



## Trace and Heavy Metals Status in Selected Staple Foods and Associated Health Risk in Artisanal and Small Scale Gold Mining Vicinity in Kuchiko-Hausa, Gurara LGA, Niger State, Nigeria.

<sup>1</sup>Aliyu Haruna Sani, <sup>1</sup>Amanabo Musa, <sup>2\*</sup>Ogbiko Cyril

<sup>1</sup>Department of Biochemistry, Faculty of Natural Sciences, Ibrahim Badamasi Babangida University Lapai, Niger State Nigeria

<sup>2</sup>Department of Pure and Applied Chemistry, Faculty of Science, Usmanu Danfodiyo University Sokoto, 85004 Sokoto State Nigeria.

### ABSTRACT

The unwanted release of environmental contaminants predisposed by mining activities had reached an alarming proportion that deserves attention. Hence, the purpose of this study was to determine the degree of trace metals contamination in selected staple foods consumed around the artisanal and small-scale gold mining vicinity in Kuchiko-Hausa, Gurara LGA of Niger State Nigeria. To this end, arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), nickel (Ni), lead (Pb) and zinc (Zn) concentrations were measured using Atomic Absorption Spectrometry. Obtained values were used to evaluate the degree of soil pollution and plant contamination using physicochemical analysis, bioaccumulation factor and translocation factor of metals into plant in surrounding mine site. Cu, Zn, Fe and Cr were detected in all the leafy vegetable samples. Zn and As were detected in all cereals and guinea corn samples respectively. While Cu, Zn and Fe were detected in all tuber samples, Cr was detected only in the powdered yam samples. All detected trace metals in the samples except Zn (among the cereals) and As (in the guinea corn samples) were all lower than the WHO permissible limits. Periodic and systematic study of the investigated and other metals concentrations is therefore recommended since long-term exposure of these metals poses significant health risk for human, animals and plants.

### ARTICLEINFO

Article History

Received: March, 2020

Received in revised form: May, 2020

Accepted: August, 2020

Published online: November, 2020

### KEYWORDS

Bioaccumulation, Heavy Metals, Mining, Staple Foods.

### INTRODUCTION

Trace metals are widely distributed in the environment where in addition to the vital roles they play in plant growth and/or human nutrition, some of them such as arsenic (As), lead (Pb), cadmium (Cd), cobalt (Co), nickel (Ni), chromium (Cr), mercury (Hg) among others have been known to cause adverse effects to human health even

at low concentrations (Jaishankar *et al.*, 2014). The occurrence of these metals in food can have geogenic or anthropogenic origins as evidence have shown that anthropogenic activities such as wastewater irrigation, solid waste disposal, mining, smelting, sewage sludge applications, fertilizers, fungicides and industrial activities contribute significantly to the deposition of

Corresponding author: Ogbiko, C. ✉ [cyril.ogbiko@udusok.edu.ng](mailto:cyril.ogbiko@udusok.edu.ng) ✉ Department of Pure and Applied Chemistry, Usman Danfodio University, Sokoto. © 2020. Faculty of Tech. Education, ATBU Bauchi. All rights reserved

these metals in cultivable land. (Armah *et al.*, 2014; Mingorance *et al.*, 2007; Xue *et al.*, 2012; Laniyan and Adewumi, 2020). Crops and vegetables grown in contaminated soil or irrigated with wastewater could take up metals and accumulate them in their edible parts with humans known to be exposed to these metals majorly through their consumption (Xue *et al.*, 2012; Agrelli *et al.*, 2007).

Mining has been identified to impact negatively on the quality of the environment (Donkor *et al.*, 2005; Acosta *et al.*, 2011). It causes the destruction of natural ecosystems by altering soil, vegetative covers and covering of organisms beneath excavation sites (Abiya *et al.*, 2018). In gold mining, like many metallurgical extractions, crystallographic bonds are broken in the ore mineral in order to recover the desired element or compound (Lottermoser, 2007). During gold mining, large quantities of wastes are produced and over 99% of the extracted ore in gold mining are released into the surrounding environment as waste mainly heavy metals (Adler and Rascher, 2007).

