



# Potential Health Risk Evaluation of Heavy Metal Exposure from Consuming Commercially Produced Food Seasonings in Enugu, Nigeria

Ozioma Ebere Obianyido <sup>a\*</sup>, Hector Okechukwu Obianyido <sup>b</sup>  
and Ruth Efevare Imosemi <sup>a</sup>

<sup>a</sup> Department of Medical Laboratory Sciences, Faculty of Health Sciences and Technology, University of Nigeria, Enugu Campus, Enugu, Nigeria.

<sup>b</sup> Department of Medical Biochemistry, Faculty of Basic Medical Sciences, University of Nigeria, Enugu Campus, Enugu, Nigeria.

## **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

## **Article Information**

DOI: 10.9734/EJNFS/2023/v15i91334

### **Open Peer Review History:**

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/103236>

**Original Research Article**

**Received: 08/06/2023**  
**Accepted: 17/08/2023**  
**Published: 30/08/2023**

## **ABSTRACT**

Heavy metals are inherently non-biodegradable elements of the earth's crust that collect and remain in the ecosystem in perpetuity due to both human and natural activity. Their contamination in seasonings remains a public health concern because of the frequency of use. Prolonged exposure to these heavy metals is a severe health risk worldwide. This study evaluated the potential health risk of heavy metal exposure from consuming commercially produced food seasonings in Enugu, Nigeria. Thirty (30) commercially produced food seasonings were selected by simple random sampling and grouped into five (5) according to different batches. Atomic

\*Corresponding author: Email: [ozioama.obianyido@unn.edu.ng](mailto:ozioama.obianyido@unn.edu.ng);

absorption spectroscopy was used to analyze arsenic, cadmium, lead and nickel. The level of arsenic in group SA(1.28±0.21mg/kg), SB(1.73±0.31mg/kg), SC(1.13±0.17mg/kg), SD (2.11±0.20mg/kg) were observed to be above (1.00mg/kg), the WHO maximum permissible limit. Cadmium levels in S<sub>A</sub> (0.36±0.01mg/kg) were observed to be above (0.30 mg/kg), the WHO maximum permissible limit. The estimated daily intake, hazard quotient and hazard index of the metals were within the normal range. The presence of heavy metals above WHO permissible limits in commercially produced food seasonings should be a public health concern. To protect the population's health, producers, retailers, and vendors of seasonings should be informed of the hazards of exposing their products to heavy metal contamination. Continuous surveillance of commercially produced food seasonings for heavy metal contamination is recommended.

*Keywords: Heavy metals; health risk; prolonged exposure; toxicity.*

## 1. INTRODUCTION

Seasonings are a group of diversely composed edible products. Numerous definitions of seasonings can be found in the literature. Codex Alimentarius lists salts, seasonings, spices, soups, sauces, salads, and protein supplements among the ingredients added to food to improve scent and flavor [1]. Most scientists classify seasonings as products of plant origin, albeit with a more complex composition than seasoning mixtures [2]. They are composed of dried seed, fruit, root, bark, or other plant parts mainly used as aromatic additives enhancing the sensory values of food or keeping food fresh [3]. In addition to plant-based constituents, seasonings may also contain salt, monosodium glutamate, and citric acid [2].

Despite all the benefits of these products, it is believed that seasonings harm the biological system, probably due to contamination. Contamination may arise from several different factors, including alterations in the amount and quality of components, the use of a raw material lacking a bioactive substance, biogenic or chemical environmental contaminants, Pesticide residues, mycotoxins, and heavy metals, as well as unintentional contaminants including floral debris, ashes and others [4, 5, 6].

The toxicity of heavy metals to human health and the environment has received much attention. Plants are the primary conduit for heavy metals from polluted soil to people. Metals can easily contaminate plants because they can emanate from the type of soil used for cultivation, the fertilizers applied, and the source of irrigation water [7]. Heavy metals in extremely low quantities may be hazardous due to their poor excretion rates via the kidneys [8]. Heavy metals

enter our food chains through soils [9, 10]. Heavy metals have piqued the attention of researchers owing to their persistent, bio accumulating, and biomagnifying properties [11, 12]. Heavy metals cause oxidative stress in aerobic cells by increasing reactive oxygen species (ROS). It has been linked to changes in the nervous system, cognitive impairment, infertility, foetal harm, preterm birth, cardiovascular disease, bronchitis, and coughing [13]. Cancers of the lung and bladder are the most common sites where it's carcinogenic effects manifest [14, 15]. Due to excessive levels of lead, the Food and Drug Administration of the United States (US FDA) reported in September 2013 that distributors of turmeric powder, including a business based in Bangladesh, were voluntarily recalling their products [16].

