UMYU Scientifica, Vol. 2 NO. 4, December 2023, Pp 085 – 091
https://doi.org/10.56919/usci.2324.010
ISSN: 2955 – 1145 (print); 2955 – 1153 (online)
A periodical of the Faculty of Natural and Applied Sciences, UMYU, Katsina

ORIGINAL RESEARCH ARTICLE

Contamination Characteristics, Source Analysis and Health Risk Assessment of Heavy Metals in Some Aquatic Insects Found in River Gashua, Yobe State Nigeria.

I.P. Aiki[1], M. Sulyman[1], H. A. Shindi[2] and A.H. Bobi[3].
[1]Department of Biological Science, Federal University Gashua, P.M.B 1005 Gashua, Yobe State, Nigeria.
[2]Federal University of Agriculture P.M.B 1028, Zuru, Kebbi State, Nigeria.
[3]SPRS Ibeto, Ibrahim Badamasi Babangida University, Lapai, Niger State, Nigeria.

ABSTRACT
The study assesses the level of heavy metals in some aquatic insects, *lethocerus* species, and *Hydrophilus piceus* (Great silver water beetles) found in river Gashua. The insects and soil samples found in the river were randomly collected, processed, and analysed for heavy metals using atomic absorption spectrophotometry (AAS). There's no significant difference in the soil samples and the aquatic insects: *Lethocerus species* and *Hydrophilus picueus*. The results also showed that the range of the concentrations of heavy metals found in the three samples in the order of their abundance as Mn > Pb > Cu > Ni > Cd and 0.03-1.71mg/kg > 0.03-1.15mg/kg > 0.05-0.54 mg/kg > 0.05-0.28 mg/kg > 0.05-0.28 mg/kg respectively. The results were compared to acceptable levels set by the FAO/WHO to see if the heavy metal levels in the insects were safe. Assessment of the heavy metals in the soil and aquatic insects gives an idea of how heavy metals are transferred within a food chain and shows the level of bioaccumulation of the metals in aquatic insects. The implications of the selected heavy metals found in the area's soil and aquatic insects were identified and discussed. Practices that will reduce heavy metal pollution rates are encouraged among the inhabitants. It was recommended that assessing the heavy metals concentration in the soil and the aquatic insects should be a routine to prevent excessive accrual in the food chain.

ARTICLE HISTORY
Received July 27, 2023.
Accepted November 03, 2023.
Published December 21, 2023.

KEYWORDS
Permissible limits; Heavy metals; Contamination; Bioaccumulation; *Lethocerus* species; *Hydrophilus picueus*

INTRODUCTION

Heavy metals are naturally occurring elements with a high atomic weight and density at least 5 times greater than water. With diverse applications, which include industrial, domestic, agricultural, medicinal, and technological, have led to their wide distribution in the environment, raising concerns over their potential effects on human health and the environment (Kaur *et al*., 2019; Tchounwou *et al*., 2012, Pourret, 2018). Alloway (2012) considered heavy metals a loose term for a wide group of metals of atomic density less than 5, which are generally associated with pollution and toxicity. They are trace elements when their environmental occurrences are less than 0.2 ppm. Trace metals occur naturally in soils but rarely at toxic levels (Knight *et al*., 1997). Although certain heavy metals (Cr, Mn, Ni, Zn, Cu, and Fe) are essential components for various biological activities within the human body, elevated metals can cause numerous health consequences to mankind.

In contrast, Pb, Cd, Hg, and As are non-essential, toxic elements associated with many chronic diseases in human beings (Chen *et al*., 2014). Similarly, due to bioaccumulation, non-degradability, and the excessive amounts in which they exist, these metals pollute the food chain and consequently become a source of toxicity to humans and the entire ecological system. Although there is a global significance to the issue, it seems more urgent for developing countries such as Nigeria, where the weight of the population increases the demand for human sustainability, food security, and total eradication of hunger.

