0.010	0.012±0.010	0.013±0.006	0.011±0.005	0.048±0.005
ZB4		0.130±0.001	0.098±0.012	0.021±0.010	0.016±0.004	0.061±0.011	0.052±0.005	0.312±0.012	0.082±0.010
ZB5		0.140±0.020	0.130±0.020	0.013±0.011	0.010±0.001	0.061±0.020	0.010±0.001	0.516±0.020	0.042±0.001
KA1	Kunu aya	0.180±0.012	0.080±0.005	0.024±0.010	0.026±0.005	0.020±0.010	0.065±0.005	0.215±0.050	0.073±0.010
KA2		0.061±0.010	0.091±0.010	0.010±0.005	0.044±0.010	0.032±0.010	0.038±0.011	0.724±0.030	0.050±0.010
KA3		0.150±0.015	0.142±0.030	0.022±0.010	0.063±0.012	0.010±0.006	0.024±0.005	0.515±0.010	0.102±0.050
KA4		0.118±0.030	0.102±0.006	0.017±0.006	0.051±0.010	0.012±0.004	0.048±0.012	0.801±0.050	0.040±0.010
KA5		0.201±0.012	0.109±0.011	0.023±0.010	0.082±0.010	0.040±0.012	0.061±0.010	0.042±0.010	0.092±0.020
FT1	smoothies	0.162±0.010	0.089±0.014	0.019±0.005	0.045±0.005	0.034±0.010	0.052±0.005	0.902±0.040	0.104±0.050
FT2		0.271±0.050	0.090±0.010	0.018±0.005	0.068±0.010	0.012±0.002	0.082±0.010	0.202±0.020	0.081±0.010
FT3		0.312±0.022	0.056±0.005	0.005±0.001	0.081±0.011	0.031±0.014	0.035±0.001	0.081±0.010	0.097±0.006
FT4		0.240±0.010	0.078±0.008	0.008±0.002	0.028±0.009	0.022±0.010	0.062±0.010	0.202±0.030	0.122±0.020
FT5		0.201±0.010	0.120±0.030	0.002±0.001	0.084±0.010	0.010±0.005	0.055±0.005	0.301±0.050	0.102±0.030
	WHO	0.500	0.050	0.003	3.0		2.0	0.30	0.01
	NSDWQ	0.200	0.050	0.003	3.0		1.0	0.30	0.01

In child and adult population, EDI values for Cd, Fe and Pb through consumption of alcoholic drinks and non-alcoholic beverages were below the acceptable provisional tolerable daily intake of 8.30E-04, 8.0E-1 and 3.57E-03 mg/kgbw/day respectively (FAO/WHO, 2001). The proposed provisional tolerable daily intake of copper is 0.5 mg/kgbw/day but there is limited data on proposed provisional tolerable daily intake for Cr, Mn and Zn by standard organisations. Interestingly the estimated daily intake of copper in alcoholic and non-alcoholic beverages investigated were within acceptable limits in both adult and children population (Tables 3 to 4). The values of estimated daily intake in the present study revealed that there are no potential non-carcinogenic health risks associated to oral consumption of alcoholic and non-alcoholic beverages by child and adult population.

3.2 Risk analysis

health risks associated with consumption of the beverage drinks.

3.2.1 Hazard quotient (HQ)

Tables 6 to 8 presents the hazard quotient for consumption of beverages by adult and child population. Calculation of hazard quotients for Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb was done using 0.14, 0.003, 0.001, 0.3, 0.02, 0.04, 0.70, and 0.004 as their corresponding RfD values. In adult population, the computed average hazard quotient for Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb through oral consumption of alcoholic beverages were 1.15E-03, 2.28E-01, 1.28E-01, 2.99E-04, 4.41E-03, 4.48E-03, 3.34E-03, and 1.35E-01 respectively. Similarly in adult population, the average hazard index for Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb through oral consumption of non-alcoholic beverages were 4.83E-03, 1.29E-01, 1.13E-01, 6.02E-04, 4.79E-03, 4.79E-03, 2.30E-03, and 7.40E-02 respectively. The average hazard quotient for Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb in child's population with respect to oral consumption of non-alcoholic beverages were 3.88E-03, 1.48E-03, 2.27E-04, 6.91E-04, 3.67E-04, 7.34E-04, 6.17E-03, and 1.13E-03 respectively. However, in both alcoholic and non-alcoholic beverages samples, the values of hazard quotient were less than one (<1.0) irrespective of the categories of population, indicating that there are no potential non-carcinogenic

