Bima Journal of Science and Technology, Vol. 8(4B) Jan, 2025 ISSN: 2536-6041

DOI: 10.56892/bima.v8i4B.1165

Heavy Metals Contamination and Health Risk Assessment in Underground Water in Azare, Bauchi State, Nigeria

Dauda Abubakar[1,2] and Auwalu Baballe[1,2]

[1]Department of Physics, Bauchi State University, Gadau, Bauchi State, Nigeria.
[2]NanoScience and Technology Research Group, Department of Physics, Bauchi State University, Gadau, Bauchi State, Nigeria.

Corresponding Author: dabubakar19@yahoo.com

ABSTRACT

Heavy metal contamination in drinking water poses a major risk to global public health, undermining the well-being of communities worldwide. The study aimed to determine concentrations of heavy metals (Fe, Cu and Cr) in 10 samples of underground water across the study area. The concentrations of heavy metals were analyzed using atomic absorption spectrometer. The results revealed that the concentrations of heavy metals Fe, Cu and Cr are 0.71 mg/l, 0.47 mg/l and 0.07 mg/l respectively. The heavy metals concentrations are higher than the recommended limits set by WHO and USEPA, with the exception of Cu, which is below the permissible limit of 2.0 mg/l. The health risk assessments were assessed by computing hazard index (HI) and Excess Lifetime Cancer Risk (ELCR). The total hazard index computed due to heavy metals is 1.52, is above the acceptable limit of ($\mathrm{HI} > 1$), also the cumulative cancer risk for carcinogenic element is 1.26×10^{-3}, which is higher than permissible limits (1×10^{-6}), indicating non-carcinogenic risk and carcinogenic due to ingestion of water contaminated with heavy metals. The study will assist relevant government agencies in taking strategic action to lessen the heavy metals contamination of drinking water.

Keywords: Heavy metal, cancer risk, hazard quotient, drinking water, anthropogenic.

INTRODUCTION

A reliable source of drinking water, which is one of the of the basic necessities of human life, is challenging due to a lack of sufficient regulation of human activities and, to a lesser extent, environmental factors. Water plays a vital role for maintaining healthy life and has a potential to spread diseases (Omotoriogun et al., 2012). The primary source of drinking water in some parts of the world is the groundwater. There is a growing need for groundwater as a freshwater supply for home, industrial, and agricultural purposes (Hussain et al., 2019). While groundwater provides a relatively pathogen-free supply of drinking water, its chemical quality is impacted by various pollutants that seep into it through aquifer rocks and sediments. Human activity and geology can both contribute to groundwater degradation. Groundwater contains a wide range of chemical compounds in different amounts as a result of the chemical reactions that occur between water and geological settings (Khanam & Singh, 2014).

The world now faces a problem with water contamination, and human survival depends on consuming enough clean drinking water to avoid any health hazards (Abedi Sarvestani & Aghasi, 2019). The drinking water for humans should be free from any harmful substance that might contaminated the water such as (radioactive elements, toxic heavy metals, microbial and chemicals) (Dalhatu et al., 2024; Dashtizadeh et al., 2019). The weathering and erosion of bed rocks, as well as anthropogenic activities such population growth,

DOI: 10.56892/bima.v8i4B.1165

industrialization, mining activities, modern farming, have contributed to a significant increase in the number of contaminants in groundwater in recent decades (Rezaei et al., 2019). Heavy metals are regarded as dangerous pollutants in the environment because of their toxicity, stability, and capacity for bioaccumulation. Metals can be absorbed through the skin, inhaled, or directly consumed by humans, all of which can be harmful to health, However, the main method that pollutants are exposed to humans and animals is through the drinking of water (Mirzabeygi et al., 2017). The degree of toxicity exhibited by distinct heavy metal species varies considerably with various parameters, including metal's physical and chemical characteristics, exposure pathways, quantity and duration of exposure, and individual metabolism. There are three possible states for heavy metals in water sources: solution, particle, and colloidal (Niknejad et al., 2023).

