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Hazard and Health Risk Assessment of Heavy Metals in Non-Alcoholic Beverage Consumed in Abia State, Nigeria

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ABSTRACT: The quality of non-alcoholic beverages consumed in Aba, Abia State, southeastern Nigeria and health risk assessment of heavy metals required periodic evaluation so as to avert potential health hazard. Hence, the objective of this paper as to evaluate the hazard and health risk assessment of heavy metals in non-alcoholic beverages consumed in Abia State, Nigeria using health risk assessment models. Heavy metals concentrations were determined using atomic absorption spectrophotometer (Agilent 280FS AA). The average heavy metal concentrations of non-alcoholic drink samples ranged from 0.040 - 1.132 mg/l in ascending order of Zn < Cd < Co < Cu < Pb <Cr < Mn < Fe respectively. The average concentrations of Mn, Cr, Cd, Fe and Pb exceeded the standard maximum permissible limits for drinking water quality. The values of estimated daily intake for Cd, Fe, Pb, Cr, Mn and Zn were within acceptable provisional tolerable daily intake and safe limits. The hazard quotient (HQ) values for Mn, Cr, Cd, Zn and Fe were within safe limit (< 1.0), except for Co and Pb that had HQ values greater than one in over 37.5 % of the total samples, indicating associated potential chronic health risks. Hazard index of 72.5% of all the non-alcoholic drink samples were above the safe limit (>1.0), signifying potential chronic health risk as a result of combine effects of these heavy metals. The incremental life cancer for Cr, Cd and Pb ranged from 2.59E-05 - 1.79E-03, 1.35E-04 – 2.81E-04 and 3.92E-06 - 3.24E-05 respectively. The incremental life cancer 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. However, Cd, and Cr had cancer risk values higher than the save limits, indicating potential life cancer health risks in both children and adult population.

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Heavy metal contamination has continued to constitute not only a major problem to our environment but also one of the major contaminants of our food supply (Abdollatif *et al.* 2 Khair, 2009; Osu *et al*, 2012; Ahamefuna *et al*, 2014; Ogoko *et al*, 2015; Omada, 2024a). The information on metal contents in food types is crucial in evaluating nutritional ingestions of essential metals and assessment of human exposure to toxic elements (Iwegbue, 2010; Osu *et al* 2014; Kelle *et al*, 2021; Kelle *et al*, 2022; Ogoko *et al*, 2022). Ingestion of heavy metals at concentrations above the standard maximum permissible limits can bioaccumulate in human body and consequently, lead to numerous diseases such as gastrointestinal tract and central nervous system disorders, kidney failure, circulatory system disorder, anaemia, liver, lungs, cancer and ultimate death (Bingol *et al*, 2010). It is therefore imperative that the concentrations of the heavy metals in beverage food be monitored. The concentration of toxic metals in beverage attracts special interest due to their toxicity (Kemasuode *et al*, 2016). Biological essential heavy metals are required in lower concentrations for the normal metabolic process in the body and exemplified by Fe, Zn, Cu, Cr, Co, and Mn. Although the biological essential elements are necessary, they become toxic at high concentrations. Non-biological essential heavy metals are exemplified by lead (Pb), mercury (Hg), cadmium (Cd) and tin (Sn). They become toxic if ingested even at lower concentrations. Beverage is any kind of portable liquid meant for consumption. Common categories of beverages or drinks include plain drinking water, milk, juice, zobo drink, smoothies, non-alcoholic drinks, alcoholic drinks, coffee, tea, hot chocolate and caffeinated drinks such as energy drink. Beverages are consumed because of their food value, thirst-quenching properties, stimulating effects and pleasure. Alcoholic drinks contain ethanol and are generally classified as beers, wines and spirits. Non-alcoholic drinks contain less than 0.5% alcohol by volume. Carbonated drinks, juices, energy drinks, bottled water, coffee and tea are typical examples non-alcoholic drinks or beverages. Non-alcoholic drinks have wider acceptance mostly for social gathering, health and religious belief (Ogidi *et al*, 2020). Non-alcoholic drinks have higher ingestion rate thereby providing hydration, energy, vitamins and minerals to the body. The purity of the constituents used by the manufacturers for these drinks is of utmost concern and need to be periodically monitored. The source and purity of water, chemical residues or constituents, nature of packaging materials and possible pollutants as a result of industrial emission during the process of packing can compromise the quality and purity of the finished product. Contamination of these drinks by heavy metals could pose cancer health risks to human over a period of time. Ogidi *et al* (2021) observed that the levels of Cd, and Pb in beverage drinks were above the permissible levels and may pose serious health hazard. Gomaa *et al* (2019), reported that the concentrations of Mn and Fe in juices and carbonated drinks sold in Egyptian market exceeded the recommended permissible limits of World Health Organisation (WHO) but that copper was found in concentrations lower than the permissible limits. Oyekunle *et al* (2017), investigated the levels of heavy metals on some commonly consumed brands of soft drinks and health implications of regular consumption of these products. The result of their study showed that most of the potentially toxic metals evaluated had concentrations higher than the recommended WHO and USEPA permissible limits and consistent consumption of these soft drinks might constitute a substantial source of exposure to potentially toxic metals. Hence, the objective of this paper as to evaluate the hazard and health risk assessment of heavy metals in non-alcoholic beverages consumed in Abia State, Nigeria

