HEAVY METAL CONTENT AND ASSOCIATED HEALTH RISKS IN SELECTED ENERGY DRINKS SOLD IN BIRNIN KEBBI, NIGERIA.

*1Yahaya, T.O., 2Gulumbe, B.H., 3Umar, A.K., 3Yusuf, A., 4Mohammed, A.Z., 1Izuafa, A. & 1Abubakar, A.

1Department of Biological Sciences, Federal University Birnin Kebbi, PMB 1157, Kebbi State, Nigeria
2Department of Microbiology, Federal University Birnin Kebbi, Kebbi State, Nigeria
3Department of Biochemistry and Molecular Biology, Federal University Birnin Kebbi, Kebbi State, Nigeria
4Department of Pure and Industrial Chemistry, Federal University Birnin Kebbi, Kebbi State, Nigeria

*Corresponding Author's E-mail: yahayatajudeen@gmail.com; yahaya.tajudeen@fubk.edu.ng

INTRODUCTION

Energy drinks are sold worldwide because they boost physical and mental performance. However, studies show that some of them contain high levels of heavy metals, prompting a safety evaluation of all brands of energy drinks. This study evaluated the safety of three brands of energy drinks (Fearless, Monster, and Power Horse) sold in Birnin Kebbi, Nigeria, with regard to heavy metal concentrations. The heavy metals evaluated are iron (Fe), copper (Cu), cadmium (Cd), zinc (Zn), and lead (Pb). Samples of the energy drinks were subjected to atomic absorption spectroscopy, and the results were compared with the World Health Organization standards for drinks. The average daily intake (ADI), hazard quotient (HQ), and carcinogenic risk (CR) of the heavy metals were also calculated. The levels of Fe, Cu, and Cd were above the permissible limits in all the energy drinks, while zinc (Zn) and lead (Pb) were below the permissible limits. The ADI of the heavy metals in the three energy drinks was within the recommended limits. However, the HQ and CR of Cd in all the energy drinks and Pb in Power Horse were beyond the recommended limits (HQ > 1 and CR > 10⁻⁶). This suggests that the three energy drinks sold and consumed in Birnin Kebbi may pose health hazards. There is a need to sensitize consumers in the city about the occurrence and risk of heavy metals in energy drinks.

Keywords: Carcinogenic risk, Energy drinks, Hazard quotient, Heavy metals, Lead
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 (Hardy et al., 2017). Energy drinks first appeared
in Europe and Asia in the 1960s in response to consumer demand for a dietary supplement that would result in increased
energy (Erdmann et al., 2021). Taisho Pharmaceuticals, a Japanese company, introduced Lipovitan D, one of the earliest
energy drinks, in 1962, and it continues to dominate the Japanese market today. Energy drinks are part of the functional
beverage category, which also includes sports and nutraceutical drinks (Alsuni, 2015). Heavy metals such as copper
(Cu), iron (Fe), manganese (Mn), zinc (Zn), lead (Pb), and cadmium (Cd) can be found in energy drinks (Kilic et al.,
2018; Golam et al., 2021).

Heavy metal contamination in energy drinks and other foods is frequently caused by environmental and industrial
contamination (Izah et al., 2017). Plant materials are commonly used as an active ingredient in beverage manufacture.
For example, plant-based hops and cereals are used in the production of beer, and the soil in which they are grown may
be contaminated by pesticides and fertilizers that may contain traces of heavy metals (Ubuoh et al., 2013). During
manufacturing and packaging, energy drinks may also become contaminated (Magomya et al., 2015). Heavy metals are
classified into two categories: essential and non-essential. Essential heavy metals are important for human health and the
health of other living organisms (Izah et al., 2016). However, essential heavy metals can be harmful to living organisms
if their concentration exceeds the organism's tolerated limit (Izah et al., 2016). Even at low concentrations, non-essential
heavy metals may be hazardous to the body’s cells. High levels of heavy metals can cause biological pathways in the
blood, colon, liver, kidney, skin, and cardiovascular systems to malfunction. Individual reactions to heavy metal exposure
can be influenced by nutritional status, metabolic rate, the integrity of detoxification pathways, the route and degree of
heavy metal exposure, and age (Ogunlana et al., 2015).