3. 2.2 Hazard index (HI)

Hazard Index of heavy metals in alcoholic drinks consumed by adult population ranged from 3.37E-02 - 7.75E-01 with a mean value of 4.95E-01. These values of HI (Table 6) were less than one (HI<1) in all the alcoholic beverage drinks evaluated, indicating that there are no potential non-carcinogenic health risks associated with consumption of alcoholic beverage by adult population. Hazard Index of heavy metals in non-alcoholic drinks consumed by adult population ranged from 2.069E-01 - 3.825E-01 with an average value of 2.791E-01. The values of hazard index (Table 7) were below the threshold value one (HI<1), signifying that there are no potential non-carcinogenic health risks associated with consumption of non-alcoholic beverage by Nigerian adult. Similarly, the hazard index of heavy metals in non-alcoholic drinks ingested by child population (Table 8) ranged from 5.69E-03 - 2.11E-02 with a mean of 1.34E-02. These values of HI were less than one (HI<1) in all the non-alcoholic beverage samples consumed by children evaluated, demonstrating that there are no possible non-carcinogenic health risks linked to consumption of non-alcoholic beverage by child population (Ogoko *et al*., 2020).

3.2.2 Incremental life cancer risk (ILCR)

Incremental life cancer risks are presented in Tables 9 to 11. International Agency for Research on Cancer (IARC) has classified Cr, Cd and Pb as group 1 and 2 probable carcinogenic metals. Mn, Zn, Co, Cu and Fe were designated as non-carcinogenic metals (IARC, 2012).

Table 3: Estimated Daily Intake (mg/kg/day) of heavy metals through consumption of alcoholic drinks in adult population

Brand	Categories	Mn	Cr	Cd	Zn	Co	Cu	Fe	Pb
SG1	Local gin	1.406E-05	5.156E-05	4.688E-06	4.219E-05	6.56E-05	5.391E-04	2.166E-03	9.375E-06
SG2		4.687E-06	5.625E-05	4.688E-06	7.969E-05	1.88E-05	3.469E-04	2.203E-04	8.906E-05
SG3		3.281E-05	4.688E-06	1.406E-05	4.688E-05	1.501E-04	2.859E-04	1.153E-03	4.219E-05
SG4		9.375E-06	4.688E-06	9.375E-06	8.438E-05	2.441E-04	2.344E-04	1.781E-04	1.078E-04
SG5		4.688E-06	5.531E-04	3.281E-05	1.406E-05	1.220E-04	2.391E-04	3.084E-03	3.281E-05
PW1	Local palm wine	3.797E-04	9.751E-04	1.547E-04	7.031E-05	6.091E-05	6.563E-05	2.536E-03	6.021E-04
PW2		3.469E-04	1.031E-03	1.594E-04	5.625E-05	3.520E-04	1.641E-04	8.437E-05	6.422E-04
PW3		3.984E-04	1.120E-03	1.688E-04	7.501E-05	4.220E-05	1.875E-04	5.255E-03	7.359E-04
PW4		4.266E-04	8.015E-04	1.875E-04	5.625E-05	7.971E-05	1.406E-05	6.525E-03	5.953E-04
PW5		3.938E-04	1.097E-03	1.922E-04	1.125E-04	9.101E-05	1.219E-04	2.348E-03	6.422E-04
HPB	Local herbal gin	6.094E-05	9.938E-04	1.875E-04	1.078E-04	7.971E-05	1.969E-04	1.444E-03	6.938E-04
PAB		7.501E-05	9.516E-04	1.922E-04	3.375E-04	9.101E-05	6.562E-05	1.542E-03	8.016E-04
SKB		4.687E-06	9.937E-04	2.063E-04	7.969E-05	6.560E-05	1.219E-04	2.475E-03	9.094E-04
KAB		1.359E-04	9.609E-04	2.016E-04	8.437E-05	7.971E-05	4.688E-05	3.876E-03	9.328E-04
IYB		1.359E-04	6.750E-04	2.109E-04	9.844E-05	9.101E-05	5.625E-05	6.234E-04	8.344E-04