MATERIALS AND METHODS

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 medium scale industries. Forty samples of non-alcoholic drinks were procured from supermarket outlets in Aba and its environs and preserved at 4ºC before analysis using a refrigerator. The non-alcoholic beverages cover different brands of bottled water, wines, juices, yoghurt, carbonated drinks, malt and tea.

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 250ºC for 120 minutes in a fume chamber. The digestion process is continued while waiting for appearance of a clear solution which was then filtered into a standard flask using Whatman filter paper. The filtrate is made up to the standard volumetric mark by addition of deionized water (Ogidi, 2021).

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 (AOAC, 2015). 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 217nm 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 ranged from of 0.001 ppm for all the metals analyzed.

Method validation for metal analysis: Validation was done by spiking the sample with 0.5 mg/l of standard solutions of the corresponding metals before digestion so as to establish accuracy of the analysis. Spiked samples were then exposed to comparable analytical conditions as the test sample. Percentage recovery was evaluated with the equation in number 1.

$$\% \text{ Recovery} = \frac{\text{SSC} - \text{USC}}{\text{ASC}} \quad (1)$$

Where SSC = spike sample concentration, USC = un-spike sample concentration, ASC = actual concentration

Recovery percentages of results for Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb were 90, 93, 91, 89, 96, 99, 97 and 101% respectively (89 -101%).

Health risks assessment: Health risks through ingestion of water and other beverage drinks can be adequately assessed using Estimated Daily Intake (EDI), Hazard Quotient (HQ), Hazard Index (HI), and Incremental Lifetime Cancer Risk (ILCR).

Estimated daily intake: The estimated daily intake (mg/kg/day) can be computed with the formula in equation 2 (USEPA, 2014; Omali, 2023).

$$EDI = \frac{CR}{BW} * IR \quad (2)$$

Where, CR is the metal concentration, IR and BW are daily consumption rate of non-alcoholic drinks and the average body weight of Nigerians respectively. 64 kg and 16.7kg were the average body weights of Nigerian adult and child respectively, while 30cl (300 ml) is the daily ingestion rate through oral consumption of beverage drinks and water in Nigerian adult respectively (Akinpelu, 2015).

Hazard quotient (HQ): Non-carcinogenic health risks of heavy metals can be obtained by computing the HQ values (Omada *et al*., 2024a).