Heavy metals pollution is of concern globally because of their deleterious effects on plants, especially those on vegetative and generative plant part, which can be translocated and accumulated in plants and animals even at low concentration (Ekaterina and Jeliazkova,

2001). In order to evaluate the damages that gold mining activities exert on the environment, especially in areas in which crude methods of mining is still largely used, there lies the need to assess the extents of pollution mainly based on studies about waste properties, heavy metals content and their relation to soil and plant. Hence, the study aim to determine the concentration of heavy metals found in common staple foods at the artisanal and small-scale gold mining vicinity in Kuchiko-Hausa, Gurara LGA of Niger State Nigeria.

## MATERIALS AND METHODS

### Study Area Description

The study area, Kuchiko-Hausa (Figure 1) is a community situated in Gurara Local Government Area of Niger State, Nigeria. It is on a geographical coordinate of longitude 7°10'E and latitude 9°16'N. The community spread into various neighbouring villages with a large ratio of the inhabitants engaging in local farming and small-scale mining. Farming activities is carried out mostly during the rainy season, with a few on irrigated lands with crops cultivated mostly sorghum, millet, soybeans, cowpeas and maize. The temperature is highest with value 28.7°C on average in April and with a lowest average value of 23.9°C around August annually. The study area witnessed 1341mm of precipitation falls annually.



**Figure 1:** Map of Nigeria showing the position of Niger State and the study area (Kuchiko-Hausa in Gurara Local Government Area (Land and Survey 2012).

Corresponding author: Ogbiko, C. ✉ [cyril.ogbiko@udusok.edu.ng](mailto:cyril.ogbiko@udusok.edu.ng) ✉ Department of Pure and Applied Chemistry, Usman Danfodio University, Sokoto. © 2020. Faculty of Tech. Education, ATBU Bauchi. All rights reserved



### Samples Collection

The selected food crop samples classified as tubers: yam (*Discorea rotundata*) and cassava (*Manihot esculenta*); cereals: maize (*Zea mays*), guinea corn (*Sorghum bicolor*) and millet (*Pennisetum glaucum*); legumes: beans (*Phaseolus vulgaris*) and soybean (*Glycine max*); leafy vegetables: okra (*Abelmoschus esculentus*), white jute (*Corchorus capsularis*) and amaranth (*Amaranthus retroflexus*) as well as garri, a processed form of cassava and powdered yam were bought from farmers at the neighboring community to Kuchiko. Quintuplet samples of each cultivar were collected at different point in the study site and its environs before been thoroughly washed to prevent airborne pollutants.

### Sample Preparation

After collection, the samples were pulverized to fine powder using the laboratory mill. The milled sample was stored separately in labeled and airtight plastic containers and preserved in desiccators until required for analyses. The

garri and powdered yam samples were dried in oven, allowed to cool, sieved through a mesh of 1mm diameter and stored in airtight plastic container.

### Laboratory Analysis

Portions of homogenized soils, water and food crops samples digested were quantified for the trace metals; As, Cd, Co, Cr, Cu, Fe, Hg, Ni, Pb and Zn, adopting various analytical techniques and instrumentation in the evaluation of each trace metal, since each element has its peculiar matrix and detection levels.

### Metal Analysis

The metal analysis was determined by comparing the absorbance  $I_0$  when no analyte exist and  $I_{trans}$  when analytes are present. Procedural blanks were prepared and aspirated along with the analytical samples in order to correct for background absorption. The limit of detection for the metal was 0.001 ppm while that of the blank was 0.00 ppm. The instrumental description for each analyzed metal is presented in table 1.