Table 4: Estimated daily intake (mg/kg/day) of heavy metals through consumption of non-alcoholic drinks in adult population

Brand code	Categories	Mn	Cr	Cd	Zn	Co	Cu	Fe	Pb
ZB1	Zobo drink	5.585E-04	4.179E-04	7.812E-05	1.211E-04	3.516E-05	1.641E-04	2.910E-03	1.561E-04
ZB2		5.117E-04	4.414E-04	3.906E-05	8.203E-05	7.812E-06	3.789E-04	2.383E-03	2.421E-04
ZB3		6.172E-04	3.125E-04	5.859E-05	1.679E-04	4.687E-05	5.078E-05	4.296E-05	1.881E-04
ZB4		5.078E-04	3.828E-04	8.203E-05	6.250E-05	2.383E-04	2.031E-04	1.219E-03	3.201E-04
ZB5		5.469E-04	5.078E-04	5.078E-05	3.906E-05	2.383E-04	3.906E-05	2.016E-03	1.641E-04

KA1	Kunu Aya	7.031E-04	3.125E-04	9.375E-05	1.016E-04	7.812E-05	2.539E-04	8.398E-04	2.850E-04
KA2		2.383E-04	3.554E-04	3.906E-05	1.718E-04	1.251E-04	1.484E-04	2.828E-03	1.951E-04
KA3		5.859E-04	5.547E-04	8.593E-05	2.461E-04	3.906E-05	9.375E-05	2.012E-03	3.980E-04
KA4		4.609E-04	3.984E-04	6.640E-05	1.992E-04	4.687E-05	1.875E-04	3.129E-03	1.561E-04
KA5		7.851E-04	4.251E-04	8.984E-05	3.203E-04	1.563E-04	2.383E-04	1.641E-04	3.590E-04
FT1	Smoothies	6.328E-04	3.476E-04	7.421E-05	1.758E-04	1.328E-04	2.031E-04	3.523E-03	4.061E-04
FT2		1.059E-03	3.516E-04	7.031E-05	2.656E-04	4.687E-05	3.203E-04	7.891E-04	3.160E-04
FT3		1.219E-04	2.187E-04	1.953E-05	3.164E-04	1.211E-04	1.367E-04	3.164E-04	3.791E-04
FT4		9.375E-04	3.047E-04	3.125E-05	1.094E-04	8.594E-05	2.422E-04	7.891E-04	4.771E-04
FT5		7.851E-04	4.687E-04	7.812E-06	3.281E-04	3.906E-05	2.148E-04	1.175E-03	3.91E-048

Table 5: Estimated daily intake (mg/kg/day) of heavy metals through consumption of non-alcoholic drinks in Children