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

Where RfD is the oral reference dose which is defined as the projected maximum permissible health risk associated with daily human ingestion or contact with heavy metals. RfD is expressed in mg/kg/day (USEPA, 2014). The collective effects of several heavy metals on the human health risk are appropriately described as hazard index (HI). HI is given by the formula in equation 4.

$$\text{HI} = \sum \text{HQ} \quad (4)$$

HI <1, indicates no potential health risk, whereas HI >1 indicates potential chronic health risk (USEPA, 2014).

Carcinogenic risk: Incremental lifetime cancer risk describes the potential carcinogenic health risk through ingestion of heavy metals. Incremental lifetime cancer risk ($ILCR$) is given by the formula in equation 5 (Gerba, 2019; Mohammadi, 2019)

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

where CDI is the chronic daily intake of carcinogenic chemical substances (mg/kg bw/day). CSF is the cancer slope factor, which is expressed with the formula in equation 6.

$$\text{But, CDI} = \frac{\boldsymbol{EDI \times EF \times ED}}{\boldsymbol{AT}} \quad (6)$$

Where, EF is the exposure frequency in days/year (365 days per year), ED is the exposure duration in years or life expectancy. The life expectancy for adult Nigerians is 54 years (World Bank, 2018). AT is the average time or period of exposure which is 365 days per year multiplied by 54 years (19,710 days.).

RESULTS AND DISCUSSION

The results of heavy metal concentrations in selected samples of non-alcoholic drinks consumed in Abia

State, Nigeria are presented in Table 1. Generally, the concentrations of manganese in different categories of non-alcoholic drinks analysed ranged from 0.025±0.008 - 3.804±0.795 mg/l with mean of 0.582 mg/l. However, malt drinks recorded the minimum Mn concentration while the different tea brands exhibited higher manganese levels. The concentrations of manganese above 0.1 mg/l in water supplied for domestic or industrial uses is associated to unpleasant taste in beverages and staining of commodities and laundry materials besides coating on water pipes (WHO, 2011; Omada *et al*, 2024a). Precipitation occurs when the manganese concentrations in water exceeds 0.2 mg/l. World health organisation has only proposed a health base value (0.5 mg/l) for manganese. However, Mn contents in most of the non-alcoholic drinks were within the health base values except the tea samples. However, the results of manganese concentration in contrast were higher in the present study than was reported by Gomaa *et al* (2019) but similar because in both studies, manganese was present in beverage drinks in levels above permissible limits. Manganese is considered an essential element required for the growth of humans and other animals. Manganese has been linked with adverse effects on learning abilities in children based on some epidemiological studies conducted. Meanwhile, these findings are yet to be confirmed. The concentration of chromium ranged from 0.210±0.131 - 0.553±0.128 mg/l with an average value 0.321 mg/l. A brand of carbonated drinks appeared to exhibit the minimum value whereas yogurt samples demonstrated higher concentration value of chromium. Interestingly, chromium concentration levels in these non-alcoholic drinks exceeded the recommended permissible limits of 0.05 mg/l (WHO, 2011; NSDWQ, 2015), indicating potential health risks associated the consumption of the beverage drinks. Chromium exhibits variable oxidation state and exists in valences ranging from +2 to +6 in compound form but appeared to be most stable at +3 oxidation state (Ogoko *et al*, 2023). Inhalation of hexa-valence form of chromium has been linked to lung cancer and hence, classified as Group 1 human carcinogen by the International Agency for Research on Cancer (IARC, 2012). Cadmium concentrations varied from 0.052±0.002 - 0.094±0.002 mg/l, with an average value 0.072 mg/l. It was observed that the different brands and samples of tea recorded higher concentration values of cadmium compared to other beverage drinks investigated in the present study. Most of the beverage samples exceeded the standard permissible limits for Cd (0.003 mg/l) recommended for portable water by WHO and Nigerian Standard for Drinking Water Quality respectively (WHO, 2008; NSDWQ, 2015). Cadmium is a raw material for steel, plastic and battery industries. Cadmium is an environmental waste discharge in effluents, air pollution and soil diffusion through fertilizers (Ogoko and Donald, 2018). However, pollution of water based non-alcoholic beverages may be due to impurities in zinc of galvanized pipes, soldering, and other metal fittings. Besides, care must be taken to ensure that plastic containers and all other additives such as colorants, flavorants and sweeteners are cadmium-free (FAO/WHO, 2011). The primary target organ of cadmium toxicity is the kidney. Cadmium is carcinogenic through inhalation pathway and consequently has been classified appropriately as probable carcinogenic to human. There is still dearth of evidence on carcinogenicity of cadmium and cadmium compounds via oral route or genotoxicity of cadmium in humans. Zinc is one of the vital trace metals found in most food and drinking water in the form of salts or complexes of organic origin (Ogoko and Ajani, 2020). Food is essentially the primary source of zinc to humans and other animals while concentrations of the range 0.01-0.05 mg/l is not uncommon in tap water. It is interesting to note that zinc dissolution in water depends on pH but dissolution from galvanized water fittings can de decreased appreciably by increasing the pH. Daily intake of 15-20 mg per day is recommended for adult men (WHO, 2003). The concentration of zinc ranged from 0.021±0.012 - 0.061±0.015 mg/l with an average value of 0.037 mg/l. Yogurt sample had the lowest concentration while malt sample exhibited a higher zinc concentration. However, the concentrations of zinc in all the brands of beverage drinks were lower than the 3.0 mg/l, indicating that zinc metal does not pose any potential health risk at the present concentrations. There is dearth of information on recommended guideline value by world health organisation for zinc in beverage drinks. However, zinc content greater than 3.0 mg/l is often not suitable and acceptable for beverages including drinking water.