Commercially produced food seasoning are preferred currently for convenience; it is easy to use. Information regarding the raw material used in the production of seasonings is supposed to be made available in the containers or packs of such seasonings. Regrettably, this information is sometimes not present on the containers of such seasonings. It may be quite challenging to spot adulterations in this all-important and every day-use product, which calls for sophisticated analytical techniques [17].

Due to a paucity of such information and because most research focused on natural food spices, it is critical to examine the heavy metal contents, estimated daily intake, total hazard quotients and hazard index in commercially produced food seasonings sold in Enugu markets. This study assessed the possible health risk of heavy metal exposure from consuming branded seasonings in Enugu, Nigeria.

## 2. MATERIALS AND METHODS

### 2.1 Sampling Area

The study was conducted in Enugu State, situated in the Southeastern region of Nigeria. Enugu is a metropolitan city notable for its coal extraction, with few industrial sites and numerous markets. This city has a population of approximately 722,664; a total area of 556 km<sup>2</sup>; latitudes of 6.4584°N and 7.5464°E; and a warm climate with an annual average temperature of 26.3°C and an average yearly rainfall of 1,730<sub>mm</sub>. Enugu State residents work in various sectors, including government, business, the arts, and agriculture. The map in Fig. 1 [18] presents where the commercially produced food seasonings were purchased. The ingredients used in the production of the food seasonings as written on the sachets were mostly iodized salt, cinnamon, rosemary soy protein, flavours, anti-caking agents, soy protein powder, paprika, glutamate inosinate, colourants and cassava flour.

#### 2.1.1 Sample selection and analysis

The food seasonings were selected by simple random sampling. Every fourth seasoning as was placed on the table was selected, as all the seasonings were placed on a table. The selected seasonings were then bought from the vendors at the different markets in Enugu municipality. A total of thirty (30) commercially produced food seasonings were purchased from four different markets in Enugu municipality. The selected

seasonings were grouped into six (6). Each group constituted of five (5) sachets from a batch as followed:

Group A- This consist of five sachets of stew seasoning (SA).

Group B- This consist of five sachets of local soup seasoning (SB)

Group C- This consist of five sachets of Beef seasoning (SC)

Group D- This consist of five sachets of Chicken seasoning (SD)

Group E- This consist of five sachets of Jollof rice seasoning (SE)

Group F- This consist of five sachets of fried rice seasoning (SF)

Their expiry dates were used in place of the batch numbers as some of the batch numbers were blurred.

#### 2.1.2 Analysis of samples for arsenic, cadmium lead and nickel.

At the National Centre for Energy Research and Development, University of Nigeria Nsukka, the selected seasonings were used for the analysis of heavy metals (arsenic, cadmium, lead and nickel) after wet acid digestion using Flame atomic spectroscopy Model AA-700 (Shimadzu, Japan) as described [19]