Olowu et al. (2010), in their quest to ascertain the heavy metals concentration in two marine organisms (Crab and Prawn), observed that the mean concentration of copper, cadmium, and zinc in prawn was observed to be within the range of the National Agency for Food and Drug Administration and Control (NAFDAC) standard in Nigeria for water and aquatic foods while crabs have

Correspondence: Aiki, I. P. Department of Biological Science, Federal University Gashua, P.M.B 1005 Gashua, Yobe state, Nigeria. ✉ istifanusaiki@fugashua.edu.ng.
How to cite: Aiki, I. P., Sulyman, M., Shindi, H. A., & Bobi, A. H. (2023). Contamination Characteristics, Source Analysis and Health Risk Assessment of Heavy Metals in Some Aquatic Insects Found in River Gashua, Yobe State Nigeria. *UMYU Scientifica*, 2(4), 85 – 91. https://doi.org/10.56919/usci.2324.010

higher mean concentration of heavy metals except for zinc and copper which are within the limit. Ametepey *et al.* (2018), in a study to find out the health risk assessment and heavy metal contamination levels in vegetables, found that the individual hazard index of vegetables for both children and adults was below 1, which indicates no potential risk to the public except for cadmium, chromium, and manganese which were above the standard index. In a similar study, Nkwunonwo *et al.* (2020) looked at heavy metals from different perspectives in a review of the health implications of heavy metals in the food chain in Nigeria, where they stated that heavy metals such as Zn, Pb, Fe, and Cu are abundant in nature and mostly provide survival and stability of ecosystem processes despite their negative impacts when found in excess.

Heavy metal pollution in soil and water has a lot of adverse effects and thus is of great concern to public health, agricultural production, and environmental health (Goyer, 1997; Fergusson, 1990). Soil pollution is mainly due to the disposal of industrial and urban wastes as well as the usage of agrochemicals (McBride, 2003), while water pollution is primarily caused by industrial wastes, sewage disposal, petroleum contamination, and agricultural drainage water, which in turn affect aquatic lives (Haq, 2005, Santos *et al.*, 2005, Tariq *et al.*, 2006).

Research has been carried out on fish (Bawuro *et al.*, 2018), vegetables (Kacholi and Sahu, 2018), and other food sources that are considered as possible routes for bioaccumulation of heavy metals, but less has been done on aquatic insects, most especially from the study area which many of them are either directly or indirectly the source of food to vertebrates and invertebrates organisms. Looking at the contribution of these insects in the aquatic ecosystem food chain which brought about the current research on aquatic insects and the availability of these insects as a source of food to the aquatic organisms, most especially the fishes, while the fishes, in turn, are a source of food and income to the people of the community. The study aims to consider the presence of heavy metals found in some aquatic insects in river Gashua in Yobe State and to measure the concentration of the heavy metals in the soil samples collected from the same river. The study is limited to nickel (Ni), cadmium (Cd), copper (Cu), manganese (Mn), and lead (Pb).

MATERIALS AND METHODS

Study area

Gashua is located within the sub-Saharan climatic zone between a latitude of 12°52'5"N and a longitude of 11°2'47"E. Gashua is a farming and fishing community in Yobe State in North-Eastern Nigeria, on the Yobe River, a few miles below the convergence of the Hadejia River and the Jama'are River. The average elevation is about 299 m. The hottest months are March and April, with temperatures of 38 to 40°C. The rainy season starts from June to September, when temperatures fall between 23 to 28°C, with rainfall of about 500 to 1000mm. The town lies near the Hadejia-Nguru Wetlands, which is economically and ecologically important in the area (Geonames.org).

Sample collections

Samples of insects were randomly collected and replicated at three different locations along the river: (i) Katuzu), (ii) New Bridge, and (iii) Old Bridge, while the soil samples were also collected from three different locations along the same river; (i) New bridge, (ii) Katuzu, and (iii) Kwata. The samples collected were also replicated randomly at each of the three locations mentioned. The Soil samples were collected up to 15 cm deep within the river, and the sample collections were carried out from sunrise to noon, between April to July. The samples of *lethocerus* species and *Hydrophilus piceus* (Great silver water beetles) were collected from river Gashu'a using a fishing drag net. After collection, the samples were transferred into a clean vial. Both the insects and the soil samples were processed at the Biological Science Laboratory Federal University Gashua, Yobe State, Nigeria, while the heavy metals analysis was carried out at the laboratory of the Biochemistry Department of Bayero University's new site in Kano, Nigeria.