Cobalt contents in non-alcoholic drinks varied from below detection limit (BDL) to 0.212±0.042 mg/l with an average value of 0.075 mg/l. Bottled water sample had comparatively higher cobalt contents while cobalt levels in most of the fruit juice, wine and ice cream samples were below detection limit. Copper concentration was found to range from 0.024±0.018 - 0.338±0.142 mg/l with mean of 0.161 mg/l. Tea samples had the maximum concentration while copper content in one of the wine samples was below detection limit of the atomic absorption spectrophotometer (AAS). Copper contents in all the samples analysed were below the recommended standard permissible limit of 2.0 mg/l, indicating that the non-alcoholic beverages were not polluted with respect to copper and hence, may not pose any potential health hazard. The source of copper in drinking water supply or water -based beverages is as a result of corrosive action of water and copper dissolution from copper pipes in buildings. Staining of wares, laundry and containers occurs if copper concentrations exceeded 1 mg/l while colour impartation and unacceptable bitter taste to water results at concentrations higher than 5mg/l. There is an increasing risk of consumers suffering from gastrointestinal irritation such as diarrhoea at concentrations above the health-based guideline value of 2 mg/l (WHO, 2011; Ogoko and Kelle, 2020; Omada et. al, 2024b). The concentrations of iron ranged from 0.163±0.180 - 0.336±0.236 mg/l with an average value of 0.848 mg/l. Tea sample had higher concentration while fruit juice sample showed a much lower iron content. The concentrations of iron in over 70% of the samples analysed were above the provisional guideline value (0.3 mg/l) recommended by World Health Organisation and Nigerian Standard for Drinking Water Quality respectively (WHO, 2011; NSDWQ, 2015). Iron concentrations were lower in the present study than was reported by Gomaa *et al* (2019). Lead content ranged from 0.118±0.018 - 0.424±0.096 mg/l with an average value of 0.264 mg/l. The concentrations of lead in the non-alcoholic drinks appeared to be higher than the WHO recommended guideline values of 0.01 mg/l, indicating possible health risk associated with their consumption. Since the non-alcoholic drinks are water based, lead contents in drinking water or water based non-alcoholic drinks may arise from lead service connection pipes and plumbing in factories or industries. This can be circumvented by corrosion control, identifying and removing service connections, water systems and fittings made of lead. In the intervening time, care must be taken to ensure that all other additives such as colorants, flavorants and sweeteners are lead-free. The hazards as a result of exposure to lead includes neurodevelopmental disorders, mortality, impaired renal function, hypertension, impaired fertility and adverse pregnancy effects among others (Ogoko *et al*, 2021).