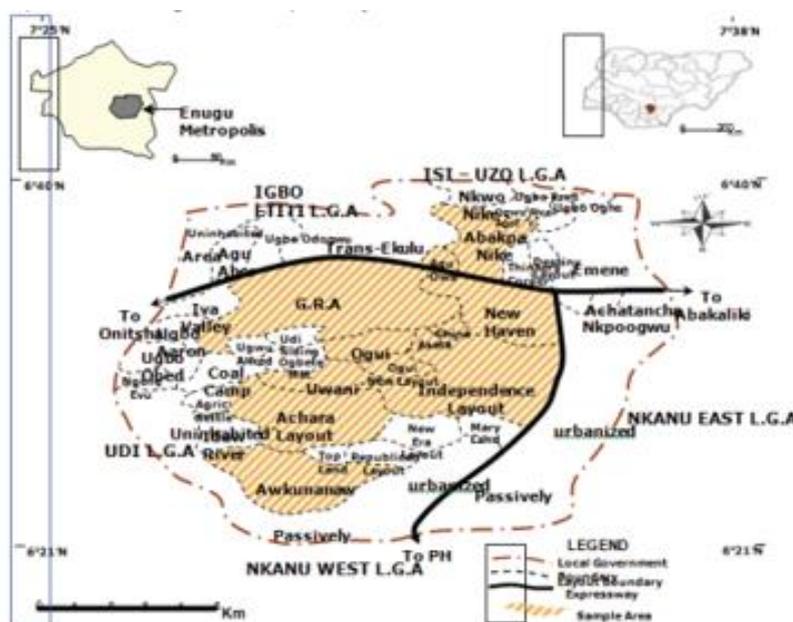


Fig. 1. Map of Enugu municipality

**2.1.3 Determination of hazard quotient and hazard index of the selected seasonings**

$$\text{DIM (mgkg}^{-1}\text{ Day}^{-1}) = X \text{ (mgkg}^{-1}) \times Y \text{ (kg)} / Z \text{ (kg)} \quad (1) [20]$$

where DIM refers to the Dietary intake of metal, X is the level of heavy metal contained in the seasoning as determined by atomic absorption in this study Y (0.01) is the ingestion rate while Z (24 for children and 60 for adults) [21].

The hazard quotient (HQ) was calculated using the ratio of the daily intake of metal (DIM) to the reference dose for heavy metals.

$$\text{Hazard quotient} = \text{Daily intake of metal} / R_fD \quad (2) \quad [22]$$

Where: R<sub>f</sub>D is the oral reference for each heavy metal investigated.

The hazard index (HI) was expressed as the total sum of the hazard quotients (HQs) of the heavy metals.

$$\text{Hazard index} = \text{HQ}_1 + \text{HQ}_2 + \text{HQ}_3 + \text{HQ}_4 / \dots \dots \dots H_{Q_n} \quad (3) [23]$$

**2.2 Statistical Data Analysis**

The statistical analysis software, Graph Pad prism version7 (Graph Pad Software Inc., USA) was used to analyse the data from this study. Values were expressed as Mean ± Standard deviation, (N=30). Student's t-test was used to compare continuous variables such as

concentration of heavy metals in the seasonings and WHO permissible limits [24]. P-value of <0.05 was considered statistically significant.

**3. RESULTS AND DISCUSSION**

The levels of heavy metals in commercially produced food seasonings consumed by Enugu metropolis residents as sold in their markets have been brought to focus. The findings of this study showed an increase level of arsenic in SA (1.28±0.21)mg/kg, SB (1.73±0.31)mg/Kg, SD (1.13±0.17)mg/kg and SE (2.11±0.20)mg/kg in comparison with the WHO maximum permissible limit (1.00) mg/kg [24] (Table 1). The beauty of this study is that it is the first to report the level of arsenic in seasonings in Nigeria. This study's results agree with the observation of Pakistan and Bangladesh studies that revealed the presence of arsenic in food spices [6, 25]. The level of arsenic found in both studies was higher than the findings in this current study. The finding of their study could be because they worked on natural spices, technological conditions or environmental contamination. Arsenic ingestion, even though at low-level may cause non carcinogenic effects, such as sore pharynx and irritated airways, vertigo, vomiting, and discolouration of skin lesions and tumours [26]. In addition, chronic consumption may result in neurobehavioral and neuropathic changes, memory loss, a decrease in intellectual level, infertility disorder, foetal injury, premature delivery, cardiovascular diseases, chronic cough, and chronic bronchitis [13]. In most cases, its carcinogenic effects manifest as lung and bladder cancer [14, 27].

**Table 1. Analytical result of the heavy metals (mg/kg) in commercially produced food seasonings in Enugu, Nigeria**

Samples		Pb	As	Ni	Cd
WHO MPL		10.00	1.00	1.50	0.30
SA	Mean±SD	0.15±0.04	1.28±0.21	0.62±0.13	0.36±0.01
SB	Mean±SD	0.18±0.02	1.73±0.31	0.38±0.12	0.24±0.01
SC	Mean±SD	0.17±0.03	0.98±0.08	0.07±0.02	0.08±0.01
SD	Mean±SD	0.10±0.02	1.13±0.17	0.79±0.12	0.02±0.01
SE	Mean±SD	0.10±0.02	2.11±0.20	0.55±0.02	0.12±0.03
SF	Mean±SD	0.15±0.07	0.75±0.16	0.62±0.80	0.05±0.01