Thus, assessment of heavy metals in various brands of energy drinks sold in every locality is necessary to ensure
consumer safety (Magomya et al., 2015). To the best of our knowledge, no study has evaluated the levels of heavy metals
in various brands of energy drinks sold in Birnin Kebbi, Nigeria. This study, therefore, assessed the levels and health risk
of heavy metals in three brands of energy drinks (Fearless, Monster, and Power Horse) sold in Birnin Kebbi, Nigeria.

METHODOLOGY

DESCRIPTION OF STUDY AREA

This study was conducted in Birnin Kebbi, Northwestern Nigeria. Birnin Kebbi is the capital of Kebbi State and the
administrative center of the Gwandu Emirate, located at latitude 12° 27’ 57.8808” N and longitude 4° 11’ 58.2864” E
(World Atlas, 2015). The city had an estimated population of 125,594 in 2007. Kebbi is dominated by the Hausa and
Fulani tribes (The World Gazetteer, 2007). Kebbi State was created out of the old Sokoto State in 1991. The state is
divided into four emirates (Gwandu, Argungu, Yauri, and Zuru) and twenty-one local government areas (Yahaya et al.,
2022).

The natural vegetation of the state is an intermix of Sudan and the Guinea Savannah. However, long-term
anthropogenic activities have changed the natural vegetation of the area. On average, Birnin Kebbi has a monthly and
annual rainfall of 112.21 mm and 787.53 mm, respectively, with rainy seasons spanning through April and October, and
reaching peak periods in June, July, August, and September. The average temperature is 260 C, but could rise above 400
C in the peak of the hot season (March-July) and fall as low as 210 C during harmattan, between December and February
(Yahaya et al., 2022).
SAMPLE COLLECTION
Ten (10) samples each of Fearless, Monster, and Power Horse energy drinks (a total of 30) were randomly purchased every other week in Birnin Kebbi between March 2021 and April 2021. In between the mentioned months, four field samplings were made, resulting in the overall collection of 120 samples of the energy drinks. The batch numbers of the samples of each brand of energy drink differed from one sampling week to another. The selection of the three brands of energy drinks was based on the most popular brands consumed by high and low-income earners in Nigeria. Samples were stored in almost the same conditions, similar to those of retail shops before heavy metal analysis.

HEAVY METAL ANALYSIS
The heavy metals in the samples were analyzed as described by Yahaya et al. (2012). Exactly 15 ml of each sample was added to 15 ml of distilled water and 15 ml of concentrated nitric acid in a beaker. The beaker was heated gently till the total volume was reduced to about 15ml to break the complex bonds and release the sample into solution. Red fumes were observed, indicating the release of nitric acid. The solution was filtered into another beaker, made up to 50 ml with distilled water and mixed thoroughly. The samples were left to settle before being analyzed for zinc (Zn), cadmium (Cd), lead (Pb), copper (Cu), and iron (Fe) using the PG-990 atomic absorption spectrophotometer (AAS).

QUALITY ASSURANCE AND CONTROL
Glassware and plastic materials were washed with detergent solution and rinsed with deionized water. The materials were thereafter sterilized with 10% nitric acid and rinsed again with deionized water. To ensure the accuracy of all values, the background contamination of the samples was checked by analyzing black samples after analyzing five samples, and all analyses were replicated three times. The reproducibility of the values was at a 95% confidence level. All the chemicals used were of high analytical grade.

HUMAN HEALTH RISK ASSESSMENT
The health risk of daily consumption of the energy drinks was calculated from the average daily intake (ADI), hazard quotient (HQ), and carcinogenic risk (CR) of the heavy metals in the drinks.