Sample preparation and digestion

Lethocerus species and *Hydrophilus piceus*

Metals were extracted using the standard acid digestion (Horwitz, 2010; Sahu and Kacholi, 2016). The heavy metals concentrations were determined with Atomic Absorption Spectrophotometer (AAS). Each sample of *Lethocerus* species and *Hydrophilus piceus* was properly cleaned by rinsing with distilled water to remove debris, plankton, and other external adherents, and it was then drained under folds of filter, weighed, wrapped in aluminum foil and then frozen at 10ºC prior to analysis. *Lethocerus* species and *Hydrophilus piceus* samples were frozen for 24 hours, it was then weighed into a pre-weighed petri-dish, and then dried at 80ºC in a Gallenkamp hot box oven. The dried samples were taken and recorded at intervals of 4 hours until a constant weight was obtained. The dried samples of *Lethocerus* species and *Hydrophilus piceus* were put in a cleaned, dried mortar separately, ground to fine particles, and then sieved using a sieve of particle size 0.02 mm. 0.5 g each sample was measured in a clean dried beaker (100 ml), and 5 ml of HCL and HNO3 (3:1) were added to the sample for digestion. The samples were allowed to be evenly distributed in the acid by stirring with a glass rod, and then the beaker was placed on the heater. The digested sample was filtered into a graduating cylinder, and the filtrate was made up to 50 ml using distilled water.

Soil samples

Soil samples collected from different study area locations were thoroughly mixed, then oven-dried at 105C for six hours until constant weight was attained. The oven-dried samples were then turned into powdered and sieved through 2.0mm wire mesh. For each sample, 1g was digested in 10 ml of 1:1 HNO_3, heated to 95ºC to dry, and refluxed for 10 minutes without boiling. After cooling, 5ml of concentrated HNO_3 was again added and refluxed for 30 minutes until brown fumes were produced. Adding 5mL of concentrated HNO_3 was repeated until white fumes appeared. The solution was vaporized to about 5 on a mantle set at 95ºC with a watch glass. After cooling the resulting sample, 2ml of H_2O and 3ml of 30%H_2O_2 were added, and the solution was placed on the heating mantle to start the oxidation of peroxide until effervescence subsided. The vessel was cooled, and the acid-peroxide digestate was heated to about 5ml at 95ºC. Later, the addition of 10ml concentrated HCl to the sample digest was done, and the solution was placed on the heating source and refluxed for 15 minutes at 95ºC. Finally, the digestate was filtered, and the filtrate was collected for analysis of heavy metals in the Atomic Absorption Spectrophotometer (Welz and Sperling, 2008)

Statistical Analysis

Kruskal-Wallis Test was conducted to examine the differences in the composition of heavy metals: nickel (Ni), cadmium (Cd), copper (Cu), manganese (Mn), and lead (Pb) found in the soil samples and the aquatic insects; *Lethocerus* species and *Hydrophilus picueus*. The statistical analysis was carried out using R version 4.1.1 with alpha level set at 0.05.

RESULTS

The samples (Soil, *Lethocerus* species, and *Hydrophilus picueus*) showed no significant difference (Chi-square = 14, p = 0.4497, df = 14) in their heavy metals compositions. According to Table 1, the total mean concentrations of heavy metals detected in the three samples collected from the study sites range from 0.05-0.28 mg/kg for Ni, 0.05-0.28 mg/kg for Cd, 0.05-0.54 mg/kg for Cu, 0.03-1.71 mg/kg for Mn and 0.03-1.15 mg/kg for Pb. The results also showed that the total mean concentrations of heavy metals found in the three samples in the order of their abundance as Mn > Pb > Cu > Ni > Cd. Figure 1 shows the distribution of the heavy metals within the three collected samples. Similarly, Table 1 also presented the standards of the selected heavy metals according to the Food and Agricultural Organization/World Health Organization (FAO/WHO) permissible limits (FAO/WHO, 2001) as published by Galal *et al.* (2021).

