Mal J Nutr 20(1): 121 - 131, 2014

Heavy Metal Hazards of Functional Beverages in Nigeria

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ABSTRACT

Introduction: In spite of an explosion in brewing and importation of energy drinks in Nigeria, information on the inherent health risks arising from its consumption is scarce. This study investigated the heavy metal hazards of popular energy drinks in Nigeria. **Methods**: Heavy metals in thirty different brands of energy drinks were analysed using Atomic Absorption Spectrophotometer. Lead, cadmium, chromium, cobalt, and nickel levels in these energy drinks were compared with permissible limits given by World Health Organization (WHO), United States Environmental Protection Agency (US EPA) and European Union (EU). The daily intake (DI) and target hazard quotient (THQ) were calculated. **Results:** For lead, 66.7%, 3.3%, and 66.7% of the energy drinks violated the WHO, EPA and EU permissible limits respectively; for chromium, only 36.7, 23.3 and 36.7% violated the WHO, EPA and EU permissible limits respectively; and for cobalt, 70% and 86.7% of the energy drinks violated the EU permissible limits. Total Hazard Quotient values for all the drinks were below 1. The estimated/calculated amount of chromium, cobalt, lead and nickel of an energy drink of a consumer who takes an average weekly volume of 1.5 L, (1.5 L of the 3 energy drinks) were 1.3857, 0.8736, 0.1845 and 1.5159 mg/L respectively. Only 33.3% of the energy drinks had negligible levels of daily intake for lead. **Conclusion**: Lead, chromium, nickel and cobalt levels in some energy drinks in Nigeria are much higher than the permissible limits and continuous consumption may increase the burden of these metals on the body.

Key words: Daily intake, functional beverages, hazard quotient, health risk, heavy metals, Nigeria

INTRODUCTION

The increase in public concern worldwide regarding food hazards and a decline in public trust in food risk regulators suggests that there is a need to identify the actual concerns of the public in relation to specific food hazards in order to develop effective risk communication. Energy drinks refer to beverages that contain, besides calories, caffeine in combination with other presumed energy-enhancing ingredients such as taurine, herbal extracts, and B vitamins. Since the 1960s, the energy drink market has grown into a multibillion dollar business which has been reported to be the fastest

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growing segment in the beverage industry (Agriculture and Agri-Food Canada, 2008). Energy drinks have established a viable position in the beverage market as evidenced by their commonplace consumption in the morning, afternoon, and night, not only by general consumers, but those of age 18 to 34 in particular (Lal, 2007). Importance should be placed on consumer safety and an understanding of how these beverages are regulated.

For the maintenance of health, a great deal of preventive measures is in place to avoid ingestion of potentially toxic metal ions. From monitoring endogenous levels of metal ions in foods and drinks to detecting contamination during food preparation, developed countries spend significant resources to avoid metal intake by the general population (Rapid Alert System for Food and Feed (RASFF) *http://ec.europa.eu/food/food/rapidalert/index_en.htm*). In addition to playing a role in health and disease, dietary metal ions have been the focus of discussion on the mechanism of ageing. However, beyond radicals, metal ions can disrupt normal cell and tissue function through multiple pathways including interactions with proteins and other biomolecules and disruption of membrane potentials (Naughton & Petróczi, 2008). Recent analyses of the levels of metal ions in one brand of red wine and subsequent determination of Total Hazard Quotient THQ values revealed a significant concern to health for people ingesting one 250 mL glass per day. THQ values for daily ingestion of 250 mL of apple juice, stout and red wine were all above the safe value of 1 (Naughton & Petróczi, 2008). The results from this study also question a popular belief about the health-giving properties of red wine: that drinking red wine daily protects one from heart attacks is often related to levels of anti-oxidants. However the finding of hazardous levels of metal ions which can be pro-oxidants leads to a major question mark over the protective benefits of red wine (Naughton & Petróczi, 2008).

The present study investigated the heavy metal hazards of popular energy drinks in Nigeria by comparing levels of lead, cadmium, chromium, cobalt, and nickel with permissible limits given by World Health Organisation (WHO), United States Environmental Protection Agency (USEPA) and European Union (EU). The intake using the arithmetic mean according to Parkhurst (1998), daily intake of Dhaware , Deshpande & Khandekar (2009) and the total hazard quotient (THQ) of Singh *et al.* (2010) have all been employed in the risk assessment of these energy drinks. We have also investigated the label information and requirements.