The small quantities of heavy metals such as, Iron (Fe), Copper (Cu), Zinc (Zn) and Chromium (Cr) are required for normal growth and functioning of the human body. The health of humans is systematically affected when heavy metal concentrations in drinking water exceed USEPA-defined regulatory levels (Egbueri & Unigwe, 2020). The high concentrations of heavy metals in drinking water above the recommended limits, are toxic and carcinogenic, which can cause health diseases such as abdominal pain, brain tumor, high blood pressure, nerve damage and anemia (Islam et al., 2015). Consequently, a number of investigations have been carried out worldwide to evaluate the quality of groundwater and the potential health hazards associated with hazardous heavy metals and trace substances. High quantities of Cr and Fe were found in the study by (Ali et al., 2019) in the groundwater in Pakistan. Another investigation in the Assam district, India revealed minimal quantities of heavy metals in both surface and ground water (Chakrabarty & Sarma, 2011).

Many models for assessing water quality have been developed, taking into account the maximum allowed levels for various heavy metals in the groundwater sources. The models are either numerical or statistical methods (Egbueri & Unigwe, 2020). The main objective of this study is to determine the contamination level of three heavy metals in the underground water of Azare City and to estimate the potential health (carcinogenic and non-carcinogenic) risk associated with the heavy metals (Fe, Cu and Cr) contamination.

MATERIALS AND METHODS

Study Area

Azare is located in the Bauchi state in northern Nigeria, which a coordinates 11°40’27″N and10°11’28″E at elevation 436 meters. It has a total land mass of 1,436 km^2 and population of 295,970. Two distinct seasons, dry and arid, characterize the study area. The rainy season starts from May and ends in October, while the dry season runs from November to March. Azare is underlain by Chad-basin (Quaternary sedimentary) geological formation (Ibrahim et al., 2023). The geological map of the study area is presented Figure 1.

Bima Journal of Science and Technology, Vol. 8(4B) Jan, 2025 ISSN: 2536-6041

DOI: 10.56892/bima.v8i4B.1165

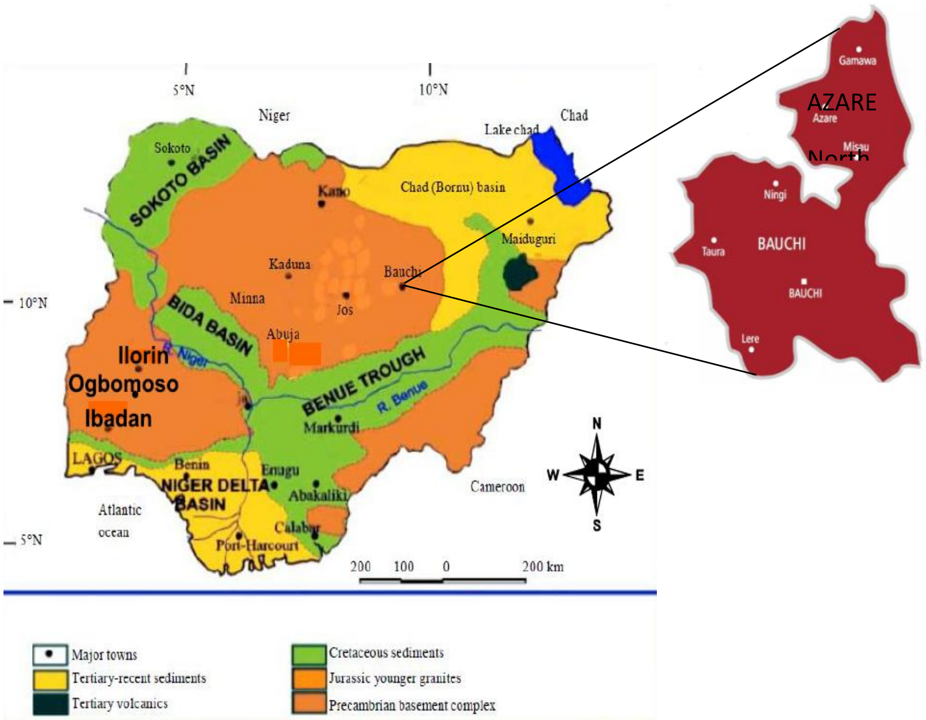

Figure 1: Map of the study area.

Collection and Preparation of Water Samples

In accordance with the water distribution system and population dispersion, the random sampling techniques were used to collect the samples of underground water (wells and borehole sources) (Dashtizadeh et al., 2019). Ten samples of water were collected randomly with 1 L capacity polyethylene bottles at different locations across the study area, to ensure equal distribution of the sampling points. The acidic digestion procedure used in previous studies was employed to prepare the samples (Momodu & Anyakora, 2010). The nitric acid was added to avoid absorption and precipitation of metals in sampling bottles. The samples were put in the refrigerator at a temperature of 4°C, then the samples were sent to central laboratory for analysis.