AVERAGE DAILY INTAKE
Equation 1 was used to calculate the average daily intake (ADI) of heavy metals from the drinks (Magomya et al., 2015). Table 1 shows the standard values for calculating the ADI of heavy metals (Yahaya et al., 2021). Oral reference doses for Zn, Cu, Pb, Fe, and Cd are shown in Table 2 (Iwuanyanwu and Chioma, 2017).

\[
ADI = \frac{C_{\text{drink}} \times IR \times EF \times ED}{BWT \times AT}
\]

From equation 1, ADI is the average daily intake of heavy metals via ingestion, C_{drink} represents the concentration of a heavy metal in energy drink, IR shows the ingestion rate per unit time, EF indicates the exposure frequency, ED reveals the exposure duration, BWT indicates the body weight and AT is the average time.
HAZARD QUOTIENT

The hazard quotient (HQ) of oral exposure to heavy metals in the energy drinks was calculated using equation 2 (Masok et al., 2017). Table 1 shows the standard values for calculating the HQ of oral exposure to heavy metals (Yahaya et al., 2021). A hazard quotient of 1 or lower means that adverse non-cancer effects are unlikely, and thus it can be considered to have a negligible hazard (Adepoju and Ojo, 2014).

\[
\text{HQ} = \frac{C_{\text{drink}} \times IR \times EF \times ED}{AT \times BW \times R_{fD}(\text{oral})}
\]

Equation 2

From equation 2, HQ is the hazard quotient of daily ingestion of heavy metals, C\text{drink} represents the concentration of a heavy metal in an energy drink, IR shows the ingestion rate per unit time, EF indicates the exposure frequency, ED reveals the exposure duration, AT is the average time, BW indicates the body weight, and RfD (oral) denotes the oral reference dose.

CARCINOGENIC RISK

The CR of oral exposure to heavy metals in the energy drinks was calculated using equation 3 (Iwuanyanwu and Chioma, 2017). Standard values for calculating the CR of exposure to heavy metals are shown in Table 3 (Masok et al., 2017). The range of CR that is acceptable or tolerable is \( \leq 10^{-6} \) (USEPA, 2011).

\[
\text{CR} = \text{CSF} \times \text{ADI}
\]

Equation 3

From equation 3, CSF is the cancer slope factor.

DATA ANALYSIS

Data obtained from various energy drink samples were presented as mean ± standard deviation (SD). The average daily intake (ADI), hazard quotient (HQ), and carcinogenic risk (CR) were calculated.

RESULTS

LEVELS OF HEAVY METALS IN THE ENERGY DRINKS

Table 5 shows the levels of Zn, Cu, Pb, Fe, and Cd in Fearless, Monster, and Power Horse energy drinks purchased in Birnin Kebbi. Fearless contained World Health Organization (WHO) non-permissible levels of Cu, Fe, and Cd. Monster contained non-permissible levels of Fe and Cd. Power Horse contained non-permissible levels of Pb, Fe, and Cd. Zinc was detected at permissible levels in all the brands.

HEALTH RISK ASSESSMENT OF THE ENERGY DRINKS

The average daily intake (ADI) of heavy metals from the energy drinks is shown in Table 6. Compared with the recommended limits (RDI), the ADI of all the evaluated heavy metals was within the recommended limits.

Table 7 shows the hazard quotient (HQ) of heavy metals, while Table 8 shows the carcinogenic risk (CR) of heavy metals. The HQ and CR of Cd in all the energy drinks and Pb in Power Horse were beyond the recommended limits, while other heavy metals were normal.
DISCUSSION