METHODS

Using a basket market protocol, thirty brands of energy drinks (imported and locally manufactured) were purchased in August 2012 in Port-Harcourt, Rivers State, Nigeria for use in the study. The samples were ashed and digested in Teflon lab ware that had been cleaned in a high-efficiency particulate air (HEPA) filtered (class 100), trace-metal-clean laboratory to minimise contamination. This protocol involved sequential cleaning of the lab ware in a series of baths in solutions (1 week each) and rinses (five per solution) in a three-step order, namely a detergent solution and deionized water rinses, then 6N HCl (reagent grade) solution and ultrapure water rinses, and finally 7.5 N HNO_3 (trace metal grade) solution and ultra pure water rinses. The lab ware was then air dried in a polypropylene laminar air flow-exhausting hood. Dry ashing method was used by adding 30 ml of each sample into a conical flask and heating on a hot plate at 200°C, for 45 min, and then in a furnace at 500°C until the volume was drastically reduced to near dryness. Digestion was done by the addition of 10 ml of concentrated aqua regia (HCl: HNO_3, 3:1) which was then heated to dryness. An amount of 20 ml deionised water was added, stirred and filtered. The filtrate was made up in standard volumetric flask and lead, cadmium, chromium, cobalt and nickel concentrations were assayed with atomic absorption spectrophotometer 205A. The limit of detection (LOD) of Cd, Cr, Co and Ni was 0.001 whereas the LOD of Pb was 0.01 ppm with blank values reading as 0.00 ppm for all the metals in deionised water with an electrical conductivity value of lower than 5 μS/cm. Samples were analysed in triplicates.

The intake using the arithmetic mean according to Parkhurst (1998) was calculated by multiplying contaminant level, that is, chemical element level by amount/ volume of beverage. In all the estimated intakes of lead, cadmium, chromium, cobalt and nickel concentrations, one and half liters were assumed to be the average volume of the beverages and the maximum contaminant level (MCL) for adults.

Daily intake (DI)

The daily intake (DI) was calculated based on the modification of a generic equation by Dhaware *et al.* (2009):

$$\text{DI } (\mu\text{g/day}) = C_{\text{metal}} \times V_{\text{analysis}} \times D_{\text{intake}}$$

Where

C_{metal} is the metal concentration in sample taken for analysis

V_{analysis} is the volume of sample taken for analysis

D_{intake} is the daily intake (number of cans per day, 2 cans / day)

For the assessment of health risks through consumption of energy drinks contaminated by heavy metals, THQ was calculated following the methodology described by United States Environmental Protection Agency (US EPA, 1989: 2000). The dose calculations were made using the standard assumption for an integrated US EPA risk analysis, based on 60kg as the average body weight of an adult and the assumption that the ingested dose is equal to the absorbed contaminant dose (Cooper, Doyle & Kipp, 1991). A hazard quotient of no more than 1.0 indicates that the intake of a contaminant would result in no significant adverse effects.

THQ was determined based on the modification of generic equation by the equation of Singh *et al.* (2010):

$$\text{THQ} = (\text{EFr} \times \text{ED}_{\text{tot}} \times \text{BIR} \times C \,/\, \text{RfD}_o \times \text{BW}_a \times \text{AT}_n) \times 10^{-3}$$

Where EFr = Exposure Frequency = 156 days/year, equivalent to three times a week

ED_{tot} = Exposure Duration = 70 years, equivalent to average lifetime

BIR = Beverage Ingestion Rate = 0.5L/ day, equivalent to two cans of energy drink per day, each 250mL

C = Concentration of metal in beverage = μg/L

RfD_o = oral Reference Dose = mg/kg/ day

BW_a = average Body Weight, adult = 60kg

AT_n = Average exposure time for non-carcinogens in days [EFr(156 days/year) x ED_{tot}(number of exposure years, assuming 70 years in this study)]