Samples Analysis

The trace of heavy metals (Fe, Cu and Cr) in the water samples were determined using atomic absorption spectrometer. The heavy metals concentration has been quantified in milligrams per liter (mg/L) and compared with the USEPA and WHO regulatory limit for heavy metals in drinking water (Reynolds et al., 2008). The results were analyzed using SPSS and Microsoft Excel software, respectively.

Health Risk Assessment Model for Heavy Metals

The process of determining the likelihood that an incident will occur or that a human health consequence will occur due to exposure to the heavy metals is known as risk assessment. The US Environmental Protection Agency (USEPA 2009) created the methodology for estimating the hazard index (HI) and excess lifetime cancer risk (ELCR) of contaminants based on the mean concentration of the heavy metals, which are classified as carcinogenic and non-carcinogenic health risk (Mandour & Azab, 2011). The respective values for cancer

DOI: 10.56892/bima.v8i4B.1165

slope factor (CSF) and oral reference dose (RFD) are represented on Table 1.

Table 1: Cancer slope factor (CSF) and oral reference dose (RFD) for different heavy metals

Heavy metal	CSF (kg/day/mg)	RFD (mg/kg-day)
Fe	-	0.7
Cu	-	0.04
Cr	0.19	0.004

Non-carcinogenic health risk

The Chronic daily intake (CDI), Hazard Quotients (HQ) and Hazard Index (HI) were used to quantify the heavy metal contamination and potential non-cancer risk caused by ingesting heavy metals in the water (Zakir et al., 2020). The parameters are computed from the following equations:

$$CDI = \frac{C_w \times IR \times EF \times ED}{BW \times AT} \quad (1)$$

$$HQ = \frac{CDI}{RFD} \quad (2)$$

$$HI = \sum_{k=1}^{n} HQ \quad (3)$$

In above equations, C_w is the concentrations of heavy metals (mg/L), IR is the ingestion rate per unit time 2 L/day, EF represents the annual exposure frequency (365 day/year), ED is the exposure period for metals (40 years), BW represents body weight (70 kg) and AT is the average time for non-carcinogenic effects (10, 950) days. The calculated HI is compared to standard values. When HI > 1, non-carcinogenic effects may occur, but when HI < 1, the exposed person is unlikely to experience obvious negative health effects (Guerra et al., 2012).

Carcinogenic risk

The ELCR can be used to calculate the likely cancer risks associated with exposure to a certain dosage of heavy metal in drinking water. The incremental lifetime risk of any kind of cancer resulting from the exposure to a specific daily dose of a carcinogenic element is known as excess lifetime cancer risk (ELCR) (Gržetić & Ghariani, 2008). The equation (4) is used to calculate the cancer risk.

$$ELCR = CDI \times CSF \quad (4)$$

The respective values for cancer slope factor (CSF) and oral reference dose (RFD) for heavy metals are represented on Table 1. For single carcinogenic elements and multi-element carcinogens, the acceptable limit for ELCR is less than 10^{-6} (Tepanosyan et al., 2017).

RESULTS AND DISCUSSION

Heavy Metals Concentrations in the Water Samples

The heavy metal (Fe, Cu and Cr) content levels, mean concentrations in the groundwater samples of Azare city and the permissible limit set by NIS and WHO are summarized in the Table 2. The mean concentrations of the trace elements are increases in the order Fe < Cu < Cr. Heavy metals are metallic elements with comparatively high atomic and are toxic even at low concentrations. The concentration of heavy metals exceeding the threshold limit are detrimental to human health (Duru et al., 2012). The variation of heavy metals with respect to the sampling locations are shown in the Figure 2.