**Table 1:** Instrumental Description of the AAS

S/N	Metals	Lamp description	Slit width (mm)	Wavelength (nm)
1	Lead	Lead hollow cathode lamps operated at 10 mÅ	0.7	253.7
2	Cadmium	Cadmium hollow cathode lamp operated at 4 mÅ	0.7	228.8
3	Arsenic	Arsenic ultra-lamp operated at 10 mÅ	1.0	189.0
4	Copper	Multi-element hollow cathode operated at 15 mÅ	1.0	324.7
5	Cobalt	Cadmium hollow cathode lamp operated at 10 mÅ	0.7	189.0
6	Mercury	Mercury hollow cathode lamp operated at 10 mÅ	0.7	253.7
7	Zinc	Multi-element hollow cathode lamp operated at 12 mÅ	3.0	213.8



S/N	Metals	Lamp description	Slit width (mm)	Wavelength (nm)
8	Iron	Multi-element hollow cathode lamp operated at 12 mA	0.2	248.3
9	Nickel	Multi-element hollow cathode lamp operated at 7 mA	0.15	232.1
10	Chromium	Chromium hollow cathode lamp of current 10 mA	1.0	540.0

### Statistical Analysis

Precision, accuracy and sensitivity of the analytical techniques employed in this research were assured by quadruplet samples, blanks and the method of standard addition. Results were expressed as the mean  $\pm$  standard deviation.

### RESULTS AND DISCUSSION

The results of the trace metal concentrations obtained from the assessment of the quality of the different staple food samples from the study location in comparison with the permissible limits of conventional standard(s) is presented in Tables 2 - 5.

**Table 2:** Ranges and Mean Concentration Values for Trace Elements in the Cereal Crops around the Study Site

Trace Element	Concentration Range (mg/kg)	Mean $\pm$ SD for QA	WHO/FAO Standard (mg/kg)
Copper	7.4 - 7.4* 7.4 - 7.4** 6.8 - 7.6***	7.4 $\pm$ 0.00 7.4 $\pm$ 0.00 7.2 $\pm$ 0.32	73.3
Lead	ND* ND** ND***	- - -	0.30
Zinc	111.2 - 137.75* 91.50 - 130.50** 94.60 - 106.90***	125.90 $\pm$ 8.80 103.8 $\pm$ 13.46 103.18 $\pm$ 5.66	99.4
Iron	106.7 - 120.0* 177.65 - 243.40** 111.85 - 177.65***	112.5 $\pm$ 4.27 196.86 $\pm$ 24.67 125.01 $\pm$ 26.32	425.5
Cadmium	ND* ND** ND***	- - -	0.20
Arsenic	ND* 0.00 - 1000** ND***	- 400 $\pm$ 17.17 -	1.4
Cobalt	ND* ND** ND***	- - -	50
Mercury	ND* ND** ND***	- - -	0.50



Trace Element	Concentration Range (mg/kg)	Mean ± SD for QA	WHO/FAO Standard (mg/kg)
Nickel	ND*	-	67
	ND**	-	
	ND***	-	
Chromium	ND*	-	2.30
	ND**	-	
	ND***	-	

Key: \* = Maize; \*\* = Guinea Corn; \*\*\* = Millet; ND = Not Detected; QA = Quintuplet analysis; WHO (1996).

The result of the analysis of heavy metals in the selected cereals presented in Table 2 showed the presence of Cu, Zn and Fe in the maize, millet and guinea corn samples though lower in the concentrations of Cu and Fe for all samples and higher in the concentration of Zn than the permissible limit set by WHO. While as was detected only in the guinea corn sample, Pb, Cd, Co, Hg, Ni and Cr were not detected in any of the sample. Among the detected metals in the samples, iron had the highest concentration with guinea corn having the highest concentration of iron compared to the maize and millet sample. The results obtained in the current study in the selected cereals are in agreement with Aremu *et al.*, 2006, who reported similar range of values of the detected metals in the cereals analyzed. The results obtained in this study differ from similar work carried out by Salihu *et al.*, 2014 and Shar *et al.*, 2011 who reported lower