Brand code	**Categories**	**Mn**	**Cr**	**Cd**	**Zn**	**Co**	**Cu**	**Fe**	**Pb**
ZB1	Zobo drink	2.141E-03	1.602E-03	2.994E-04	4.640E-04	1.347E-04	6.287E-04	1.115E-02	5.991E-04
ZB2		1.961E-03	1.692E-03	1.497E-04	3.144E-04	2.994E-05	1.452E-03	9.131E-03	9.281E-04
ZB3		2.365E-03	1.198E-03	2.245E-04	6.437E-04	1.796E-04	1.946E-04	1.647E-04	7.190E-04
ZB4		1.946E-03	1.467E-03	3.143E-04	2.395E-04	9.132E-04	7.784E-04	4.671E-03	1.228E-03
ZB5		2.095E-03	1.946E-03	1.946E-04	1.497E-04	9.132E-04	1.497E-04	7.725E-03	6.291E-04
KA1	Kunu Aya	2.695E-03	1.197E-03	3.592E-04	3.892E-04	2.994E-04	9.731E-04	3.218E-03	1.093E-03
KA2		9.132E-04	1.362E-03	1.497E-04	6.587E-04	4.790E-04	5.689E-04	1.084 E-03	7.491E-04
KA3		2.246E-03	2.125E-03	3.293E-04	9.431E-04	1.497E-04	3.593E-04	7.709 E-03	1.527E-03
KA4		1.766E-03	1.526E-03	2.545E-04	7.634E-04	1.796E-04	7.186E-04	1.199E-02	5.991E-04
KA5		3.009E-03	1.632E-03	3.443E-04	1.228E-04	5.988E-04	9.132E-04	6.287 E-04	1.377E-03
FT1	Smoothies	2.425E-03	1.332E-03	2.844E-04	6.737E-04	5.089E-04	7.784E-04	1.350E-02	1.557E-03
FT2		4.057E-03	1.347E-03	2.694E-04	1.018E-03	1.796E-04	1.227E-03	3.023E-03	1.213E-03
FT3		4.671E-03	8.383E-04	7.485E-05	1.212E-03	4.640E-04	5.239E-04	1.212E-03	1.452E-03
FT4		3.592E-03	1.167E-03	1.197E-04	4.192E-04	3.293E-04	9.281E-04	3.023E-03	1.826E-03
FT5		3.008E-03	1.796E-03	2.994E-05	1.257E-03	1.497E-04	8.233E-04	4.505E-03	1.527E-03

Table 6: Hazard Quotient (HQ) and Hazard Index of heavy metals in alcoholic drinks consumed by adult population

Brand	Categories	Mn	Cr	Cd	Zn	Co	Cu	Fe	Pb	HI
SG1	Local Gin	1.004E-04	1.719E-02	4.687E-03	1.406E-04	3.281E-03	1.347E-02	3.093E-03	2.344E-03	4.43E-02
SG2		3.348E-05	1.875E-02	4.687E-03	2.656E-04	9.381E-04	8.671E-03	3.147E-04	2.226 E-02	3.37E-02
SG3		2.344E-04	1.563E-03	1.406E-02	1.562E-04	7.501E-03	7.148E-03	1.647E-03	1.054E-02	4.28E-02
SG4		6.696E-05	1.562E-03	9.375E-03	2.812E-04	1.218E-02	5.859E-03	2.544E-03	2.695E-02	5.88E-02
SG5		3.348E-05	1.844E-01	3.281E-02	4.687E-05	6.094E-03	5.976E-03	4.406E-03	8.203E-03	2.42E-01
PW1	Local palm Wine	2.712E-03	3.251E-01	1.547E-01	2.343E-04	3.047E-03	1.640E-03	3.622E-03	1.501E-01	6.41E-01
PW2		2.477E-03	3.438E-01	1.594E-01	1.875E-04	1.758E-03	4.101E-03	1.205E-04	1.605E-01	6.72E-01
PW3		2.846E-03	3.734E-01	1.687E-01	2.501E-04	2.109E-03	4.687E-03	7.506E-03	1.839E-01	7.43E-01
PW4		3.047E-03	2.672E-01	1.875E-01	1.875E-04	3.984E-03	3.516E-04	9.321E-03	1.488E-01	6.20E-01
PW5		2.813E-03	3.656E-01	1.922E-01	3.751E-04	4.688E-03	3.046E-03	3.354E-03	1.605E-01	7.33E-01
HPB	Local herbal gin	4.353E-04	3.312E-01	1.875E-01	3.593E-04	3.984E-03	4.921E-03	2.062E-03	1.734E-01	7.00E-01
PAB		5.357E-04	3.172E-01	1.922E-01	1.125E-03	4.688E-03	1.640E-03	2.203E-03	2.004E-01	7.15E-01
SKB		3.348E-05	3.312E-01	2.063E-01	2.656E-04	3.281E-03	3.046E-03	3.535E-03	2.273E-01	7.75E-01
KAB		9.709E-04	3.203E-01	2.016E-01	2.812E-04	3.984E-03	1.171E-03	5.537E-03	2.332E-01	7.63E-01
IYB		9.709E-04	2.251E-01	2.109E-01	3.281E-04	4.688E-03	1.406E-03	8.906E-04	2.085E-01	6.48E-01
Average		1.15E-03	2.28E-01	1.28E-01	2.99E-04	4.41E-03	4.48E-03	3.34E-03	1.35E-01	4.95E-01