Concentration of Iron (Fe)

As illustrates from the Table 2, the results showed that, the concentration of Iron (Fe) varied from 0.299 to 1.493 mg/L with mean value of 0.715 mg/L. The mean value of iron concentration in the water samples exceeded the maximum permissible limit of 0.3 mg/L set by (WHO, 2017) and 80% of samples are above the recommended level. The contamination level of Fe in the drinking water of the current study can be attributed partially due quaternary sedimentary

DOI: 10.56892/bima.v8i4B.1165

geological formation and anthropogenic activities in the area. In the study reported by (Islam et al., 2015), it was found that the higher iron concentration is due to the geological nature and human activities. The human body requires trace of metal iron (Fe), Because it boosts body energy, encourages blood production, DNA synthesis and supports a healthy pregnancy in women. Nonetheless, an abundance of this element in water might result in severe health risk such as heart and liver related diseases (Ukah et al., 2019). The contamination level of Iron in the present study is found to be higher than that reported by (Niknejad et al., 2023) and (Dabai et al., 2013). The results are comparably lower obtained in the previous study by (Fallahzadeh et al., 2017).

Table 2: Heavy metals concentration in the water samples.

Sample locations	Latitude	Longitude	Heavy metals concentration (mg/L)		
			Iron (Fe)	Copper (Cu)	Chromium (Cr)
S1 (Tsakuwa)	11°40’44’’N	10°11˙37˙˙E	1.493	0.196	0.041
S2 (Fatara)	11°40’22’’N	10°13˙14˙˙E	0.163	0.662	0.062
S3 (Chiran kori)	11°38’59’’N	10°11˙59˙˙E	0.299	0.170	0.058
S4 (Matsango)	11°39’55’’N	10°11˙30˙˙E	0.758	0.189	0.053
S5 (Bidawa)	11°38’38’’N	10°10˙44˙˙E	0.990	0.190	0.069
S6 (Kakudi)	11°39’14’’N	10°10˙05˙˙E	0.852	0.173	0.079
S7 (Kasuwar Kaji)	11°40’23’’N	10°10˙58˙˙E	0.375	2.65	0.078
S8 (Katsalle)	11°39’54’’N	10°10˙33˙˙E	0.618	0.140	0.082
S9 (Chara Chara)	11°42’11’’N	10°10˙29˙˙E	0.796	0.204	0.088
S10 (Unguwar Dankawu)	11°41’37’’N	10°11˙47˙˙E	0.803	0.152	0.093
Mean			0.715	0.473	0.070
WHO (2017)			0.3	2.0	0.05

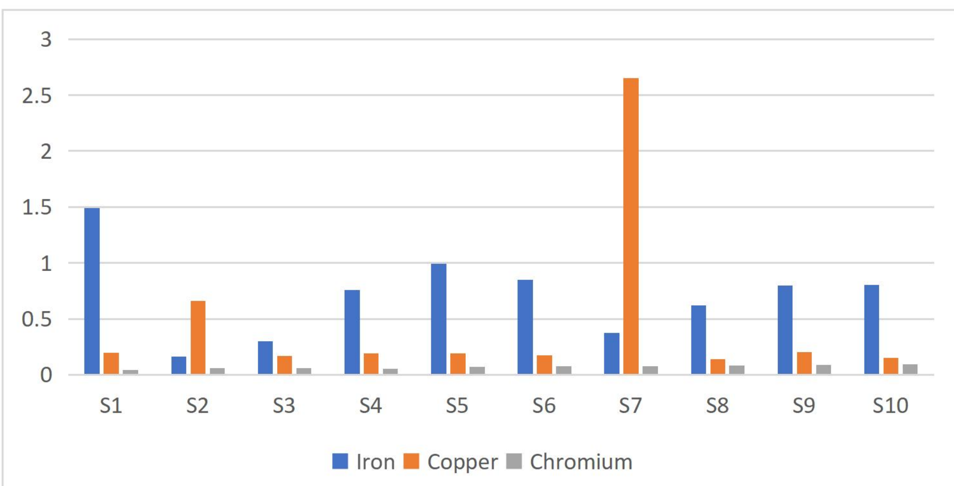

Figure 2: The variation of heavy metals with respect to the sampling locations

Concentration of Copper (Cu)

The average value of Copper concentration of the analyzed water samples is 0.473 mg/L ranging from 1.4 – 2.65 mg/L as shown in the Table 2. The contamination level of the trace element Copper (Cu) in this study is lower than recommended safe limit of 2.0 mg/L, in accordance with the WHO guidelines, except for sampling point S7, which has a concentration of 2.65 mg/L exceeds the threshold limit. Copper at moderate level is an

DOI: 10.56892/bima.v8i4B.1165

essential element in the human body as it regulates cell metabolism, plays a vital role in the synthesis of hormones as well as formation of hemoglobin, however, higher concentration of Cu can cause considerable diseases such as Parkinson and Anemia (Squitti, 2012). The elevated value Copper in the water could be due the flows of the underground water into aquifers and anthropogenic activities as reported by (Nouri et al., 2006) and (Anake et al., 2014). The results of the current study are in close agreement with the study in Nigeria by (Ayantobo et al., 2014), however, the lower concentration of copper in comparison to this study was found in a research by (Hussain et al., 2019) in Pakistan.