DISCUSSION

Heavy metal pollution is a menace to our ecosystem as they are a source of environmental contamination. Aquatic insects get contaminated by absorbing heavy metals from polluted water or soil, sometimes from the atmosphere, and most of these insects are eaten by other organisms that prey on them, most especially fishes, while humans sometimes also consume both the insects and the fishes (Anankware *et al*., 2015, Banjo *et al*., 2006). Gashua is known for its fishing activities, which is a source of livelihood for many households. Aside from being a source of income for many families, it is also consumed as a source of protein due to its availability and affordability. The findings showed no significant difference in the bioaccumulation of the heavy metals in the soils of the river and the aquatic insects, *Lethocerus* species and *Hydrophilus picueus* found in the river, which is similar to the findings of Badejo *et al.* (2017) in their study to evaluate the Concentration of heavy metals in Gashua river. The observed mean concentrations of Ni, Cd, Mn, Pb, and Cu in the soil sample, *Lethocerus* species, and *Hydrophilus picueus* were compared with the recommended limits established by the FAO/WHO to ensure the safety and well-being of the consumers along the food chain (Galal et al., 2021, Mok *et al*., 2015, FAO/WHO, 2001).

The mean concentration of all the metals is within the FAO/WHO permissible limits in all three samples except Pb, which exceeds the permissible limit in all three samples (Kacholi and Sahu, 2018) and Cu in *Lethocerus* species (Table 1). Excessive levels of heavy metals can be introduced into the environment, for example, by industrial waste or fertilizer application. Soil represents a major sink for heavy metal ions, which can enter the food chain via plants or leach into groundwater (Bradl, 2005). Looking at the mean composition of the metals, Figure 1 supports the idea that soil is one of the major sources of the metals found in aquatic insects, which serve as a sink and get dissolved by the river water, which bioaccumulates in the aquatic insects and then gets transfer into the food

Table 1. Mean (mg/kg) and standard deviation (±) of heavy metals concentration found in *Lethocerus* species, *Hydrophilus piceus* and soil samples with FAO/WHO (2001) standard

Metals	*Lethocerus species*	*Hydrophilus piceus*	Soil Sample	Total	Range	FAO/WHO
Ni	0.26 ± 0.03	0.06 ± 0.01	0.23 ± 0.04	0.55±0.08	0.05-0.28	5.0
Cd	0.07 ± 0.01	0.26 ± 0.03	0.06 ± 0.01	0.39±0.05	0.05-0.28	0.02
Cu	0.39 ± 0.14	0.12 ± 0.02	0.10 ± 0.09	0.61±0.25	0.05-0.54	0.27
Mn	0.04 ± 0.01	0.18 ± 0.07	0.60 ± 0.96	0.82±1.04	0.03-1.71	20.0
Pb	1.00 ± 0.19	0.06 ± 0.04	0.88 ± 0.27	1.94±0.50	0.03-1.15	0.01