Table 7: Hazard Quotient (HQ) and Hazard Index of heavy metals in non-alcoholic drinks consumed by adult population

Brand code	Categories	Mn	Cr	Cd	Zn	Co	Cu	Fe	Pb	HI
ZB1	Zobo drink	3.989E-03	1.393E-01	7.812E-01	4.036E-04	1.76E-03	4.101E-03	4.157E-03	3.901E-02	2.708E-1
ZB2		3.655E-03	1.471E-01	3.911E-02	2.730E-04	3.91E-04	9.472E-03	3.404E-03	6.051E-02	2.639E-1
ZB3		4.408E-03	1.041E-01	5.859E-02	5.599E-04	2.34E-03	1.269E-03	6.138E-05	4.701E-02	2.184E-1
ZB4		3.627E-03	1.276E-01	8.201E-02	2.081E-04	1.19E-02	5.078E-03	1.741E-03	8.011E-02	3.121E-1
ZB5		3.906E-03	1.692E-01	5.078E-02	1.302E-04	1.19E-02	9.765E-04	2.879E-03	4.101E-02	2.808E-1

KA1	Kunu Aya	5.022E-03	1.041E-01	9.381E-02	3.391E-04	3.91E-03	6.347E-03	1.199E-03	7.125E-02	2.860E-1
KA2		1.702E-03	1.185E-01	3.906E-02	5.729E-04	6.25E-03	3.711E-03	4.040E-03	4.875E-02	2.225E-1
KA3		4.185E-03	1.848E-01	8.591E-02	8.201E-04	1.95E-03	2.344E-03	2.874E-03	9.950E-02	3.824E-1
KA4		3.292E-03	1.328E-01	6.641E-02	6.640E-04	2.34E-03	4.687E-03	4.469E-03	3.901E-02	2.537E-1
KA5		5.608E-03	1.419E-01	8.981E-02	1.071E-03	7.81E-03	5.957E-03	2.343E-04	8.975E-02	3.421E-1
FT1	Smoothies	4.520E-03	1.158E-01	7.421E-02	5.859E-04	6.64E-03	5.078E-03	5.033E-03	1.015E-01	3.134E-1
FT2		7.561E-03	1.171E-01	7.031E-02	8.851E-04	2.34E-03	8.008E-03	1.127E-03	7.901E-02	2.864E-1
FT3		8.705E-03	7.292E-02	1.953E-02	1.054E-03	6.05E-03	3.418E-03	4.520E-04	9.475E-02	2.068E-1
FT4		6.696E-03	1.016E-01	3.130E-02	3.651E-04	4.30E-03	6.055E-03	1.127E-03	1.192E-01	2.706E-1
FT5		5.608E-03	1.562E-01	7.812E-03	1.093E-03	1.95E-03	5.371E-03	1.679E-03	9.951E-02	2.792E-1
Average		4.83E-03	1.29E-01	1.13E-01	6.02E-04	4.79E-03	4.79E-03	2.30E-03	7.40E-02	2.79E-01

Table 8: Hazard Quotient (HQ) and Hazard Index of heavy metals in non-alcoholic drinks consumed by child population