Concentration of Chromium (Cr)

The Concentration of chromium (Cr) in the present study varied from 0.041 – 0.093 mg/L with a mean value of 0.07 mg/L. 90% of the water samples exceed the maximum allowable limit of 0.05 mg/L set by (WHO, 20017). The chromium at low concentration is an important heavy metal that is used for removal of glucose from the blood, however high amounts of chromium in the human body cause kidney disorder through oxidation reactions, which eventually leads to hemolysis (Prashanth et al., 2015). Geochemical processes, soil erosion, leaching and dispose of industrial effluent on soil are responsible for the higher concentration in the underground water as reported by several researchers, few among are (Izah et al., 2016) and (Musa & Ahanonu, 2013). The average concentration of chromium (Cr) obtained from this study is compared with other studies worldwide. In a research conducted in Iran by (Fallahzadeh et al., 2017), the result reveals that the contamination level of chromium agrees with this study, but is higher in another study by (Musa & Ahanonu, 2013). The present work is lower than that obtained in the previous studies.

Health risk Assessment of Exposure to Heavy Metals

Heavy metal exposure risk can be effectively evaluated through health risk assessment. The potential health risk associated with the heavy metals (Fe, Cu and Cr) contamination can be categorized as either carcinogenic or non-carcinogenic hazard risk.

Non- carcinogenic assessment

The hazard quotient (HQ) and hazard indices (HI) are the parameter used to quantify the degree of non- cancer risk due to exposure of toxic heavy metals (Fe, Cu and Cr). The results for non-carcinogenic risk are presented in the Table 3. The average value of the hazard quotient (HQ) for the trace elements are 0.041, 0.495 and 0.982 for Fe, Cu and Cr respectively. The (HQ) for respective elements (Fe, Cu and Cr) did not exceed acceptable level of ($HQ < 1$) (Wu et al., 2020), suggesting there is no significant non-carcinogenic adverse health effects for each single heavy metal. The findings of this study is similar with results obtained in China by (Zhang et al., 2018) on health risk assessment associated with heavy metals in drinking water, the finding revealed that the non-carcinogenic risk is lower than the acceptable level.

Similarly, the hazard indices (HI) which expressed as total non-carcinogenic risk impacted by more than one metal is obtained by summing the HQ for each trace element as illustrated in the Table 3. Based on the results, the (HI) varies from 0.895 to 3.888 with mean value of 1.518. The mean value of (HI) for multiple heavy metals is greater than one, exceeding the acceptable limit of ($HI < 1$), the result suggests that consumption of water containing multiple toxic element will substantially enhance deleterious health effect (non-carcinogenic risk). In a previous study reported by (Alves et al., 2014) and (Kavcar et al., 2009), the hazard indices is greater than 1 for heavy metals, indicating the possibility of non-cancer risk. In another study, it was revealed that the hazard indices (HI) is lower than 1, the HMs in the drinking water did not pose any health risks (Githaiga et al., 2021). The researchers attributed the elevation of hazard indices due to anthropogenic activities and geochemical processes.

Table 3: Carcinogenic and non-carcinogenic risk associated with heavy metals

Sample locations	**Carcinogenic risk (ELCR)**	**Non-carcinogenic risk (Hazard quotient)**			**Total Non-carcinogenic risk Hazard indices (HI)**
	Cr	Fe	Cu	Cr	
S1	7.40×10^{-4}	0.088	0.205	0.572	0.865
S2	1.10×10^{-3}	0.001	0.694	0.866	1.561
S3	1.00×10^{-3}	0.018	0.178	0.810	1.006
S4	9.50×10^{-4}	0.045	0.198	0.740	0.983
S5	1.20×10^{-3}	0.058	0.199	0.964	1.221
S6	1.41×10^{-3}	0.050	0.181	1.103	1.334
S7	1.40×10^{-3}	0.022	2.777	1.089	3.888
S8	1.47×10^{-3}	0.036	0.147	1.145	1.328
S9	1.60×10^{-3}	0.047	0.214	1.229	1.490
S10	1.70×10^{-3}	0.048	0.159	1.299	1.505
Mean	1.26×10^{-3}	0.041	0.495	0.982	1.518