FAO = Food and Agricultural Organization, WHO = World Health Organization

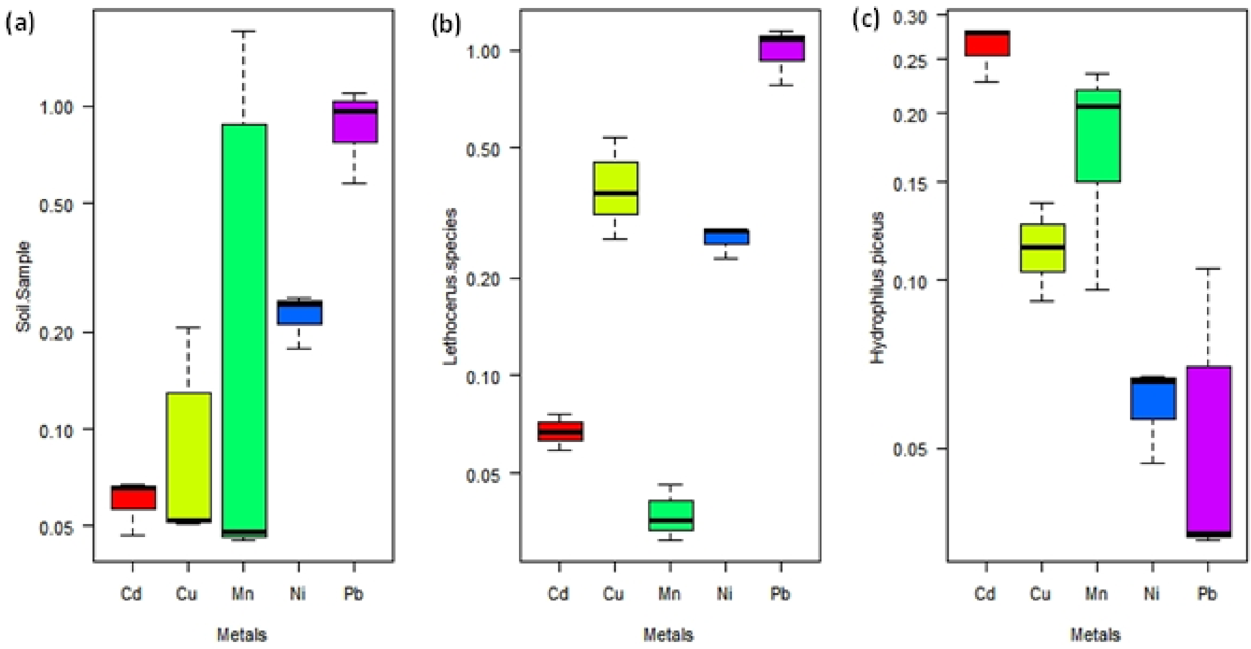

Figure 1. Boxplots representing heavy metals mean concentration found in (a) soil sample, (b) *Lethocerus* species and (c) *Hydrophilus picueus.* Showing inter quartile range, median, lowest and the highest values.

chain (Ali and Khan, 2018). Though Gashua is not an industrial hub where we expect a lot of industrial waste except for the industrial waste brought by the river from other places, domestic waste, and sewages are found in almost every corner of the town (Saleh and Ahmed, 2019) which might be a factor in the accumulation of some of these heavy metals such as Cu in *Lethocerus* species and Pb in all the samples found in the study area. Agricultural activities occur almost throughout the year, and farmers are actively involved in wet and dry season farming along the river. Most of the soils lost their nutrients due to frequent farming activities that farmers supplement with fertilizers.

Similarly, farmers around the area no longer weed their farms regularly, which is considered as an ancient way of farming, but settled for herbicides, pesticides, and other chemicals, which makes farming easier though harmful to the ecosystem, especially when applied in excess or not in accordance with the laydown procedures. Fertilizers and herbicides (chemicals) make farming easier, but they also contribute to the increase in the level of heavy metals in the soil and water found in the area. These happen through leaching and washing of the chemicals into the river or sinking into the water table, contaminating the water (Chen *et al.*, 2014; Bradl, 2005).

Tasrina *et al.* (2015) and Kananke *et al.* (2014) suggest that the possible sources of heavy metals like Pb and Cu could be road runoff and atmospheric deposition, which are the two metals that exceed the FAO/WHO permissible limit in their mean concentrations from the study area. This is because the river runs along a major road connecting several states within the region, making it a busy road with heavy traffic. Mebale *et al.* (2014) reiterate that increased levels of heavy metals are associated with atmospheric deposition, which also adds to the levels of the metals found in the river, which in turn increases the levels of bioaccumulation of the metals in the aquatic insects.