\*Who Mpl=World Health Organization Maximum Permissible Limit; Sa= Stew Seasoning; Sb= Local Soup Seasoning; Sc= Beef Seasoning; Sd= Chicken Seasoning; Se= Jollof Rice Seasoning; Sf= Fried Rice Seasoning; Pb=Lead; As= Arsenic; Ni=Nickel; Cd=Cadmium

The findings of this study showed an increased cadmium level in SA (0.36±0.01)mg/kg in comparison with the WHO maximum permissible limit (Table 1). These findings are lower than those of [6,24,28] and are higher than that observed in the work of Nnorom et al [29]. Variability in outcomes may be attributable to variations in raw materials used in manufacturing, technological processes, and distribution networks. Colourants may also contribute to cadmium contamination of spices. Cadmium (Cd) causes chronic human diseases. It predominantly affects the liver, kidneys, testicles, pancreas, and bones [30]. Cd<sup>2+</sup> may also inhibit the liver enzymes catalase, glutathione peroxidase, and superoxide dismutase [28]. In addition to damaging the skeletal system by interfering with the metabolism of Ca, Zn, Cu, Fe and Mg [31]. Cd may also play an initial role in the development of cancer in the breasts, pancreas, lungs, prostate, kidneys, nasopharynx, and genitalia [32]. Cadmium levels in SA, SC, SD, SE, and SF were below the WHO maximum permissible limit [24] (Table 1).

The levels of other heavy metals such as Lead (Pb) and Nickel assayed in this study were all within the WHO maximum permissible limit as observed in this study. Pb primarily affects the brain, the kidneys, the liver, and the reproductive system [33]. It may induce a decline in IQ and perceptual ability. It may also increase nervous system hyperactivity [34]. Moreover, the presence of Pb in the blood causes bladder cancer [35]. Nickel can induce a variety of pathological effects in humans. The chronic accumulation of nickel

and nickel compounds in the human body may be responsible for a variety of adverse health effects, including pulmonary fibrosis, renal and cardiovascular diseases, and respiratory cancer [32].

A health risk assessment was conducted to determine if there may be a link between the intake of branded seasoning and the overall well-being of the study population. The EDIs of the heavy metals as a consequence of seasoning intake are shown in Table 2. The EDI ranged from 1.03x10<sup>-5</sup> to 9.17x10<sup>-6</sup> in adults and 1.00x10<sup>-5</sup> to 8.33x10<sup>-7</sup> in juveniles. All EDIs were lower than the TDIs [35], indicating that the individual consumption of branded seasonings sold in Enugu metropolis markets may not pose any health hazards to the population.

The Hazard quotient (HQ) of all the heavy metals in this study were less than 1 (HQ<1) as shown in Table 3 in this study. HQ values less than 1 (HQ<1) indicate that the cumulative consumption of that substance will not induce an adverse effect but with the tendency of adverse effect when it is above 1 (HQ>1); the same applies also to HI. The HI of all spices were less than 1.

The HI of the heavy metals, the source of contamination and methods to eradicate them have been described as a constant focus of research [36]. It is necessary to periodically check the commercially produced food seasonings for these heavy metals contamination in order to rule out any potential chronic heavy metal toxicity in the population.

**Table 2. Estimated Daily Intake (EDI) (µ/kg) of commercially produced food seasonings in Enugu, Nigeria**

Samples	Pb		As		Ni		Cd	
	Adults	Children	Adult	Children	Adult	Children	Adult	Children
SA	0.025	0.620	0.021	0.533	0.103	0.258	0.060	0.150
SB	0.030	0.075	0.029	0.720	0.063	0.158	0.040	0.100
SC	0.028	0.070	0.163	0.408	0.011	0.292	0.013	0.033
SD	0.017	0.042	0.188	0.471	0.132	0.329	0.003	0.008
SE	0.017	0.042	0.352	0.879	0.091	0.229	0.200	0.050
SF	0.025	0.063	0.125	0.313	0.103	0.258	0.008	0.020

SA= Stew Seasoning; SB= Local Soup Seasoning; SC= Beef Seasoning; SD= Chicken Seasoning; SE= Jollof Rice Seasoning; SF= Fried Rice Seasoning; Pb=Lead; As= Arsenic; Ni=Nickel; Cd=Cadmium