10^{-3} = the unit of conversion

RESULTS

Heavy metal levels (mg/l) and label information of the energy drinks namely the countries where the analysed energy drinks were produced, drinks with NAFDAC number, manufacture dates as well as expiry dates are shown on Table 1. Only 6.7% of the energy drinks analysed were found to be produced locally while others were imported. About 46.7% of the energy drinks imported were without NAFDAC number.. About 6.7% were without expiry dates, and their place of manufacture was not indicated while 26.7 % did not indicate manufacture dates. The mean and range of chromium, cobalt, lead and nickel were (0.129, 0.001-0.699), (0.097, 0.001-0.462), (0.031, 0.001-0.053) and (0.189, 0.001- 0.583) mg/l respectively.

Table 1. Heavy metal levels (mg/l) and label information of the energy drinks

Product name	*Place of manufacture*	*NAFDAC number*	*Production date*	*Expiry date*	*Chromium*	*Cadmium*	*Cobalt*	*Lead*	*Nickel*
5HE	NI	NI	NI	-/07/2013	<0.001	<0.001	<0.001	0.0314	0.0461
BE	USA	A1-1811	02/04/2012	01/04/2014	<0.001	<0.001	0.0895	0.0449	0.0504
BJ	EU	NI	20/12/2011	20/12/2013	0.3241	<0.001	0.0363	<0.001	0.1618
BS	Austria	A1-2644	24/08/2011	24/08/2013	0.4752	<0.001	0.0217	0.0163	0.0364
Bo	UK	NI	NI	13/10/-	0.0037	<0.001	0.017	0.0117	0.2123
Bul	England	A1-5034	07/05/2012	07/11/2013	0.2343	<0.001	0.0061	0.037	0.3653
Command	Thailand	A1-0945	02/04/2012	01/04/2014	0.043	<0.001	0.0417	0.0418	0.0374
Envi	Korea	A1-9281	06/03/2012	05/03/2014	0.049	<0.001	0.0024	0.0193	0.2758
FABED	USA	NI	06/01/2012	06/01/2014	0.0181	<0.001	0.0121	0.0236	0.281
HEE	South Africa	NI	NI	NI	0.1887	<0.001	0.0749	0.0225	0.2084
LB	Nigeria	01-1305	-/04/2012	-/01/2013	0.0724	<0.001	0.0182	<0.001	0.0421
LE	UK	NI	NI	-/12/2012	0.0471	<0.001	0.0076	<0.001	0.0167
LS	Nigeria	A1-3933	04/02/2012	01/02/2013	0.0487	<0.01	0.0325	0.0167	0.1894
MU	SAU	NI	NI	10/12/2013	<0.001	<0.001	0.0298	0.0328	0.0697
NED	Malaysia	A1-3313	20/12/2011	19/12/2012	0.0269	<0.001	<0.001	<0.001	0.0531
PH	EU	NI	01/12/2011	01/12/2013	0.387	<0.001	0.0972	0.037	0.2598
P Horse	Austria	01-6204	24/04/2012	24/04/2014	0.1756	<0.001	0.0133	0.0274	0.4543
P Malt	Denmark	NI	NI	04/03/2013	0.0112	<0.001	<0.001	<0.001	0.3151
PP	Dubai-UAE	NI	27/05/2012	26/05/2013	<0.001	<0.001	0.3556	<0.001	0.0469
P Sport	EU	NI	26/04/2012	26/04/2014	0.0769	<0.01	0.0014	<0.001	0.0803
PU	*	NI	NI	-/12/2012	0.0011	<0.001	0.2429	<0.001	0.0472
RB	Austria	01-6209	NI	08/02/2014	<0.001	<0.001	0.0453	<0.001	0.0522
Rock	USA	B1-2798	02/04/2012	02/04/2014	<0.001	<0.001	0.0064	0.0452	<0.001
SD	UK	NI	-/08/2013	NI	0.0493	<0.001	0.0312	0.0411	<0.001
V 500	Korea	A1-2891	12/07/2011	11/07/2013	0.0196	<0.001	<0.001	0.0275	0.0758
VME	Thailand	A1-8989	06/01/2012	06/01/2013	0.0189	<0.001	<0.001	0.0313	0.583
Vita	Japan	A1-9548	*	*	0.0642	<0.001	<0.001	0.0271	0.0959
Well M	England	01-7208	30/11/2011	13/03/-	0.0562	<0.001	0.3421	0.0393	<0.001
Win	NI	NI	21/02/2012	21/02/2014	0.0011	<0.001	0.3396	<0.001	0.7583
XTC	Austria	A1-1791	14/12/2011	14/12/2013	0.6989	<0.001	0.4617	0.0532	0.2753