Even though Cu, Ni, and Mn are considered essential elements for various biological activities within the human body, elevated levels of these metals can negatively affect consumer health. Apart from being an important biocatalyst in the body, copper is essential for body pigmentation, maintenance of the central nervous system, and preventing anemia, and it is associated with the functions of Fe and Zn in the body (Kananke *et al.*, 2014, Järup, 2003). On the other hand, Cd and Pb are non-essential toxic elements that cause carcinogenic effects and teratogenic abnormalities in humans, even at very low concentrations (Nazar *et al.*, 2012; Ali and Khan, 2018). Phosphate fertilizers are the major sources of soil contamination by trace metals, especially Cd, as it is naturally found as an impurity in phosphate rocks (Nazar *et al.*, 2012; Bakhshayesh *et al.*, 2014). Similarly, Pb and Cu stem from nearby traffic activities and the use of agrochemicals, respectively (Kananke *et al.*, 2014). For Pb and Cu, exceeding limits is not surprising since Gashua is an agrarian community; therefore, the possibility of the presence of these heavy metals might be due to the frequent use of inorganic fertilizers by the farmers and heavy traffic along the major roads.

Amshi *et al.* (2019) highlighted the health challenges associated with the presence of heavy metals in Gashua town and its environments. They also emphasized the extent of heavy metal concentration in agricultural soil, which has serious health implications such as kidney failure, mental lapse, and central nervous system disorder in humans and higher animals.

Excessive use of fertilizers, pesticides, and herbicides should be discouraged, alternative fuel and vehicles should be encouraged to reduce the atmospheric pollution that causes health risks within the community, and regular medical checkups should be a priority within the populace. Heavy metal assessments should also be a continuous process within the area so as to keep abreast with the levels of the heavy metal contaminations.

CONCLUSION

The findings showed no significant difference in the bioaccumulation of the heavy metals found in the soil of the river and the aquatic insects, *Lethocerus* species, and *Hydrophilus picueus* found in the river. The observed mean concentrations of Ni, Cd, Mn, Pb, and Cu in the soil sample, *Lethocerus* species, and *Hydrophilus picueus* were compared with the recommended limits established by the FAO/WHO. The mean concentration of all the metals is within the recommended limits in all three samples except Pb, which exceeds the permissible limit in all three samples, and Cu in *Lethocerus* species. River Gashua is a source of food and income to many inhabitants of the land and its environs, and heavy metals contaminate most of the soils, farmlands, and aquatic life, which in turn flows into the food chain and causes health challenges to the inhabitants. The study recommends regular monitoring of heavy metals in soils, water, and food to prevent excessive accrual in the food chain.

Similarly, there should be a routine check-up of the inhabitant to check for heavy metals-related illnesses to prevent any health challenge that might arise from accumulations of heavy metals. Farmers should be enlightened on the dangers of too much use or wrong use of chemicals and fertilizers in their farms, which sometimes contaminate the river and the environment. Similarly, alternative fuels and vehicles should be encouraged to reduce the study area's atmospheric pollution.

ACKNOWLEDGMENTS

Our appreciation goes to the entire academic staff of the Department of Biological Science of Federal University Gashua for their constructive criticism during this work. We also thank Abubakar Muhammad and Muhammad Aji Fatima, our undergraduate students, who contributed in no small measure to making this work a reality. We also appreciate the effort of the laboratory scientists of the department, whose work has not gone unnoticed. We also appreciate the laboratory scientists of the Biochemistry Department of Bayero University's new site, Kano, who helped analyze the samples.

DATA AVAILABILITY

Data are available with the corresponding author.

DECLARATIONS

Conflict of interest

The authors declare no competing interests

REFERENCES

Ali, H. & Khan, E. 2018. Bioaccumulation of Non-Essential Hazardous Heavy Metals and Metalloids in Freshwater Fish. Risk to Human Health. *Environmental Chemistry letters*, 16,903-917. **[Crossref]**

Alloway, B. J. 2012. Heavy Metals in Soils: *Trace Metals and Metalloids in Soils and their Bioavailability*, Springer Science & Business Media. **[Crossref]**

Amshi, S. A., Adamu, A., Yesufu, H. & Milagawanda, H. 2019. Health Risk Assessment of SomeHeavy Metals (Cd, Pb, Cr) in Soil Sample from Gashua, Yobe, Nigeria. *Journal of Science and Technology Research*, 1, 136-143.