values of these heavy metals in cereals than the one obtained in this work. The difference may be due to heavy metal accumulation in plant which depends principally in this case the soil type and other factor like plant species, genetics, soil conditions, weather, environment, stage of maturity and supply route to the market, as reported by Ismail *et al.*, 2011 and Judy *et al.*, 2012. Farmlands situated in industrialized areas are prone to pollution by the release of chemicals into the farmlands leading to contamination of plant crops (Abdulrazak *et al.*, 2014) hence the variation of this work with other similar works could also be because of heavy metal toxicity. The result of the concentration range and mean concentrations of *D. rotundata*, *M. esculenta*, garri (processed form of *M. esculenta*) and powdered yam (processed form of *M. esculenta*) is presented in table 3.

**Table 3:** Ranges and Mean Concentration Values for Trace Elements in the Tuber Crops around the Study Site

Trace Element	Concentration Range (mg/kg)	Mean ± SD for QA	WHO/FAO Standard (mg/kg)
Copper	7.4 - 7.4*	7.4±0.00	73.3
	7.4 - 7.4**	7.4±0.00	
	7.4 - 7.4***	7.4±0.00	
	7.4 - 7.4****	7.4±0.00	
Lead	ND*	-	0.10
	ND**	-	
	ND***	-	
	ND****	-	

Corresponding author: Ogbiko, C. ✉ [cyril.ogbiko@udusok.edu.ng](mailto:cyril.ogbiko@udusok.edu.ng) ✉ Department of Pure and Applied Chemistry, Usman Danfodio University, Sokoto. © 2020. Faculty of Tech. Education, ATBU Bauchi. All rights reserved



Trace Element	Concentration Range (mg/kg)	Mean $\pm$ SD for QA	WHO/FAO Standard (mg/kg)
Zinc	45.00-59.90* 40.08-50.10** 44.08-59.90*** 40.17-55.07****	49.87 $\pm$ 6.12 45.13 $\pm$ 3.17 48.10 $\pm$ 5.94 49.75 $\pm$ 6.01	99.40
Iron	111.85-111.85* 46.05-58.85** 40.09-78.19*** 40.09-78.19****	111.85 $\pm$ 0.00 57.32 $\pm$ 29.49 59.91 $\pm$ 12.78 59.91 $\pm$ 12.78	425.5
Cadmium	ND* ND** ND*** ND****	- - - -	0.10
Arsenic	ND* ND** ND*** ND****	- - - -	1.4
Cobalt	ND* ND** ND*** ND****	- - - -	-
Mercury	ND* ND** ND*** ND****	- - - -	0.50
Nickel	ND* ND** ND*** ND****	- - - -	-
Chromium	ND* ND** ND*** 0.05-0.35****	- - - 0.08 $\pm$ 0.001	-

**Key:** \* = Yam; \*\* = Cassava; \*\*\* = Garri; \*\*\*\* = Powdered Yam. ND = Not Detected; QA = Quintuplet analysis; WHO (1996).

The heavy metal concentrations in all the analyzed samples were in the following order: Fe > Zn > Cu. The other analyzed metals were not detected in the samples except for Cr, which were detected only in the powdered yam sample. All the heavy metal concentrations in the samples were below the maximum permissible level of WHO. The lower concentration of the

analyzed metals is as a result of the low transfer factor of heavy metals from soil to plants - a ratio which determines the concentration of heavy metals in a plant from its cultivated soil (Lago-Villa *et al.*, 2015). Although Cr noticed in the processed form of yam (powdered yam) with none observed in the processed form of cassava (garri), indicates that the Cr might not



possess any toxic effect since it could be present in the chromium (III) form since the chromium form is less toxic causing little or no health problems (Obasi, 2020). The result

of the concentration range and mean concentrations of the investigated legumes and leafy vegetables are presented in tables 4 and 5 respectively.