The heavy metal profiles and health risks of daily consumption of Fearless, Monster, and Power Horse energy drinks sold in Birnin Kebbi are determined in this study. This study was conceptualized to investigate the involvement of energy drinks in human exposure to heavy metals. Table 5 shows that samples of the three brands of energy drinks contained non-permissible levels of two or more of the evaluated heavy metals (Cu, Pb, Fe, and Cd), except Zn. This suggests that daily consumption of the energy drinks might predispose consumers to health hazards. Excessive levels of heavy metals can cause many health problems, including impairment of mental and neurological functions, neurotransmitter production and utilization, and alter numerous metabolic processes (Balali-Mood et al., 2021). The result of the current study is consistent with that of Salako et al. (2016), who detected permissible levels of Zn in samples of Schappes energy drink purchased in Lagos, Nigeria. The result is also in line with those of Izah et al. (2017) and Udota and Umuodofia (2011), who reported high concentrations of heavy metals including Cu and Cd above the recommended limits in certain energy drinks in Nigeria. Moreover, the result is consistent with Magomya et al. (2015), who detected permissible levels of Pb in some alcoholic and non-alcoholic beverages purchased in Nigeria.

Tables 7 and 8 further show that the hazard quotient (HQ) and carcinogenic risk (CR) of Cd in all the energy drinks as well as Pb in Power Horse were beyond the recommended limits. This finding again proved that energy drinks can induce toxicity. Because the risk was calculated using life expectancy, it may be more dangerous to consumers who live beyond the average life expectancy of Nigerians (55 years). The finding also indicates that Cd and Pb pose more risk to consumers than other evaluated heavy metals. Cadmium is highly toxic and exposure to the heavy metal can cause cancer and target the body’s cardiovascular, renal, gastrointestinal, neurological, reproductive, and respiratory systems (Kim et al., 2020). Abnormal levels of Pb may cause high blood pressure, vitamin D and calcium metabolism imbalances, neurological disorders, and multi-organ damage (Popoola et al., 2019). Although the HQ of other heavy metals was within the permissible range, in strict toxicological terms, there is no safe level for heavy metals. These heavy metals can combine additively and pose a significant risk to those who are exposed (Yahaya et al., 2021).

CONCLUSION

The findings of this study demonstrated that Power Horse and Monster energy drinks consumed in Birnin Kebbi contain high levels of Fe, Pb, and Cd, while Fearless energy drink contains Cu in addition to the mentioned heavy metals. The average daily intake (ADI) of heavy metals from the energy drinks was within the recommended limits. However, the hazard quotient (HQ) and carcinogenic risk (CR) of Cd in all the energy drinks and Pb in Power Horse were beyond the recommended limits. This suggests that the three energy drinks sold and consumed in Birnin Kebbi may not be suitable for consumption.

RECOMMENDATIONS

Based on the findings of this study, the following are recommended:

- Consumers should be sensitized on the occurrence and risk of heavy metals in energy drinks.
- Agencies responsible for monitoring the safety of food and drinks, such as the National Agency for Food and Drug Administration and Control (NAFDAC), should compel the producers of energy drinks to do quality control.
- Similar studies are needed to ascertain the health safety of other energy drinks.
CONFLICT OF INTEREST

The authors have no conflict of interest.

REFERENCES

Adepoju, O.T. and Ojo, V.O. (2014). Consumption pattern of energy drinks by university of Ibadan students and associated health risks factors. Food and Nutrition Sciences, 5(22): 2209-2216. DOI: 10.4236/fns.2014.522234.

Alsunny, A.A. (2015). Energy Drink Consumption: Beneficial and Adverse Health Effects. International Journal of Health Sciences, 9 (4): 468-474. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4682602/.

Balali-Mood, M., Naseri, K., Tahergorabi, Z., Khazdair, M.R. and Sadeghi, M. (2021) Toxic Mechanisms of Five Heavy Metals: Mercury, Lead, Chromium, Cadmium, and Arsenic. Frontier in Pharmacology, 12:643972. Doi: 10.3389/fphar.2021.643972.

Erdmann, J., Wiciński, M., Wódkiewicz, E., Nowaczewska, M., Otto, S.W., Kubiak, K. and Huk-Wieliczuk, E. (2021). Malinowski, B. Effects of Energy Drink Consumption on Physical Performance and Potential Danger of Inordinate Usage. Nutrients, 13: 2506. https://doi.org/10.3390/nu13082506.