Table 1: Heavy metals concentrations (mg/l) in non-alcoholic drinks sold at Aba, Abia State

Sample	Mn	Cr	Cd	Zn	Co	Cu	Fe	Pb
Juices	0.084± 0.066	0.239± 0.053	0.052± 0.002	0.038± 0.011	0.001± 0.002	0.024± 0.018	0.163± 0.180	0.246± 0.072
Wines	0.049± 0.025	0.302± 0.042	0.057± 0.002	0.033± 0.010	BDL	0.032± 0.021	0.336± 0.236	0.228± 0.033
Malt drinks	0.025± 0.008	0.313± 0.047	0.063± 0.002	0.050± 0.081	0.028± 0.001	0.108± 0.072	0.258± 0.165	0.187± 0.022
carbonated drinks	0.028± 0.013	0.210± 0.131	0.075± 0.006	0.029± 0.005	0.0158 ±0.023	0.212± 0.034	0.345± 0.314	0.296± 0.082
Tea	3.804± 0.795	0.417± 0.092	0.088± 0.006	0.061± 0.015	0.105± 0.091	0.338± 0.142	3.117± 1.106	0.352± 0.170
Yogurt	0.055± 0.021	0.553± 0.128	0.094± 0.002	0.029± 0.024	0.164± 0.026	0.279± 0.049	1.245± 0.651	0.424± 0.096
Bottle water	0.029± 0.005	0.214± 0.090	0.070± 0.013	0.021± 0.012	0.212± 0.042	0.136± 0.045	0.475± 0.312	0.118± 0.018
WHO, 2003	0.500	0.050	0.003	3.0		2.0	0.30	0.01
NSDWQ, 2015	0.200	0.050	0.003	3.0		1.0	0.30	0.01

The estimated Daily Intake (EDI): The estimated daily intake of heavy metal through consumption of seven categories of non-alcoholic drinks are presented in Table 2. Generally, considering the seven brands of non-alcoholic drinks, the EDI values in adult ranged from 1.41E-04 - 1.78E-02, 9.21E-04 - 3.72E-03, 2.43E-04 - 4.42E-04, 9.84E-05 - 2.91E-04, BDL to 9.93E-04, 1.14E-04 - 1.36E-03, 1.08E-03 - 1.41E-02 and 5.53E-04 - 2.00E-03 mg/kg/day for Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb respectively. In children, the EDI values for manganese, chromium, cadmium, zinc, cobalt, copper, iron and lead ranged from 4.52E-04 - 6.83E-02, 3.66E-03 - 9.94E-03, 9.30E-04 - 1.69E-03, 2.84E-04- 1.114E-03, <1.80E-05 - 3.85E-03, 4.38E-04 - 5.86E-03, 2.92E-03 - 4.64E-02 and 2.12E-03 - 7.62E-03 mg/kg/day respectively. It is interesting to note that most of the tea samples had the maximum EDI values for Mn, Cd, Cu, Fe and Pb respectively. The values of estimated daily intake for Cd, Fe and Pb through oral consumption of non-alcoholic drinks appeared to be lower in adult population than acceptable provisional tolerable daily intake of 0.00083, 0.80 and 0.00357 mg/kgbw/day respectively, but slightly higher in children (FAO/WHO, 2001). The proposed provisional tolerable daily intake of copper is 0.5 mg/kgbw/day, but the estimated daily intake of copper in the present study were within acceptable limits in both adult and children (Tables 2). There is limited information on the proposed acceptable provisional tolerable daily intake Cr, Mn and Zn by World health organisation and other standard organisations. It can therefore be stated that there is no indication of any potential non-carcinogenic health risk through oral consumption of these non-alcoholic drinks based on the estimated daily intake values reported in this study.