NI - Not indicated

* - Language used not understood

Table 2. Heavy metal levels (mg/l) and percentage violation of standards

Heavy metal	*Average*	*Range*	*WHO Limits*		*USEPA Limits*		*EU Limits*		*Percentage of samples in violation(WHO/ EPA/EU)*
			Lower	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*	
Chromium	0.129	0.001 -0.699	-	0.05	-	0.1	-	0.05	36.7%/23.3%/36.7%
Cadmium	-	-	-	0.005	-	0.005	0.003	0.005	nil/nil/nil
Cobalt	0.097	0.001 -0.462	-	-	-	-	-	0.005	-/-/70%
Lead	0.031	0.001 -0.053	-	0.01	-	0.05	-	0.002	66.7%/3.3%/66.7%
Nickel	0.189	0.001 -0.583	-	-	-	-	-	0.02	-/-/86.7%

Table 3. Example of calculating heavy metal weekly intake.

True Cr intake = 1.5 *x 0.6989 + 1.5 x 0.0493 + 1.5 x 0.1756 = 1.3857mg/L Cr
True Co intake = 1.5 x 0.4617 + 1.5 x 0.0312 + 1.5 x 0.0895 = 0.8736mg/L Co
True Pb intake = 1.5 x 0.0328 + 1.5 x 0.0370 + 1.5 x 0.0532 = 0.1845mg/L Pb
True Ni intake = 1.5 x 0.2810 + 1.5 x 0.4543 + 1.5 x 0.2753 = 1.5159mg/L Ni

*(1.5 L is assumed to be the weekly beverage consumption, which is multiplied by the highest concentration of heavy metal contaminant from each beverage group: the volume of the each beverage was assumed to be one litre).

Table 2 shows the heavy metal levels and percentage violation of standards when compared with permissible limits given by World Health Organisation (WHO), United States Environmental Protection Agency (US EPA) and European Union (EU). About 66.7%, 3.3%, and 66.7% of the energy drinks violated the WHO, EPA and EU permissible limits for lead respectively. Only 36.7%, 23.3% and 36.7% of the energy drinks violated the WHO, EPA and EU permissible limits for chromium respectively. Seventy percent and 86.7% of the energy drinks violated the EU permissible limits for cobalt and nickel respectively. Cadmium did not show any violation.

The estimated/calculated intakes for chromium, cobalt, lead and nickel are shown in Table 3. The calculated amounts of chromium, cobalt, lead and nickel of a energy drink consumed by a consumer who takes an average weekly volume of 1.5 L (1.5 L of the 3 energy drink) are 1.3857, 0.8736, 0.1845 and 1.5159 mg/L respectively.

Table 4 shows the calculated THQ values to assess the potential health risk in the consumption of contaminated energy drinks. These results were calculated using the reference doses (Cr - 1.5; Ni - 2.0×10^{-2}; Pb - 1.5; Cd - 5×10^{-4}) of the various metals as stipulated by US EPA (US EPA, 2000). There is no oral reference dose for cobalt. All the THQ values were below 1.

Table 5 shows the daily intake of lead, cadmium chromium and cobalt compared with the provisional tolerable weekly intake (PTWI) and the proposed maximum permissible level suggested by the Food and Agriculture Organization /World Health Organization (FAO/WHO, 1989).