Golam, KAHM, Khalequzzaman, M., Khan, A.F., Rayna, E.S., Khan, M.M.H., Saha, B.K., Motalab, M. and Islam, S.S. (2021). Health-compromising ingredients in fizzy drinks available in the markets of Dhaka city, Bangladesh. Journal of Food Science and Nutrition Research, 4: 057-065. DOI: 10.26502/jfsnr.2642-11000062.

Hardy, R., Kliemann, N., Evansen, T. and Brand, J. (2017). Relationship between energy drink consumption and nutrition knowledge in student-athletes. Journal of Nutrition Education and Behavior, 49 (1):1 9-26.e1. https://doi.org/10.1016/j.jneb.2016.08.008.

Iwuanyanwu, K.P. and Chioma, N.C. (2017). Evaluation of Heavy Metals Content and Human Health Risk Assessment via Consumption of Vegetables from Selected Markets in Bayelsa State, Nigeria. Biochemistry and Analytical Biochemistry, 6(3):1-6. DOI: http://dx.doi.org/10.11722/bab.2017.1000332.

Izah, S.C., Chakrabarty, N. and Srivastav, A.L. (2016). A Review on Heavy Metal Concentration in Potable Water Sources in Nigeria: Human Health Effects and Mitigating Measures. Experimental Health, 8: 285–304. http://dx.doi.org/10.1007%2Fs12403-016-0195-9.

Izah, C.S., Inyang, I.R., Angaye, T.C.N. and Okowa, I.P. (2017). A Review of Heavy Metal Concentration and Potential Health Implications of Beverages Consumed in Nigeria. Toxics, 5 (1): 1-15. Doi:10.3390/toxics5010001.

Kim, T.H., Kim, J.H., Le Kim, M.D., Suh, W.D., Kim, J.E. and Yeon, H.J. (2020). Exposure assessment and safe intake guidelines for heavy metals in consumed fishery products in the Republic of Korea. Environmental Science and Pollution Research, 27:33042–33051. doi:10.1007/s11356-020-09624-0.

Magonya, A.M., Yebpella, G.G. and Okpaegbe, U.C. (2015). An Assessment of metal contaminant levels in selected soft drinks sold in Nigeria. International Journal of Innovation Science Engineer Technology, 2: 517–522. http://ijiset.com/vol2/v2s10/IJISET_V2_I10_66.pdf.

Masok, F.B., Masiteng, P.L., Mavunda, R.D. and Maleka, P.P. (2017). An Integrated Health Risk Evaluation of Toxic Heavy Metals in Water from Richards Bay, South Africa. Journal of Environmental and Analytical Toxicology, 7(4): 1-7. DOI: http://dx.doi.org/10.4172/2161-0525.1000487.
Ogunlana, O.O., Ogunlana, O.E., Akinsanya, A.E. and Ologbenla, O.O. (2015). Heavy Metal Analysis of Selected Soft Drinks in Nigeria. *Journal of Global Biosciences, 4* (2): 1335-1338. [http://eprints.covenantuniversity.edu.ng/4728/1/02.pdf](http://eprints.covenantuniversity.edu.ng/4728/1/02.pdf).

Popoola, O.E., Popoola, A.O. and Purchase, D. (2019). Levels of Awareness and Concentrations of Heavy Metals in the Blood of Electronic Waste Scavengers in Nigeria. *Journal of Health and Pollution, 9*(21):190311. https://doi.org/10.5696/2156-9614-9.21.190311.

Salako, S.G., Adekoyeni, O.O., Adegbite, A.A. and Hammed, T.B. (2016). Determination of Metals Content of Alcohol and Non-alcoholic Canned Drinks Consumed at Idiroko Border Town Ogun State Nigeria. *British Journal of Applied Sciences and Technology, 12*: 1–8. DOI: 10.9734/BJAST/2016/19163.