**Table 3. Hazard quotient (HQ) and (HI) of commercially produced food seasonings in Enugu, Nigeria**

Metals	RfD	SA		SB		SC		SD		SE		SF	
		Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children
Nickel	0.02	5.15x10 <sup>-4</sup>	1.29x10 <sup>-4</sup>	3.16x10 <sup>-4</sup>	7.9x10 <sup>-4</sup>	5.85x10 <sup>-5</sup>	1.46x10 <sup>-4</sup>	6.60x10 <sup>-3</sup>	1.60x10 <sup>-3</sup>	4.85x10 <sup>-4</sup>	1.14x10 <sup>-3</sup>	5.15x10 <sup>-4</sup>	1.29x10 <sup>-3</sup>
Cadmium	0.001	6.0x10 <sup>-3</sup>	1.5x10 <sup>-2</sup>	4.0x10 <sup>-3</sup>	1.0x10 <sup>-2</sup>	1.30x10 <sup>-03</sup>	3.3x10 <sup>-3</sup>	3.3x10 <sup>-4</sup>	8.33x10 <sup>-4</sup>	2.00x10 <sup>-4</sup>	5.00x10 <sup>-3</sup>	8.33x10 <sup>-4</sup>	2.08x10 <sup>-3</sup>
Lead	0.0035	7.14x10 <sup>-4</sup>	1.7x10 <sup>-2</sup>	8.57x10 <sup>-4</sup>	2.1 x10 <sup>-3</sup>	8.09x10 <sup>-4</sup>	2.00x10 <sup>-3</sup>	4.77x10 <sup>-4</sup>	2.00x10 <sup>-3</sup>	4.77x10 <sup>-4</sup>	1.00x10 <sup>-3</sup>	7.14x10 <sup>-4</sup>	1.7x10 <sup>-2</sup>
Arsenic	0.0003	7.1x10 <sup>-2</sup>	2.1x10 <sup>-2</sup>	9.6x10 <sup>-2</sup>	2.0x10 <sup>-3</sup>	5.40x10 <sup>-2</sup>	3.6x10 <sup>-2</sup>	6.20x10 <sup>-3</sup>	1.57x10 <sup>-2</sup>	3.50x10 <sup>-2</sup>	2.93x10 <sup>-2</sup>	1.25x10 <sup>-2</sup>	1.04x10 <sup>-1</sup>
HI		7.8x10 <sup>-2</sup>	5.3x10 <sup>-2</sup>	1.0x10 <sup>-1</sup>	4.5x10 <sup>-2</sup>	5.6x10 <sup>-2</sup>	4.14x10 <sup>-2</sup>	7.6x10 <sup>-3</sup>	2.00x10 <sup>-2</sup>	7.2x10 <sup>-2</sup>	3.64x10 <sup>-2</sup>	1.40x10 <sup>-2</sup>	1.24x10 <sup>-1</sup>

SA= Stew seasoning; SB= Local soup seasoning; SC= Beef seasoning; SD= Chicken seasoning; SE= Jollof rice seasoning; SF= Fried rice seasoning;  
 HI=Hazard Index; RfD=Oral Reference Dose

#### 4. CONCLUSION

This study revealed an arsenic level above the WHO maximum permissible limit in SA, SB, SD and SE. The cadmium levels in SA was above the WHO maximum permissible limit. However, the Nickel and Lead levels in the selected commercially produced food seasonings were below the WHO permissible limits. The risk assessment indicates that there is little cause for concern. The presence of these contaminants in commercially produced food seasonings should be a public health concern. To protect the population's health, producers, retailers, and vendors of commercially produced food seasonings should be informed of the hazards of exposing their products to heavy metal contamination. Continuous surveillance on commercially produced food seasonings for heavy metal contamination is recommended.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