Table 2: Estimated Daily Intake (mg/kg/day) of heavy metals through consumption of non- alcoholic drinks

EDI (mg/kg/day) in adult population								
Sample	**Mn**	**Cr**	**Cd**	**Zn**	**Co**	**Cu**	**Fe**	**Pb**
Juices	3.92E-04	1.12E-03	2.43E-04	1.76E-04	2.34E-05	1.14E-04	1.08E-03	1.15E-03
Wines	2.32E-04	3.72E-03	2.63E-04	1.77E-04	BDL	1.96E-04	1.23E-03	1.11E-03
Malt drinks	1.18E-04	9.21E-04	2.91E-04	1.75E-04	1.31E-04	5.63E-04	1.41E-03	8.78E-04
carbonated drinks	1.32E-04	9.56E-04	3.41E-04	2.91E-04	9.69E-05	7.97E-04	2.00E-03	1.25E-03
Tea	1.78E-02	1.89E-03	4.05E-04	2.70E-04	4.30E-04	1.36E-03	1.41E-02	1.74E-03
Yogurt	2.99E-04	2.66E-03	4.42E-04	1.11E-04	7.70E-04	1.30E-03	6.23E-03	2.00E-03
Bottle water	1.41E-04	1.60E-03	3.29E-04	9.84E-05	9.93E-04	6.71E-04	2.46E-03	5.53E-04
EDI (mg/kg/day) in child population								
	Mn	**Cr**	**Cd**	**Zn**	**Co**	**Cu**	**Fe**	**Pb**
Juices	1.50E-03	4.29E-03	9.30E-04	6.75E-04	1.80E-05	4.38E-04	2.92E-03	4.42E-03
Wines	8.87E-04	5.41E-03	1.00E-03	6.79E-04	BDL	6.01E-04	4.72E-03	4.25E-03
Malt drinks	4.52E-04	5.45E-03	1.11E-03	2.84E-04	1.01E-04	1.21E-03	5.40E-03	3.36E-03
Carbonated drinks	5.06E-04	3.66E-03	1.30E-03	1.114E-03	2.23E-04	3.85E-03	6.82E-03	4.77E-03
Tea	6.83E-02	7.24E-03	1.55E-03	1.037E-03	1.64E-03	5.86E-03	4.64E-02	6.32E-03
Yogurt	9.88E-04	9.94E-03	1.69E-03	5.21E-04	2.95E-03	5.01E-03	2.23E-02	7.62E-03
Bottle water	5.31E-04	3.85E-03	1.26E-03	3.77E-04	3.85E-03	2.45E-03	8.53E-03	2.12E-03

Table 3: Hazard Quotient (HQ) and Hazard Index (HI) of heavy metals in non-alcoholic drinks