Table 4. Target hazard quotient for different heavy metals from consumption of energy drinks

Energy drinks	*Cr*	*Cd*	*Co*	*Pb*	*Ni*
5 HE	0.0000	0.0167	-	0.0002	0.0192
BE	0.0000	0.0167	-	0.0002	0.0210
BJ	0.0018	0.0167	-	0.0000	0.0674
BS	0.0026	0.0167	-	0.0001	0.0152
Bo	0.0000	0.0167	-	0.0001	0.0885
Bul	0.0013	0.0167	-	0.0002	0.1522
Command	0.0002	0.0167	-	0.0002	0.0156
Envi	0.0003	0.0167	-	0.0001	0.1149
FABED	0.0001	0.0167	-	0.0001	0.1171
HEE	0.0010	0.0167	-	0.0001	0.0868
LB	0.0004	0.0167	-	0.0000	0.0175
LE	0.0003	0.0167	-	0.0000	0.0070
LS	0.0003	0.0167	-	0.0001	0.0789
MU	0.0000	0.0167	-	0.0002	0.0290
NED	0.0001	0.0167	-	0.0000	0.0221
PH	0.0022	0.0167	-	0.0002	0.1083
P Horse	0.0010	0.0167	-	0.0002	0.1893
P Malt	0.0001	0.0167	-	0.0000	0.1313
PP	0.0000	0.0167	-	0.0000	0.0195
P Sport	0.0004	0.0167	-	0.0000	0.0335
PU	0.0000	0.0167	-	0.0000	0.0197
RB	0.0000	0.0167	-	0.0000	0.0218
Rock	0.0000	0.0167	-	0.0003	0.0004
SD	0.0003	0.0167	-	0.0002	0.0004
V 500	0.0001	0.0167	-	0.0002	0.0316
VME	0.0001	0.0167	-	0.0002	0.2429
Vita	0.0004	0.0167	-	0.0002	0.0400
Well M	0.0003	0.0167	-	0.0002	0.0004
Win	0.0000	0.0167	-	0.0000	0.3160
XTC	0.0039	0.0167	-	0.0003	0.1147

Table 5. Permissible intake levels as per FAO/WHO recommendations

Metal	*Provisional tolerable weekly intake(ig/kg/week)*	*Per Day Intake (ig/kg/day)*	*For a 60-kg individual (ig/day)*	*Ref.*
Pb	25.0	5.0	300.0	FAO/WHO
Ni	1.0	0.2	12.0	FAO
Cd	3.5	0.2-1.0	30.0	WHO/JECFA
Cr	0.5	0.1	6.0	FAO

DISCUSSION

The primary aim of this study is to ascertain the levels of heavy metals such as lead, cobalt, chromium, nickel and cadmium in functional drinks sold in Nigerian markets. This is done with a view to lending credence to the assertion by Gidlow (2004) that irrespective of the effort to reduce heavy metal exposure in the general population, legislation must be based on genuine scientific evaluation of the available evidence. We are not aware of any previous study that has determined the THQs and investigated the heavy metal levels of energy drinks in Nigeria.

Most of the energy drinks in this study were imported and had some degree of violation of label requirements. The mean and range of chromium was 0.129, 0.001-0.699 mg/1; cobalt 0.097, 0.001-0.462mg/1; lead 0.031, 0.001-0.053mg/1; and for nickel, it was 0.189, 0.001- 0.583 mg/l. Lead showed the highest percentage of violation when compared with WHO, EPA and EU permissible limits in the energy drinks. For a consumer who takes an average weekly volume of 1.5L, the estimated/calculated amount of chromium, cobalt, lead and nickel was 1.3857, 0.8736, 0.1845 and 1.5159 mg/L respectively. Consumption of XTC, P Horse, PH, HEE, Bul, BS and BJ will lead to high daily intake of Cr, with XTC having the highest value; XTC, Win, Well M, PU and P P energy drinks have high values of daily intake rates of cobalt; Win shows the highest nickel intake rate. Only 33.3% of the energy drinks had negligible levels of daily intake for lead. These values are higher than the Provisional Tolerable Weekly Intake [(PTWI) (μg/kg/week)].

In addition to the endogenous heavy metal content of foods, steps during processing and packaging may add to the heavy metal burden. Probably the continuous exposure that accompanies repetitive ingestion of foods that contain known low levels of heavy metals may be of greater public health importance. A key potential source of exposure is processed beverages that are known to contain metals, and frequent exposure may result in accumulative effects. Common beverages are assessed for their metal content with regulatory controls over maximum permitted levels in place in most countries. These permitted levels are subject to frequent review and revisions and take account of varying dietary habits in different populations and countries. The heavy metal in beverages has been determined in several studies for consumer protection against contamination, method development or an evaluation of the nutritional status (Moreno *et al.*, 2008).