**Table 4:** Ranges and Mean Concentration Values for Trace Elements in the Legumes around the Study Site

Trace Element	Concentration Range (mg/kg)	Mean ± SD for QA	WHO/FAO Standard (mg/kg)
Copper	(a) 7.4-15.0 (b) 7.4-2.4	(a) 10.44±3.72 (b) 7.40±0.00	73.3
Lead	(a) ND (b) ND	-	0.30
Zinc	(a) 106.90-118.30 (b) 91.45-99.15	(a) 112.63±4.19 (b) 96.41±3.90	99.4
Iron	(a) 111.85-243.40 (b) 111.85-177.60	(a) 176.53±52.90 (b) 125.01±26.32	425.5
Cadmium	(a) ND (b) ND	-	0.20
Arsenic	(a) 0 - 1000 (b) ND	(a) 600±489.89 (b) -	-
Cobalt	(a) ND (b) ND	-	-
Mercury	(a) ND (b) ND	-	0.50
Nickel	(a) ND (b) ND	-	-
Chromium	(a) ND (b) ND	-	2.30

**Key:** (a) = Soybeans; (b) = Beans. ND = Not Detected; QA = Quintuplet analysis; WHO (1996).

The result of the analysis showed the presence of only Cu, Zn and Fe in both samples while as was only detected in the soybeans sample and not detected in the

beans sample. The concentration of Cu, Zn and Fe were all found to be higher in the soybeans sample than the beans sample.

**Table 5:** Ranges and Mean Concentration Values for Trace Elements in the Leafy Vegetables around the Study Site

Trace Element	Concentration Range (mg/kg)	Mean ± SD for QA	WHO/FAO Standard (mg/kg)
Copper	0 - 2.4* 0 - 7.4** 0 - 7.4***	1.48 ± 0.00 4.44 ± 0.00 4.44 ± 0.00	-
Lead	ND* ND** ND***	-	0.30

Corresponding author: Ogbiko, C. ✉ [cyril.ogbiko@udusok.edu.ng](mailto:cyril.ogbiko@udusok.edu.ng) ✉ Department of Pure and Applied Chemistry, Usman Danfodio University, Sokoto. © 2020. Faculty of Tech. Education, ATBU Bauchi. All rights reserved



Trace Element	Concentration Range (mg/kg)	Mean ± SD for QA	WHO/FAO Standard (mg/kg)
Zinc	126.40 - 137.75* 32.90 - 130.05** 52.90 - 110.00***	130.74 ± 3.76 89.49 ± 24.80 72.91 ± 19.74	-
Iron	165.17 - 309.20* 908.45 - 5243.40** 177.65 - 908.05***	234.10 ± 49.60 1925.63 ± 1669.84 104.07 ± 291.25	-
Cadmium	ND* ND** ND***	-	0.20
Arsenic	ND* ND** ND***	-	-
Cobalt	ND* ND** ND***	-	-
Mercury	ND* ND** ND***	-	-
Nickel	ND* ND** ND***	-	-
Chromium	0.05 - 0.455* 0.0 - 0.5** 0.0 - 0.5***	0.4 ± 0.14 0.15 ± 0.01 0.4 ± 0.01	-

**Key:** \* = Okra; \*\* = Amaranth; \*\*\* = Jute; ND = Not Detected; QA = Quintuplet analysis; WHO (1996).

The result presented in table 5 shows that only Cu, Zn, Fe and Cr were detected in the leafy samples while Pb, Cd, As, Co, Hg and Hg were below the detectable limit. Of these analyzed vegetable species, while Amaranth and Jute had the highest mean concentration of Cu and Okra having the least concentration, Jute had the highest concentration of Cr compared to Amaranth and Okra. The order of the concentrations of Zn and Fe in the samples are Okra > Jute > Amaranth and Amaranth > Jute > Okra respectively. The concentration of Zn and Fe in the staple foods (tubers, cereals, legumes, leafy vegetables) were significantly high in the present study, whereas the concentration of Cu was low. The observed