The World Gazetteer (2007). Birnin Kebbi. Available at [https://en.m.wikipedia.org/wiki/Birnin_Kebbi](https://en.m.wikipedia.org/wiki/Birnin_Kebbi). (Accessed June 20, 2021).

Ubuoh, E.A., Comas, C.U., Eze, C.E. (2013). Analysis of metal concentrations in selected canned beers consumed in Owerri Urban, Imo State, Nigeria. *European International Journal of Science and Technology, 2* (8): 35–42. [https://eijst.org.uk/images/frontImages/gallery/Vol._2_No._8/4.pdf](https://eijst.org.uk/images/frontImages/gallery/Vol._2_No._8/4.pdf).

Udota, H.I.J. and Umoudofia, S.J. (2011). Heavy metal contamination of some selected Nigerian and imported alcoholic drinks. *Journal of Industrial Pollution Control, 27*: 1–4. [https://www.icontrolpollution.com/articles/heavy-metal-contamination-of-some-selected-nigerian-and-imported-alcoholic-drinks-.pdf](https://www.icontrolpollution.com/articles/heavy-metal-contamination-of-some-selected-nigerian-and-imported-alcoholic-drinks-.pdf).

United State Environmental Protection Agency (2011). Exposure factors handbook: 2011 edition. Washington, D. C, pp. 1436. Available at [https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252](https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252).

WorldAtlas (2015). Where is Birnin Kebbi, Nigeria. Available at [http://www.worldatlas.com/af/ng/ke/where-is-birnin-kebbi.html](http://www.worldatlas.com/af/ng/ke/where-is-birnin-kebbi.html). (Accessed June 20, 2021).

World Health Organization (2014). Training Package for the Health Sector: Adverse Health Effects of Heavy Metals in Children. Available at [http://www.who.int/ceh/capacity/heavy_metals](http://www.who.int/ceh/capacity/heavy_metals). (Accessed June 6, 2021).

World Health Organization (2018). International Program on Chemical Safety. Available at [http://www.who.int/ipcs/assessment/public_health/chemicals_phc/en/](http://www.who.int/ipcs/assessment/public_health/chemicals_phc/en/). (Accessed June 6, 2021).

Yahaya, T. and Okpuzor, J. (2012). Investigation of Cytotoxicity and Mutagenicity of Cement dust Using *Allium cepa* Test. *Research Journal of Mutagenesis, 2* (1): 10-18. http://dx.doi.org/10.3923/rjmutag.2012.10.18.

Yahaya, T., Oladele, E., Abiola, O.R., Ologe, O. and Abdulhazeez, A. (2021). Carcinogenic and Non-carcinogenic Risks of Heavy Metals in *Clarias gariepinus* (African Catfish) Obtained from Bariga Section of Lagos Lagoon. *Iranian (Iranica) Journal of Energy and Environment, 12*(1): 61-67, 2021. Doi: 10.5829/ijkee.2021.12.01.08.

Yahaya, T., Ologe, O., Yaro, C., Abdullahi, L., Abubakar, H., Gazal, A. and Abubakar, J. (2022). Quality and Safety Assessment of Water Samples Collected from Wells in Four Emirate Zones of Kebbi State, Nigeria. *Iranian (Iranica) Journal of Energy and Environment, 13*(1):79-86. doi: 10.5829/ijkee.2022.13.01.09.
### Table 1: Standard values for calculating average daily intake and non-carcinogenic risk of oral exposure to heavy metals

| Exposure factor         | Unit      | Value      |
|-------------------------|-----------|------------|
| Exposure frequency ($Ef$) | Days/year | 365        |
| Ingestion rate ($Ir$)   | L/day     | 0.5        |
| Exposure duration ($Ed$) | Years     | 30         |
| Average body weight ($Bwt$) | kg     | 65         |
| Average time ($At$)     | Days      | 4680 ($Ef \times Ed$) |