#### REFERENCES

1. García-Casal M, Peña-Rosas JP, Malavé HG. Sauces, Spices, and Condiments: Definitions, Potential Benefits, CONSUMPTION Patterns, and Global Markets. *Ann. N. Y. Acad. Sci.* 2016;1379: 3–16.  
Available online: <http://www.innocua.net/w eb/download-5387/garc-a-casal-et-al-2016-annals-of-the-new-york-academy-of-sciences.pdf> (Accessed on 19 August 2021).
2. Smiechowska M, Newerli-Guz J, Skotnicka M. Spices and seasoning Mixes in European Union—Innovations and Ensuring Safety. *Foods.* 2021;10:2289. [Doi.org/10.3390/foods10102289](https://doi.org/10.3390/foods10102289)
3. Kowalski G. The safety assessment of toxic metals in commonly used herbs, spices, tea, and coffee in Poland. *Int. J. Environ. Res. Public Health.* 2021;18:5779. [DOI.org/10.3390/ijerph18115779](https://doi.org/10.3390/ijerph18115779)
4. Kucharska-Ambrożej K, Karpinska J. The application of spectroscopic techniques in combination with chemometrics for detection adulteration of some herbs and spices. *Microchem. J.* 2020;153:104278.
5. Karadaş C, Kara D. Chemometric approach to evaluate trace metal concentrations in some spices and herbs. *Food Chem* 2012;130(1):196–202.
6. Baig JA, Bhatti S, Kazi TG, Afridi HI. Evaluation of arsenic, cadmium, nickel and lead in common spices in Pakistan. *Biological Trace Element Research.* 2019;187:586-595.
7. Nnari N, Ow hoeke E, Naze A. Health risk of selected inorganic contaminants in some food spices sold in markets within port harcourt metropolis, Nigeria. *Asian Journal of Research in Biology.* 2020;3(1): 15-21.
8. Jaeyoung Shim, Taeyoung Cho, Donggil Leem, Youngmi Cho, Changhee Lee ( ): Heavy metals in spices commonly consumed in Republic of Korea;2018. *Food Additives & Contaminants: Part B.* DOI: 10.1080/19393210.2018.1546772
9. Margenat A, Matamoros V, Díez S, Cañameras N, Comas J, Bayona JM,. Occurrence and human health implications of chemical contaminants in vegetables grown in peri-urban agriculture. *Environ. Int.* 2019;124:49–57.
10. Khalid S, Shahid M, Niazi NK, Murtaza B, Bibi I, Dumat C. A comparison of technologies for remediation of heavy metal contaminated soils. *J. Geochem. Explor.* 2017;182:247–268.
11. Zakaria Z, Zulkafflee NS, Mohd Redzuan NA, Selamat J, Ismail MR, Praveena SM, Tóth G, Abdull Razis AF. Understanding potential heavy metal contamination, absorption, translocation and accumulation in rice and human health risks. *Plants.* 2021;10:1070. [Doi:Org/10.3390/Plants10061070](https://doi.org/10.3390/Plants10061070)
12. Pandiyan J, Mahboob S, Govindarajan M, Al-Ghanim KA, Ahmed Z, Al-Mulhm N, Jagadheesan R, Krishnappa K. An assessment of level of heavy metals pollution in the water, sediment and aquatic organisms: a perspective of tackling environmental threats for food security. *Saudi J. Biol. Sci.* 2021;28(2): 1218– 1225.
13. Milton AH, Rahman M,. Respiratory effects and arsenic contaminated well water in Bangladesh. *Int. J. Environ. Health Res.* 2002;12 (2):175–179.
14. Cohen G, Levy I, Yuval Kark JD, Levin N, Witberg G, Gerber Y. Chronic exposure to traffic-related air pollution and cancer incidence among 10,000 patients undergoing percutaneous coronary interventions: A historical prospective