high levels were significantly higher in the vegetables than the staple foods. This is in agreement with the findings from previous researches, which indicated that some edible roots/tubers and vegetables were hyperaccumulators of trace elements (Colin and Eddo, 2010; Duffus, 2009). These tendencies could translate into major exogenous contamination source of these trace elements among the inhabitants and neighbors of the contaminated study area. Several toxicity complications associated with overloads of these metals are well documented (Akubue, 1997; Abdu, 2010; Fernando *et al.*, 2011). Consequences upon consumption of high amount of zinc could lead to side effects such as slowed growth,





low insulin levels, irritability, and hair loss, loss of appetite, diarrhea, and nausea (Akubue, 1997; Dooyema, 2010).

## CONCLUSION

The concentration levels of the investigated trace and heavy in the staple food samples from the mining site were mostly within the World Health Organization (WHO) permissible levels. This could probably be due to the fact the mining operations in the site are low scale and artisanal in operation unlike other sites where mechanized mining techniques could predispose release of more pollutants and tailings. It could hence be inferred that the soils at Kuchiko-Hausa around the mining site at the time of this study are yet to be impacted negatively by mining activity. Increased mine expansion would also necessitate continued assessment for possible pollution around the mine site

## REFERENCES

- Abdu, N. (2010). Availability, transfer and balance of heavy metals in urban agriculture of West Africa. Unpublished Faculty of Organic Agricultural Sciences, University of Kassel. Kassel: University Press GmbH, Kassel. Retrieved from <https://d-nb.info/101114493X/34>.
- Abdulrazak, S., Otie, D. and Oniwapele, Y.A. (2014). Concentration of nitrate and nitrite in some selected cereals sourced within Kaduna state, Nigeria. *Online J. Anim. Feed Res.* 4(3): 37 - 41.
- Abiya, S.E., Odiyi, B.O., Ologundudu, F.A., Akinnifesi, O.J. and Akadiri, S. (2018). Assessment of heavy metal pollution in a gold mining site in Southwestern Nigeria. *Journal of Genetics and Cell Biology.* 1(2): 30-35.
- Acosta, J.A., Faz, A., Martínez-Martínez, S., Zornoza, R. and Carmona, D.M. (2011). Multivariate statistical and GIS-based approach to evaluate heavy metals behavior in mine sites for future reclamation. *J Geochem Explor.* 109: 8-17.
- Adler, R. and Rascher, J.A. (2007). Strategy for the management of acid mine drainage from gold mines in Gauteng. CSIR: Pretoria, South Africa.
- Agrelli, D., Adamo, P., Cirillo, T., Duri, L.G., Duro, I., Fasano, E., Ottaiano, L., Ruggiero, L., Scognamiglio, G. and Fagnano, M. (2017). Soil versus plant as indicators of agroecosystem pollution by potentially toxic elements. *J Plant Nutr Soil Sci.* 180(6): 705 - 719. DOI: 10.1002/jpln.201700050.
- Akubue, P.I. (1997). Poison in our environment and drug over-dosage. In: *A guide for health professionals and the lay public.* (1st ed.), Nigeria Rex Charles and Patric Ltd. pp: 60-77.
- Aremu, M.O., Olanisokin, A. and Ahmed, S.A. (2006). "Assessment of some heavy metal content in some selected agricultural products planted along some roads in Nasarawa State, Nigeria. *J. Engr. and Appl. Sci.* 1: 199-204.
- Armah, F.A., Quansah, R. and Luginaah, I. (2014). A systematic review of heavy metals of anthropogenic origin in environmental media and biota in the context of gold mining in Ghana. *Int Sch Res Notices.* Article ID: 252148. DOI: 10.1155/2014/252148.
- Colin, H. and Eddo, J.H. (2010). Technical digest on lead in drinking water. Institute for Health and Consumer Protection, Via E. Fermi 2749, 21027 Ispra (VA), Italy Mohsen Dehghani and Alireza Kashefi.