Carcinogenic assessment

The carcinogenic assessment is used to assess the probable cancer risk due to exposure to heavy metals. Chromium (Cr) is the only toxic element that significantly enhance cancer risk among the three analyzed heavy metals (Fe, Cu and Cr). It can be seen clearly from the Table 3; the Cr carcinogenic risk range from 1.0×10^{-3} to 7.40×10^{-4} with a mean value of 1.26×10^{-3}. The results revealed that the mean carcinogenic risk for Cr exceeds the permissible limit of 10^{-6} in accordance with the USEPA guideline for drinking water (Turdi & Yang, 2016). Since, the computed (ELCR) is greater than 10^{-6}, the contamination level of Cr in the water sample is capable of inducing risk lifetime cancer. The ELCR value is substantially greater than the global average, showing a likelihood of developing cancer. The finding of current study is comparable to another research conducted in Iran, in which lifetime cancer is found to be 1.09×10^{-3} (Fallahzadeh et al., 2017), while the cancer risk is very high compared to a similar study, where the ELCR is (1.0×10^{-4}) reported in China by (Lu et al., 2015). The ELCR of the present work is lower than that obtained in the previous studies by (Hassaan et al., 2016).

CONCLUSION

This study assessed the contamination levels of heavy metals (Fe, Cu and Cr) and the associated health risks in the underground water in Azare, Bauchi State, Nigeria. The concentrations of heavy metals Fe, Cu and Cr are higher than the recommended limits set by WHO and USEPA, with the exception of Cu, which is below the permissible limit of 2.0 mg/l. The potential health risk assessment revealed the HQ values for respective trace element is found to be > 1, suggesting there is no significant non-carcinogenic adverse health effects for each single heavy metal, but for multiple. The hazard indices (HI) exceeds the acceptable limit of ($HI < 1$), indicating the consumption of water containing multiple toxic element will substantially enhance non-carcinogenic risk. The carcinogenic risk for Chromium is also computed. The lifetime cancer risk is found to be 1.26×10^{-3}; The results showed the carcinogenic risk for Cr is above allowable limit of 10^{-6} in accordance

DOI: 10.56892/bima.v8i4B.1165

with the USEPA guideline for drinking water. Therefore, the contamination level of Cr in the drinking water is capable of inducing risk lifetime cancer. Regular monitoring of heavy metal contamination in drinking water by government and health authorities is crucial to protect communities from potential health hazards. In addition, the government should improve the water treatment methods by developing new remediation technologies.

Acknowledgement

The research is funded by Tertiary Education Trust Fund (TETFund) through institutional based research approved 2023 for Bauchi State University, Gadau Nigeria.

REFERENCES

Abedi Sarvestani, R., & Aghasi, M. (2019). Health risk assessment of heavy metals exposure (lead, cadmium, and copper) through drinking water consumption in Kerman city, Iran. *Environmental earth sciences*, *78*(24), 714.

Ali, U., Batool, A., Ghufran, M., Asad-Ghufran, M., Sabahat-Kazmi, S., & Hina-Fatimah, S. (2019). Assessment of heavy metal contamination in the drinking water of muzaffarabad, Azad Jammu and Kashmir, Pakistan. *Int J Hydro*, *3*(5), 331-337.

Alves, R. I., Sampaio, C. F., Nadal, M., Schuhmacher, M., Domingo, J. L., & Segura-Muñoz, S. I. (2014). Metal concentrations in surface water and sediments from Pardo River, Brazil: human health risks. *Environmental research*, *133*, 149-155.

Anake, W. U., Benson, N. U., Akinsiku, A. A., Ehi-Eromosele, C. O., & Adeniyi, I. O. (2014). Assessment of trace metals in drinking water and groundwater sources in Ota, Nigeria. *International Journal of Scientific and Research Publications*, *4*(5), 1-4.

Ayantobo, O., Awomeso, J., Oluwasanya, G., Bada, B., & Taiwo, A. (2014). Gold mining in Igun-Ijesha, Southwest Nigeria: impacts and implications for water quality. *American Journal of Environmental Sciences*, *10*(3), 289.