Anankware, P., Fening, K. O., Osekre, E. & Obeng-Ofori, D. 2015. Insects as Food and Feed: A Review. *Int J Agric Res Rev,* 3, 143-151.

Badejo, B. I., Abdulrahman, A. K., Dali, Z. J. & Badgal, E. B. 2017. Assessment of Physicochemical Parameters of River Yobe, Gashua, Yobe State, Nigeria. *InternationalJournal of Fisheries and Aquatic Studies,* 5, 2, 93-98.

Bakhshayesh, B. E., Delkash, M. & Scholz, M. 2014. Response of Vegetables to Cadmium-Enriched Soil. *Water*, 6, 1246-1256. **[Crossref]**

Banjo, A., Lawal, O. & Songonuga, E. 2006. The Nutritional Value of Fourteen Species of EdibleInsects in Southwestern Nigeria. African Journal of Biotechnology, 5, 298-301.

Bawuro, A. A., Voegborlo, R. B. & Adimado, A. A. 2018. Bioaccumulation of Heavy Metals in Some Tissues of Fish in Lake Geriyo, Adamawa State, *Nigeria. Journal of Environmental andPublic Health*, 2018, 1854892. **[Crossref]**

Bradl, H. 2005. Heavy Metals in the Environment: *Origin, Interaction and Remediation*,Elsevier.

Chen, Y., Wu, P., Shao, Y. & Ying, Y. 2014. Health Risk Assessment of Heavy Metals in Vegetables Grown Around Battery Production Area. *Scientia Agricola*, 71, 126-132. **[Crossref]**

FAO/WHO, C. a. C. 2001. Food Additives and Contaminants. *Joint FAO. WHO Food Standards Program*, 1, 1-289.

Fergusson, J. E. 1990. The Heavy Elements: *Chemistry, Environmental Impact and Health Effects*\Jack E. Fergusson.

Galal, T. M., Hassan, L. M., Ahmed, D. A., Alamri, S. A., Alrumman, S. A. & Eid, E. M. 2021. Heavy Metals Uptake by the Global Economic Crop (Pisum sativum L.) Grown in Contaminated Soils and its Associated Health Risks. *Plos One*, 16, e0252229. **[Crossref]**

Geonames.Org .

Goyer, R. A. 1997. Toxic and Essential Metal Interactions. *Annual Review of Nutrition*, 17, 37-50. **[Crossref]**

Haq, M. 2005. Surface and Ground Water Contamination in NWFP and Sindh Provinces withRespect to Trace Elements. *Int J Agric Biol*, 7, 214-217.

Horwitz, W. 2010. Official Methods of Analysis of AOAC International. Volume I, Agricultural Chemicals, Contaminants, Drugs/Edited by William Horwitz, Gaithersburg (Maryland): *AOAC International*, 1997.

Järup, L. 2003. Hazards of Heavy Metal Contamination. *British Medical Bulletin*, 68, 167-182.**[Crossref]**

Kacholi, D. S. & Sahu, M. 2018. Levels and Health Risk Assessment of Heavy Metals in Soil,Water, and Vegetables of Dar es Salaam, Tanzania. *Journal of Chemistry*, 2018. **[Crossref]**

Kananke, T., Wansapala, J. & Gunaratne, A. 2014. Heavy Metal Contamination in Green Leafy Vegetables Collected from Selected Market Sites of Piliyandala Area, Colombo District, Sri Lanka. *American Journal of Food Science and Technology*, 2, 139-144. **[Crossref]**

Kaur, R., Sharma, S. & Kaur, H. 2019. Heavy Metals Toxicity and the Environment. *Journal of Pharmacognosy and Phytochemistry*, SP1, 247-249.