Brand code	Categories	Mn	Cr	Cd	Zn	Co	Cu	Fe	Pb	HI
ZB1	Zobo drink	2.141E-02	1.602E-03	2.994E-04	4.640E-04	1.347E-04	6.287E-04	1.115E-02	5.991E-04	1.702E-02
ZB2		1.961E-03	1.691E-03	1.497E-04	3.143E-04	2.994E-05	1.452E-03	9.131E-03	9.281E-04	1.565E-02
ZB3		2.365E-03	1.197E-03	2.245E-04	6.437E-04	1.796E-04	1.946E-04	1.646E-04	7.191E-04	5.689E-03
ZB4		1.946E-03	1.467E-03	3.143E-04	2.395E-04	9.131E-04	7.784E-04	4.671E-03	1.228E-03	1.155E-02
ZB5		2.095E-03	1.946E-03	1.946E-04	1.497E-04	9.131E-04	1.497E-04	7.724E-03	6.291E-04	1.380E-02
KA1	Kunu Aya	2.694E-03	1.197E-03	3.592E-04	3.892E-04	2.994E-04	9.730E-04	3.218E-03	1.093E-03	1.022E-02
KA2		9.131E-04	1.362E-03	1.497E-04	6.586E-04	4.790E-04	5.688E-04	1.083E-02	7.492E-04	1.571E-02
KA3		2.245E-03	2.125E-03	3.293E-04	9.431E-04	1.497E-04	3.592E-04	7.709E-03	1.527E-03	1.538E-02
KA4		1.766E-03	1.526E-03	2.544E-04	7.634E-04	1.796E-04	7.185E-04	1.199E-02	5.991E-04	1.782E-02
KA5		3.009E-03	1.631E-03	3.443E-04	1.227E-03	5.988E-04	9.131E-04	6.287E-04	1.377E-03	9.731E-03
FT1	Smoothies	2.425E-03	1.332E-03	2.844E-04	6.736E-04	5.089E-04	7.784E-04	1.350E-02	1.557E-03	2.106E-02
FT2		4.056E-03	1.347E-03	2.694E-04	1.017E-03	1.796E-04	1.227E-03	3.023E-03	1.213E-03	1.233E-02
FT3		4.671E-03	8.383E-04	7.485E-05	1.212E-03	4.640E-04	5.239E-04	1.212E-03	1.452E-03	1.044E-02
FT4		3.592E-03	1.167E-03	1.197E-04	4.191E-04	3.293E-04	9.281E-04	3.023E-03	1.826E-03	1.140E-02
FT5		3.009E-03	1.796E-03	2.994E-05	1.257E-03	1.497E-04	8.233E-04	4.505E-03	1.527E-03	1.309E-02
Average		3.88E-03	1.48E-03	2.27E-04	6.91E-04	3.67E-04	7.34E-04	6.17E-03	1.13E-03	1.34E-02

Table 9: Incremental Life Cancer Risk of heavy metal through consumption of alcoholic drinks in adult population

Brand	Categories	Cr	Cd	Pb
SG1	Local gin	2.58E-05	2.81E-06	8.44E-08
SG2		2.82E-05	2.81E-06	8.02E-07
SG3		2.35E-06	8.44E-06	3.80E-07
SG4		2.35E-06	5.63E-06	9.70E-07
SG5		2.77E-04	1.97E-05	2.95E-07
PW1	Local Palm wine	4.88E-04	9.28E-05	5.40E-06
PW2		5.17E-04	9.56E-05	5.78E-06
PW3		5.61E-04	1.01E-04	6.62E-06
PW4		4.02E-04	1.13E-04	5.36E-06
PW5		5.50E-04	1.15E-04	5.78E-06
HPB	Local Herbal gin	4.98E-04	1.13E-04	6.24E-06
PAB		4.77E-04	1.15E-04	7.21E-06
SKB		4.98E-04	1.24E-04	8.18E-06
KAB		4.81E-04	1.21E-04	8.40E-06
IYB		3.38E-04	1.27E-04	7.51E-06

Table 10: Incremental Life Cancer Risk of heavy metal through consumption of non-alcoholic drinks in adult population

Brand	Categories	Cr	Cd	Pb
ZB1	Zobo drink	2.094E-04	4.687E-05	1.404E-06
ZB2		2.211E-04	2.341E-05	2.178E-06
ZB3		1.565E-04	3.515E-05	1.692E-06
ZB4		1.917E-04	4.921E-05	2.881E-06
ZB5		2.544E-04	3.046E-05	1.476E-06
KA1	Kunu Aya	1.565E-04	5.631E-05	2.565E-06
KA2		1.780E-04	2.343E-05	1.755E-06
KA3		2.779E-04	5.161E-05	3.582E-06
KA4		1.996E-04	3.984E-05	1.404E-06
KA5		2.133E-04	5.391E-05	3.231E-06
FT1	Smoothies	1.741E-04	4.453E-05	3.654E-06
FT2		1.761E-04	4.221E-05	2.844E-06
FT3		1.095E-04	1.171E-05	3.411E-06
FT4		1.526E-04	1.881E-05	4.293E-06
FT5		2.094E-04	4.687E-06	3.582E-06