Lead and cadmium are described as the most dangerous contaminants in human civilization (Jarup, 2003) due to the extent that they are distributed in the environment as polluting elements. The toxicity of Pb and Cd at high levels of exposure is well known, but continual exposure to relatively low levels of lead may entail adverse health effects. An increase in Pb and Cd may cause serious health hazards such as both acute and chronic poisoning, pathological change of organs and diseases related to cardiovascular, kidney, bone, and liver, and they can even cause cancer owing to excessive accumulation in the human body (Jarup, 2003). The importance of lowering the blood lead limit to 2 μg/ dL is affirmed by sufficient scientific evidence to show that an 10 μg /dL lead level could compromise neuro-behaviour development in kids (Bellinger, 2008). Sterility and spontaneous abortion are also caused by prolonged exposure to lead (Mendola, Messer & Rappazzo (2008). Prolonged exposure precipitates lead accumulation in the body in an asymptomatic manner, leading to different health effects which manifest only after a medium-long time period through high blood pressure, renal damages, anemia, and learning difficulties etc.

Although chromium, in limited amounts, is an essential nutrient that helps in the utilisation of sugar protein and fat in the body, high levels of chromium, however, can cause irritation to the nose, and cause a running nose, nosebleeds, and ulcers and perforations in the nasal septum. Ingesting large amounts of chromium can cause stomach upsets and ulcers, convulsions, kidney and liver damage, lung function and blood system problems and even death. Death may be the result of pulmonary or cardiac arrest (ATSDR, 2000). Although it has long been established that inhalation of chromium, in particular hexavalent chromium (CrVI), can cause human lung cancer (IARC, 1990) a recent publication by Beaumont *et al.* (2008) on a study in the Liaoning Province in China documents increased cancer risks following ingestion of CrVI in drinking water; in particular, increased stomach cancer risks were demonstrated, but some evidence also indicated increased lung cancer risks.

Soft drinking water and acidic beverages may dissolve nickel from containers. While nickel has long been recognised as a contact irritant, many studies have also demonstrated dermal effects in sensitive humans resulting from ingesting nickel (IRIS, 2005). The existence of clinically relevant systemic reactions to oral nickel exposure, especially systemic reactions to nickel in the daily diet, remains controversial (Cempel & Nikel 2006). Other studies have shown that oral exposure to nickel may invoke an eruption or worsening of eczema in nickel sensitive individuals; however, a dose-response relationship is difficult to establish (Jensen *et al.*, 2003). Chronic non-cancer health effects may result from long-term exposure to relatively low concentrations of pollutants. Acute health effects generally result from short-term exposure to high concentrations of pollutants, manifested as a variety of clinical symptoms (nausea, vomiting, abdominal discomfort, diarrhea, visual disturbance, headache, giddiness, and cough). Nickel has been shown to inhibit DNA repair in a way that may play a role in its toxicity. It has been proposed that nickel may bind to DNA-repair enzymes and generate oxygen free radicals which cause *in situ* protein degradation. This irreversible damage to the proteins involved in DNA repair, replication, recombination, and transcription could be important for the toxic effects of nickel (Lynn *et al.* 1997). Often co-exposure to a second carcinogen causes a synergistic cancer increase (Duda-Chodak & Baszczyk 2008). This co-exposure to other carcinogens is of vital public health importance in sub Sahara Africa given the recent trend towards a cancer storm.

Cobalt exerts well-known and documented toxic effects on the thyroid, heart and the haematopoietic system, in addition to occupational lung disease, allergic manifestations and a probable carcinogenic action. Cobalt neurotoxicity is reported in isolated cases, but it has never been systematically treated (Catalani *et al.*, 2012). Cobalt is acutely toxic in larger doses, and in mammalian *in vitro* test systems, cobalt ions and cobalt metal were found to be cytotoxic, inducing apoptosis and at higher concentrations, necrosis with inflammatory response. Cobalt metal and salts are also genotoxic, mainly caused by oxidative DNA damage by reactive oxygen species, perhaps combined with inhibition of DNA repair. Of note, the evidence for carcinogenicity of cobalt metal and cobalt sulfate is considered sufficient in experimental animals, but is as yet considered inadequate in humans. Interestingly, some of the toxic effects of cobalt (Co^{2+}) have recently been proposed to be due to putative inhibition of Ca^{2+} entry and Ca^{2+}-signaling and competition with Ca^{2+} for intracellular Ca^{2+}-binding proteins (Simonsen, Harbak & Bennekou (2012).