- Donkor, A.K., Bonzongo, J.C.J., Nartey, V.K. and Adotey, D.K. (2005). Heavy metals in sediments of the gold mining impacted Pra River basin, Ghana, West Africa. *Soil and Sediment Contamination*. 14: 479-503.
- Dooyema, C.A. (2010). Outbreak of fatal childhood lead poisoning related to artisanal gold mining in North-Western Nigeria. *Environmental Health Perspectives*. 120: 601-608.
- Duffus, J.H. (2009). "Heavy metals" a meaningless term? (IUPAC Technical Report). *Journal of Pure and Applied Chemistry*. 74: 793.
- Ekaterina, A. and Jeliakova, L.E. (2001). Heavy metals and seed germination in some medicinal and aromatic plants. Department of Plant and Soil Science, University of Massachusetts, Amherst, MA, USA.
- Fernando, P.C., João, M. and Oliveira, G.A. (2011). Factors affecting 210Po and 210Pb activity concentrations in mussels and implications for environmental biomonitoring programmes. *Journal of Environmental Radioactivity*. 102: 128 - 137.
- Ismail, F., Anjum, M.R., Mamon, A.N. and Kazi, T.G. (2011). Trace metal contents of vegetables and fruits of hyderabad retail market. *Pak. J. Nutr.* 10: 365 - 372.
- Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B.B. and Beeregowda, K.N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdiscip Toxicol*. 7(2): 60 - 72.
- Judy, I.K., Fanuel, K. George, O. and Paul, O. (2012). Assessment of heavy metal concentrations in urban grown vegetables in Thika Town, Kenya. *Afr. J. Food Sci*. 6: 41- 46.
- Lago-Villa, M., Arenas-Lago, D., Rodriguez-Seijo, A., Andrade-Couce, M.L. and Vega, F.A. (2015). Cobalt, chromium and nickel contents in soils and plants from a serpentine quarry. *Solid Earth*. 6(1): 323 - 335.
- Laniyan, T.A. and Adewumi, A.J. (2020). Evaluation of contamination and ecological risk of heavy metals associated with cement production in Ewekoro, Southwest Nigeria. *J Health Pollut*. 10(25): Article 200306. DOI: 10.5696/2156-9614-10.25.200306
- Lottermoser, B. (2007). *Mine wastes: Characterization, treatment and environmental impacts*. Springer: New York, NY, USA, pp: 1-290.
- Mingorance, M.D., Valdes, B. and Oliva, S.R. (2007). Strategies of heavy metal uptake by plants growing under industrial emissions. *Environ Int*. 33(4): 514-20. DOI: 10.1016/j.envint.2007.01.005.
- Obasi, P.N. and Akudinobi, B.B. (2020). Potential health risk and levels of heavy metals in water resources of lead-zinc mining communities of Abakaliki, Southeast Nigeria. *Applied Water Science*. 10: 184. DOI: 10.1007/s13201-020-01233-z.
- Salihu, S.O., John, O.J., Matthew, J. and Kolo, T. (2014). Heavy metals in some fruits and cereals in Minna markets, Nigeria. *Pakistan Journal of Nutrition*. 13(12): 722-727.
- Shar, G., Kazi, Q., Tasneem, G., Shah, F.A., Shar, A.H. and Soomro, F.M. (2011). Variable uptake, accumulation of essential, and heavy metals in maize (*Zea mays* L.) grains of six maize varieties. *Aust. J. Basic and Appl. Sci*. 5: 117-121.
- WHO/FAO/IAEA, (1996). *World Health Organization Switzerland; General Trace Elements in Human*



Nutrition and Health. Wisconsin,  
pp: 19-48.

Xue, Z.J., Liu, S.Q., Liu, Y.L. and Yan, Y.L.  
(2012). Health risk assessment of  
heavy metals for edible parts of  
vegetables grown in sewage-  
irrigated soils in suburbs of  
Baoding City, China. Environ  
Monit Assess. 184(6): 3503-3513.  
DOI: 10.1007/s10661-011- 2204-  
2206.