Table 11: Incremental Life Cancer Risk of heavy metal through consumption of non-alcoholic drinks in children population

Brand	Categories	Cr	Cd	Pb
ZB1	Zobo drink	8.025E-04	1.796E-04	5.391E-06
ZB2		8.475E-04	8.982E-05	8.352E-06
ZB3		6.012E-04	1.347E-04	6.471E-06
ZB4		7.351E-04	1.886E-04	1.105E-05
ZB5		9.751E-04	1.167E-04	5.661E-06
KA1	Kunu Aya	6.012E-04	2.156E-04	9.837E-06
KA2		6.825E-04	8.982E-05	6.741E-06
KA3		1.065E-03	1.976E-04	1.374E-05
KA4		7.651E-04	1.527E-04	5.391E-06
KA5		8.175E-04	2.066E-04	1.239E-05
FT1	Smoothies	6.675E-04	1.707E-04	1.401E-05
FT2		6.751E-04	1.617E-04	1.092E-05
FT3		4.201E-04	4.491E-05	1.306E-05
FT4		5.851E-04	7.186E-05	1.643E-05
FT5		9.010E-04	1.796E-05	1.374E-05

Cancer slope factors for Cr (0.501), Cd (0.6) and Pb (0.009) were used in the calculation of incremental life cancer risk (Ogoko *et al.*, 2023). The ILCR of Cr, Cd and Pb through consumption alcohol by adult population ranged from 2.35E-06 - 5.61E-04, 2.81E-06 - 1.27E-04 and 8.44E-08 - 8.40E-06 respectively. Similarly, the incremental life cancer risk for Cr, Cd and Pb through consumption non-alcohol in adult population ranged from 1.10E-04 - 2.78E-04, 4.69E-06 - 5.63E-05 and 1.40E-06 - 4.29E-06 respectively. The ILCR for Cr, Cd and Pb through ingestion of non-alcohol in child population ranged from 4.20E-04 - 1.07E-03, 1.80E-05 - 2.16E-04 and 5.39E-06 - 1.64E-05 respectively. The incremental life cancer risk values of Pb were within the recommended safe limit of not greater than 1.0×10^{-4} and has the least likelihood of any potential cancer risks in adult and children population. The incremental life cancer risk for Cd were within recommended safe limits in adult population for both alcoholic and non-alcoholic samples evaluated. In contrast, the incremental life cancer risk for Cd appeared to have exceeded the safe limit in children population, indicating potential long time carcinogenic health risks through consumption in over 60% of the total non-alcoholic beverages assessed in the present study. The ILCR of Cr were above the recommended safe limit in most alcoholic and nonalcoholic beverages for both adult and children population except in the alcoholic gin samples, indicating potential long time carcinogenic health risks through consumption of beverage drinks.

4.0 Conclusion

The concentrations of Mn, Zn and Cu were present at levels below the maximum permissible limits for drinking-water, whereas the levels of Cr, Cd and Pb exceeded the recommended safe limits. The incremental life cancer risk values of Pb were within the recommended safe limit. The incremental life cancer risk for Cd were above safe limit in children population only. Chromium had incremental life cancer risk above the safe limits in almost all the non-alcoholic and alcoholic beverages irrespective of the population evaluated. The values of incremental life cancer risk were suggestive of very high probability of potential carcinogenic health risks of Cd and

Cr in the two categories of human population assessed.

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Compliance with Ethical Standards Declaration

Ethical Approval

Not Applicable

Competing interests

The authors declare that they have no known competing financial interests

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Availability of data and materials

Data would be made available on request.

Authors Contribution

Ogoko E. C. designed the study, Aletan, U.I., Osu C. I., Kelle, H.I., and Ogoko N. I. sampled the materials and performed the laboratory analysis. Ogoko E. C. wrote the manuscript, Aletan, U.I., Osu C. I., Kelle, H. I and Ogoko N. I proofread and edited the manuscript.