Drinking water generally contains nickel at concentrations of less than 10 $\mu g/l$ (Cempel & Nikel 2006). The safe permissible limits for Pb, Cd, Cr for water and other food products are 15, 5 and 100 parts per billions (Joanne, Arsenault & Brown (2003)). That the concentration detected in this study in various energy drinks samples was much higher than these safe permissible limits is a matter of great concern.

The target hazard quotient THQs values to assess the potential health risk in the consumption of contaminated energy drinks using the reference doses (Cr – 1.5; Ni – 2.0×10^{-2}; Pb – 1.5; Cd – 5×10^{-4}) of the various metal as stipulated by US EPA (US EPA, 2000) were all below 1. THQ values were developed by the Environmental Protection

Agency (EPA) in the US for the estimation of potential health risks associated with long term exposure to chemical pollutants (US EPA, 1989). The THQ is a ratio between the measured concentration and the oral reference dose, weighted by the length and frequency of exposure, amount ingested and body weight. The THQ value is a dimensionless index of risk associated with long term exposure to chemicals based upon reference upper safe limits.

A limited number of THQ investigations have been reported in foodstuffs with the focus being on estimating health risks associated with exposure to heavy metals found in sea foods and in one case breast milk (US EPA, 1989). This study adds to the short list of THQ investigations that have been reported in beverages (Naughton & Petróczi, 2008,). The THQ values calculated in this study suggest the safety of these energy drinks since all the THQ values were below 1. The interpretation of the THQ value is binary: THQ is either ≥ 1 or < 1, where THQ > 1 indicates a reason for health concern (US EPA, 1989). It must be noted that THQ is not a measure of risk (Tannenbaum, Johnson & Bazar, 2003) but indicates a level of concern and while the THQ values are additive, they are not multiplicative,for example, the level of concern at THQ of 20 is larger but not tenfold of those at THQ = 2. Many of the toxic effects associated with metals are still under investigation, especially for low concentrations and for lifetime exposure. It is notable that for many metal ions, upper safe limits are unavailable which prevents THQ estimations (Tannenbaum, Johnson & Bazar 2003). Apart from some well recognised cases of metal ion overload, the full effects of metal ions in the body may remain in the realm of sub-clinical pathology acting through numerous mechanisms including oxidative stress.

Most of the energy drinks > 90% were imported with 46.7% not registered by the regulatory body, 6.7% without expiry dates and their place of manufacture, while 26.7 % did not indicate manufacture dates. Orisakwe (1992) and Stanley *et al.* (2010) have documented that most consumables in Nigeria show varying degrees of label requirements.

CONCLUSION

The absence of regulations relevant to the export of energy drinks could allow the sale of products with harmful ingredients that jeopardise consumer health. The important findings of this study are that the concentration of some of the toxic metals like lead, chromium, and cadmium are much higher than the safe permissible limits, which is a matter of grave concern. This data indicate that the continuous consumption of these energy drinks could result in an increase in the trace metal levels in the body beyond acceptable limits. The consumption of these energy drinks needs to be considered as a source of lead, cadmium, chromium in evaluating patients with symptoms of lead intoxication in Nigeria.

In view of the varying degree of violation of the toxic metal content of the energy drinks involved in the present study, we do agree with the cautionary remarks of previous workers (Seifert *et al.*, 2011) that toxicity surveillance should be improved, and regulations related to energy drink sales and consumption should be based on appropriate research. Although the THQ values found in this study suggest safety of the energy drinks, potentially hazardous metal ions have been found in some beverages in Nigeria warranting further research in the interest of public health to determine the mechanisms of metal inclusion/retention during beverage production. In addition, levels of metal ions should appear on labels of beverages along with the introduction of further steps to remove key hazardous metal ions during production.

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