Hazard Quotient and Hazard Index of heavy metals in adult population									
Sample	Mn	Cr	Cd	Zn	Co	Cu	Fe	Pb	HI=∑HQ
Juices	2.80E-03	3.74E-01	2.43E-01	5.87E-04	1.17E-03	2.86E-03	1.09E-03	2.40E-01	8.66E-01
Wines	1.65E-03	4.71E-01	2.63E-01	5.91E-04	BDL	4.89E-03	2.07E-03	1.30E+00	2.04E+00
Malt drinks	8.44E-04	8.66E+01	2.91E-01	2.47E-04	6.56E-03	9.70E-03	2.02E-03	1.33E+00	8.82E+01
carbonated drinks	9.44E-04	3.19E-01	3.41E-01	4.09E-04	4.84E-03	2.51E-02	2.54E-03	7.36E-01	1.43E+00
Tea	1.36E-01	6.30E-01	4.03E-01	9.02E-04	2.17E-02	3.82E-02	1.71E-02	7.12E+00	8.37E+00
Yogurt	1.84E-03	8.65E-01	1.75E+02	4.53E-04	3.85E-02	3.27E-02	8.34E-03	1.18E+00	1.77E+02
Bottle water	1.05E-03	3.35E-01	3.29E-01	3.28E-04	4.96E-02	1.60E-02	3.18E-03	4.08E+00	4.81E+00
Hazard Quotient (HQ) and Hazard Index of heavy metals in child population									
Sample	Mn	Cr	Cd	Zn	Co	Cu	Fe	Pb	HI=∑HQ
Juices	1.07E-02	1.43E+00	9.30E-01	2.25E-03	9.00E-04	1.10E-02	4.17E-03	1.11E+00	3.50E+00
Wines	6.34E-03	1.80E+00	1.00E+00	2.26E-03		1.50E-02	6.74E-03	1.06E+00	3.89E+00
Malt drinks	7.13E-02	3.02E-03	1.11E-03	1.25E-01	5.05E-03	8.05E-02	8.01E-01	3.16E-03	1.09E+00
carbonated drinks	7.99E-02	2.03E-03	1.30E-03	4.92E-01	1.12E-02	2.56E-01	1.01E+00	4.49E-03	1.86E+00
Tea	8.55E-01	3.57E+00	1.19E+00	2.11E-03	8.20E-02	2.29E-02	4.59E-02	1.41E+00	7.18E+00
Yogurt	1.24E-02	4.90E+00	1.30E+00	1.06E-03	3.60E-02	1.96E-02	2.20E-02	1.70E+00	7.99E+00
Bottle water	4.29E-02	7.86E-04	9.69E-04	3.56E-01	4.69E-02	1.25E-01	3.87E-01	1.25E-03	9.61E-01

Hazard quotient (HQ) and Hazard index (HI): The RfD values used for the computation of hazard quotients of Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb in non-alcoholic drinks were 0.14, 0.003, 0.001, 0.3, 0.02, 0.04, 0.70, and 0.004 respectively (FAO/WHO, 2001). Table 3 revealed that the hazard quotient of Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb ranged from 0.000502 - 0.162455, 0.017188 - 1.1875, 0.225- 0.46875, 0.0000938 - 0.003047, 0.000234 – 0.0623, 0.000938 - 0.082617, 0.0000804 - 0.025835 and 0.046965 - 26.59378 respectively. The hazard quotient of Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb in children ranged from 6.34E-03 - 8.55E-01, 7.86E-04 - 4.90E+00, 9.69E-04 - 1.30E+00, 1.06E-03 - 4.92E-01, 9.00E-04 - 8.20E-02, 1.10E-02 - 2.56E-01, 4.17E-03 - 1.01E+00 and 1.25E-03 - 1.70E+00 respectively. These metals except for Pb have hazard quotient values less than one across most of the non-alcoholic beverages in both adult and child population. Cobalt in several wine samples had concentrations below detection limits and had no HQ values. The values of hazard index (Table 3) in adult population ranged from 8.66E-01 - 1.77E+02 with juices and yogurt samples having minimum and maximum hazard index respectively. Table 3 also revealed that the 85.7% of the non-alcoholic drinks samples analysed had hazard index (HI) above the threshold value of 1.0. The hazard index of these heavy metals in children ranged from

9.61E-01 - 7.99E+00 but were greater than one in 85.7% of beverage samples. Hazard Index greater than one in most of the samples revealed potential chronic non-carcinogenic health risk due to combined effects of these heavy metals through oral ingestion.

Incremental life cancer risk: In the present study, the calculated incremental life cancer risk values for adult and child population are presented in Fig. 1 and 2 respectively.