### Table 2: Oral reference doses for Zn, Cu, Pb, Fe, Cd in (mg/L/day)$^{-1}$

| Metal | Value |
|-------|-------|
| Zn    | 0.30  |
| Cu    | 0.0371|
| Pb    | 0.001 |
| Fe    | 0.7   |
| Cd    | 0.0005|

### Table 3: Standard values for calculating carcinogenic risk of exposure to heavy metals

| Exposure factor         | Unit      | Value      |
|-------------------------|-----------|------------|
| Exposure frequency ($Ef$) | Days/year | 365        |
| Ingestion rate ($Ir$)   | L/day     | 2.0        |
| Exposure duration ($Ed$) | Years     | 70         |
| Average body weight ($Bwt$) | kg     | 65         |
| Average time ($At$)     | Days      | 25,550 ($Ef \times Ed$) |

### Table 4: Cancer slope factor for heavy metals

| Metal | Value |
|-------|-------|
| Zn    | 0.00  |
| Cu    | 0.00  |
| Pb    | 0.0085|
| Fe    | 0.00  |
| Cd    | 6.3   |
Table 5: Levels of heavy metals in Fearless, Monster, and Power Horse energy drinks purchased from Birnin Kebbi, Nigeria

| Energy drinks | Zn       | Cu       | Pb            | Fe            | Cd            |
|---------------|----------|----------|---------------|---------------|---------------|
| Fearless      | 1.005±0.0012 | 14.041±0.0021 | 0.012±0.0006  | 1.083±0.0058  | 0.779±0.0015  |
| Monster       | 0.937±0.0012 | ND       | 0.012±0.0000  | 1.143±0.0021  | 0.769±0.0000  |
| Power Horse   | 0.942±0.0000 | ND       | 0.323±0.0015  | 1.157±0.0025  | 0.779±0.0000  |
| WHO Limit     | 5.00     | 0.05     | 0.01          | 0.1           | 0.02          |

Values were expressed as Mean ± SD and mg/L; ND = Not Detected; WHO = World Health Organization (Source: WHO, 2014)

Table 6: Average daily intake of heavy metals from Fearless, Monster, and Power Horse energy drinks purchased from Birnin Kebbi, Nigeria

| Energy drink  | Zn | Cu  | Pb   | Fe  | Cd  |
|---------------|----|-----|------|-----|-----|
| Fearless      | 0.018 | 0.252 | 0.002 | 0.019 | 0.014 |
| Monster       | 0.017 | _   | 0.002 | 0.021 | 0.014 |
| Power Horse   | 0.017 | _   | 0.006 | 0.021 | 0.014 |
| RDI (WHO, 2014) | 8  | 0.900 | 0.21 | 10  | 0.06 |

Values were expressed in mg/L, RDI = Recommended daily intake (mg/L); WHO = World Health Organization

Table 7: Hazard quotient of heavy metals in Fearless, Monster, and Power Horse energy drinks purchased from Birnin Kebbi, Nigeria

| Energy drink  | Zn   | Cu   | Pb   | Fe   | Cd   |
|---------------|------|------|------|------|------|
| Fearless      | 0.06 | 6.81 | 0.15 | 0.03 | 28.00|
| Monster       | 0.06 | _   | 0.15 | 0.03 | 27.68|
| Power Horse   | 0.06 | _   | 4.15 | 0.03 | 26.35|

Table 8: Carcinogenic risk of heavy metals in Fearless, Monster, and Power Horse energy drinks purchased from Birnin Kebbi, Nigeria

| Energy drink  | Zn    | Cu   | Pb    | Fe    | Cd   |
|---------------|-------|------|-------|-------|------|
| Fearless      | NC    | NC   | 0.000017 | NC    | 0.088|
| Monster       | NC    | NC   | 0.000017 | NC    | 0.088|
| Power Horse   | NC    | NC   | 0.000052 | NC    | 0.088|

NC = non-carcinogenic