Knight, C., Kaiser, J., Lalor, G., Robotham, H. & Witter, J. 1997. Heavy Metals in Surface Water and Stream Sediments in Jamaica. *Environmental Geochemistry and Health*, 19, 63-66. **[Crossref]**

Mcbride, M. B. 2003. Toxic Metals in Sewage Sludge-Amended Soils: Has Promotion ofBeneficial Use Discounted the Risks? *Advances in Environmental Research*, 8, 5-19. **[Crossref]**

Mebale, A.-J. A., Ndong, R. O., Affane, L. N., Omanda, H. M., Nziengui, P. P., Biyogo, R. M. &Ondo, J. A. 2014. Assessment of Metal Content in Leafy Vegetables Sold in Markets of Libreville, Gabon. *International Journal of Current Research and Review*, 6, 28.

Mok, J. S., Kwon, J. Y., Son, K. T., Choi, W. S., Kim, P. H., Lee, T. S. & Kim, J. H. 2015. Distribution of Heavy Metals in Internal Organs and Tissues of Korean Molluscan Shellfish and Potential Risk to Human Health. *Journal of Environmental Biology*, 36, 1161.

Nazar, R., Iqbal, N., Masood, A., Khan, M. I. R., Syeed, S. & Khan, N. A. 2012. Cadmium Toxicityin Plants and Role of Mineral Nutrients in its alleviation. **[Crossref]**

Pourret, O. 2018. On the Necessity of Banning the Term "Heavy Metal" from the Scientific Literature. *Sustainability*, 10, 2879. **[Crossref]**

Sahu, M. & Kacholi, D. S. 2016. Heavy Metal Levels in Amaranthus Species from Chang'ombe-Mchicha Area in Temeke District, Dar es Salaam, Tanzania. *Asian Journal of Chemistry*, 28, 1123. **[Crossref]**

Saleh, A. & Ahmed, A. 2019. Solid Waste Management Practice and Challenges in Gashua,Yobe State, Nigeria. *Nigerian Journal of Environmental Sciences and Technology* (NIJEST) Vol, 3, 298-303. **[Crossref]**

Santos, I. R., Silva-Filho, E. V., Schaefer, C. E., Albuquerque-Filho, M. R. & Campos, L. S. 2005. Heavy Metal Contamination in Coastal Sediments and Soils Near the Brazilian Antarctic Station, King George Island. *Marine Pollution Bulletin*, 50, 185-194. **[Crossref]**

Tariq, M., Ali, M. & Shah, Z. 2006. Characteristics of Industrial Effluents and their PossibleImpacts on Quality of Underground Water. *Soil Environ*, 25, 64-69.

Tasrina, R., Rowshon, A., Mustafizur, A., Rafiqul, I. & Ali, M. 2015. Heavy Metals Contamination in Vegetables and its Growing Soil. *J Environ Anal Chem*, 2, 2.

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K. & Sutton, D. J. 2012. Heavy Metal Toxicity and the Environment. *Molecular, clinical and environmental toxicology*, 133-164. **[Crossref]**

Welz, B. & Sperling, M. 2008. Atomic Absorption Spectrometry, John Wiley & Sons.

Olowu R. A., Ayejuyo, O. O., Adewuyi, G. O., Adejoro, I. A., Denloye, A. A. B., Babatunde, A. O., Ogundajo, A. L. 2010. "Determination of Heavy Metals in Fish Tissues, Water and Sediment from Epe and Badagry Lagoons, Lagos, Nigeria", *Journal of Chemistry*, 7, 1 -7. **[Crossref]**

Ametepey, S.T., Cobbina, S.J., Akpabey, F.J., Duwiejuah, A.B and Abuntori, Z.N. 2018. Health Risk Assessment and Heavy Metal Contamination Levels in Vegetables from Tamale Metropolis, Ghana. *Food Contamination* 5, 5. **[Crossref]**

Nkwunonwo U.C., Odika P.O., Onyia N.I. 2020. A Review of the Health Implications of Heavy Metals in Food Chain in Nigeria. *Scientific World Journal*. 6594109. . PMID: 32351345; PMCID: PMC7182971. **[Crossref]**