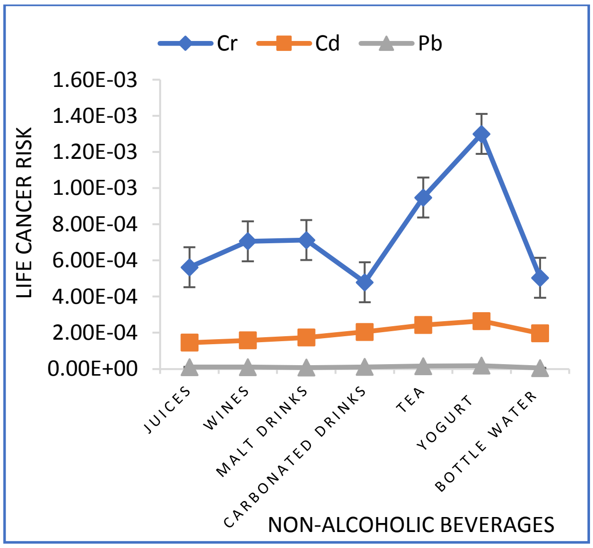

Fig. 1: Incremental life cancer risk among adult

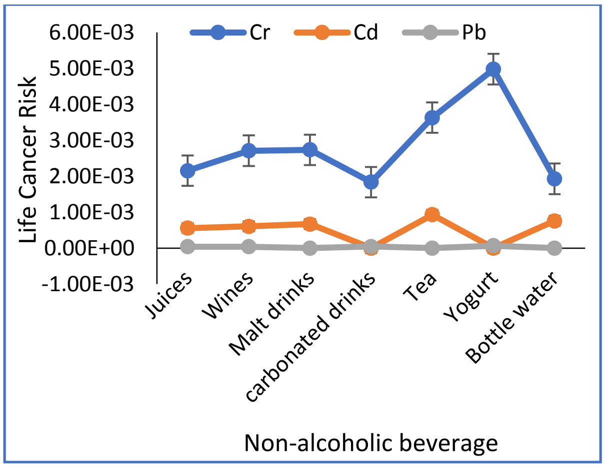

Fig. 2: Incremental life cancer risk among children

Chromium, cadmium and lead were classified as group 1 and 2 probable carcinogenic metals by the International Agency for Research on Cancer (IARC) whereas Mn, Zn and Cu were designated as non-carcinogenic metals (IARC, 2012). The cancer slope factor of Cr, Cd and Pb were 0.501, 0.6 and 0.009 respectively, which was used in the computation of incremental life cancer risk (USEPA, 2014). The incremental life cancer for Cr, Cd and Pb ranged from 2.59E-05 - 1.79E-03, 1.35E-04 - 2.81E-04 and 3.92E-06 - 3.24E-05 respectively. Nonetheless, the incremental life cancer 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. However, Cd, and Cr had cancer risk values higher than the safe limits in both population of adult and children, which demonstrate high prospect of carcinogenic effects through ingestion of non-alcoholic drinks.

Conclusion: Mn, Cr, Cd, Zn, Co, Cu, Fe and Pb were present in the non-alcoholic drinks sample but Ni was in quantities below detection limit of the AAS instrument. Mn, Cr, Cd, Fe and Pb were present in concentrations above the recommended standard permissible limits. Meanwhile, Pb had incremental life cancer risk within safe limits while Cd, and Cr had cancer risk values higher than the acceptable limits, indicating potential life cancer risks as a result of these heavy metals ingestion through non-alcoholic drinks consumption. There is therefore urgent need for strict adherence to food safety standard operational procedures during the production process of non-alcoholic drinks so as to circumvent incident of high levels of toxic metals contents. There is also need to set tolerable limit for each metal in all the brands of non-alcoholic drinks evaluated in the present study. Regular monitoring of raw materials for the non-alcoholic beverages and the production processes is hereby recommended to drastically reduce transference of hazardous metals into the finished products.

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Data Availability Statement: Data are available upon request from the first author or corresponding author or any of the other authors

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