- study. *European Journal of Preventive Cardiology*. 2018;25(6):659-670.
15. Sanyal T, Bhattacharjee P, Paul S, Bhattacharjee P. Recent advances in arsenic research: significance of differential susceptibility and sustainable strategies for mitigation. *Frontiers in Public Health*. 2020;8:464.
  16. U.S. Food and Drug Administration. 2013. Recalls PRAN brand turmeric powder due to elevated levels of lead. [accessed 2013 Oct 04]. [www.fda.gov/Safety/Recalls/ucm371206.htm](http://www.fda.gov/Safety/Recalls/ucm371206.htm)
  17. Wadood SA, Boli G, Xiaowen Z, Hussain I, Yimin W. Recent development in the application of analytical techniques for the traceability and authenticity of food of plant origin. *Microchemical Journal*, 152, 104295.
  18. Ubachukwu NN, Phil-Eze PO, Emeribe CN. Analysis of household hazardous wastes awareness level in Enugu metropolis. *Academic Journal of Interdisciplinary Studies*. 2014;3(1):369.
  19. Oluremi OI, Solomon AO, Saheed AA, Fatty acids, metal composition and physico-chemical parameters of Igbemo Ekiti rice bran oil. *Journal of Environmental Chemistry and Ecotoxicology*. 2013;5(3):39-46.
  20. USEPA (US Environmental Protection Agency), Exposure factors handbook general factors. EPA/600/P-95/002Fa, vol. I. Office of Research and Development, National Center for Environmental Assessment, US Environmental Protection Agency. Washington, DC; 2010.
  21. Orisakwe OE, Ozoani HA, Nwaogazie IL, Ezejiofor AN. Probabilistic health risk assessment of heavy metals in honey, Manihot esculenta, and Vernonia amygdalina consumed in Enugu State, Nigeria. *Environ Monit Assess*. 2019; 191(7):424.
  22. USEPA (US Environmental Protection Agency), Exposure factors handbook general factors. EPA/600/P-95/002Fa, vol. I. Office of Research and Development, National Center for Environmental Assessment, US Environmental Protection Agency. Washington, DC; 2010.
  23. USEPA (US Environmental Protection Agency). Risk assessment guidance for superfund. Human Health Evaluation Manual Part A, Interim Final, vol. I. Washington (DC), United States Environmental Protection Agency; EPA/540/1-89/002;1989.
  24. WHO WHO guidelines for assessing quality of herbal medicines with reference to contaminants and residues. World Health Organization, Geneva, Switzerland; 2006.
  25. Mahtab Ali Mollah\*, Golam Rabbany, M Nurunnabi, Sha Md.Shahan Shahriar and Sayed M A Salam. Health Risk Assessment of Heavy Metals Through Six Common Spices of Mohanpur Upazila of Rajshahi District, Bangladesh. *Glob J Nutri Food Sci*. 2022;3(5):GJNFS. MS.ID.000574. DOI:10.33552/GJNFS.2022.03.000574
  26. Signes-Pastor AJ, Carey M, Meharg AA., Inorganic arsenic in rice-based products for infants and young children. *Food Chem*. 2016;191:128–134.
  27. Umar MA, Salihu ZO, Pepper C. Heavy metals content of some spices available within FCT-Abuja, Nigeria. *International Journal of Agricultural and food science*. 2014;4(1):66-74.
  28. Nnorom IC, Osibanjo O, Ogunua K. Trace heavy metal levels of some bouillon cubes, and food condiments readily consumed in Nigeria. *Pakistan Journal Of Nutrition*, 2007;6(2):122-127.
  29. Fu Z, Xi S. The effects of heavy metals on human metabolism. *Toxicol. Mech. Methods*. 2020;30(3):167–176.
  30. Kim HS, Kim YJ, Seo YR., An overview of carcinogenic heavy metal: molecular toxicity mechanism and prevention. *J. Can. Prevent*. 2015;20(4):232. Kumar V, Thakur RK. Health risk assessment of heavy metals via dietary intake of vegetables grown in wastewater irrigated areas of Jagjeetpur, Haridwar India. *Arch. Agricult. Environ. Sci*. 2018;3(1):73–80.
  31. Genchi G, Carocci A, Lauria G, Sinicropi MS, Catalano A. Nickel: Human Health and Environmental Toxicology. *Int J Environ Res Public Health*. 2020 Jan 21;17(3):679. DOI: 10.3390/ijerph17030679. PMID: 31973020; PMCID: PMC7037090
  32. Brewer GJ, Prasad AS. eds. *Essential and Toxic Trace Elements and Vitamins in Human Health*. Academic Press; 202
  33. Awadalla A, Mortada WI, Abol-Enein H, Shokeir AA. Correlation between blood levels of cadmium and lead and the expression of microRNA-21 in Egyptian

- bladder cancer patients. *Heliyon* 2020;6 (12).
34. Baars AJ, Theelen RMC, Janssen PJCM, Hesse JM, van Apeldoorn MV, Meijerink MV. Re-evaluation of human-toxicological maximum permissible risk levels, Microsoft Word - 711701025.doc (openrepository.com); 2001.
35. Barnaby R, Liefeld A, Jackson BP, Hampton TH, Stanton BA. Effectiveness of table top water pitcher filters to remove arsenic from drinking water. *Environ. Res.* 2017;158:610–615.
36. Wongsasuluk P, Chotpantarat S, Siriwong W, Robson M. Heavy metal contamination and human health risk assessment in drinking water from shallow groundwater wells in an agricultural area in Ubon Ratchathani province, Thailand. *Environ Geochem Hlth.* 2013;36:169–182.

---

© 2023 Obianyido et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

*Peer-review history:*

*The peer review history for this paper can be accessed here:*  
<https://www.sdiarticle5.com/review-history/103236>