Chakrabarty, S., & Sarma, H. P. (2011). Heavy metal contamination of drinking water in Kamrup district, Assam, India. *Environmental monitoring and assessment*, *179*, 479-486.

Dabai, M. U., Bagudo, B., Jodi, L., & Ocheni, L. (2013). Evaluation of some trace metal levels in the water, fish and aquatic plant in River Sokoto, North-Western Nigeria. *Asian Journal of Applied Sciences*, *1*(5).

Dalhatu, S. A., Baballe, A., Dahuwa, D., & Ahamed, H. (2024). Radiation hazard assessment of natural radionuclides in the soil samples from the quarry area of Shira, Bauchi State, Nigeria. *BIMA JOURNAL OF SCIENCE AND TECHNOLOGY (2536-6041)*, *8*(2A), 342-350.

Dashtizadeh, M., Kamani, H., Ashrafi, S. D., Panahi, A. H., Mahvi, A. H., Balarak, D., Hoseini, M., Ansari, H., Bazrafshan, E., & Parsafar, F. (2019). Human health risk assessment of trace elements in drinking tap water in Zahedan city, Iran. *Journal of Environmental Health Science and Engineering*, *17*, 1163-1169.

Duru, M. K., Nwanekwu, K. E., Adindu, E. A., & Odika, P. (2012). Heavy metal and bioload levels of Otamiri river, Owerri, Imo State, Nigeria.

Egbueri, J. C., & Unigwe, C. O. (2020). Understanding the extent of heavy metal pollution in drinking water supplies from Umunya, Nigeria: an indexical and statistical assessment. *Analytical letters*, *53*(13), 2122-2144.

Fallahzadeh, R. A., Ghaneian, M. T., Miri, M., & Dashti, M. M. (2017). Spatial

DOI: 10.56892/bima.v8i4B.1165

analysis and health risk assessment of heavy metals concentration in drinking water resources. *Environmental Science and Pollution Research*, *24*, 24790-24802.

Githaiga, K. B., Njuguna, S. M., Gituru, R. W., & Yan, X. (2021). Water quality assessment, multivariate analysis and human health risks of heavy metals in eight major lakes in Kenya. *Journal of Environmental Management*, *297*, 113410.

Gržetić, I., & Ghariani, R. H. A. (2008). Potential health risk assessment for soil heavy metal contamination in the central zone of Belgrade (Serbia). *Journal of the Serbian Chemical Society*, *73*(8-9), 923-934.

Guerra, F., Trevizam, A. R., Muraoka, T., Marcante, N. C., & Canniatti-Brazaca, S. G. (2012). Heavy metals in vegetables and potential risk for human health. *Scientia agricola*, *69*, 54-60.

Hassaan, M. A., El Nemr, A., & Madkour, F. F. (2016). Environmental assessment of heavy metal pollution and human health risk. *American Journal of Water Science and Engineering*, *2*(3), 14-19.

Hussain, S., Habib-Ur-Rehman, M., Khanam, T., Sheer, A., Kebin, Z., & Jianjun, Y. (2019). Health risk assessment of different heavy metals dissolved in drinking water. *International journal of environmental research and public health*, *16*(10), 1737.

Ibrahim, S., Koki, F. S., Maibulangu, M. H., & Baballe, A. (2023). Terrestrial gamma radiation dose (TGRD) levels in northern zone of Bauchi, Nigeria: mapping and statistical relationship between gamma dose rates and geological formations. *Gadau Journal of Pure and Allied Sciences*, *2*(1), 9-15.

Islam, M. S., Ahmed, M. K., Raknuzzaman, M., Habibullah-Al-Mamun, M., & Islam, M. K. (2015). Heavy metal pollution in surface water and sediment: a preliminary assessment of an urban river in a developing country. *Ecological indicators*, *48*, 282-291.

Izah, S., Chakrabarty, N., & Srivastav, A. (2016). A review on heavy metal concentration in potable water sources in Nigeria: human health effects and mitigating measures. Expos Health 8: 285–304. *Int. J. Appl. Environ. Sci*, *11*(2), 559-581.

Kavcar, P., Sofuoglu, A., & Sofuoglu, S. C. (2009). A health risk assessment for exposure to trace metals via drinking water ingestion pathway. *International journal of hygiene and environmental health*, *212*(2), 216-227.

Khanam, Z., & Singh, V. (2014). Research article on ground water quality assessment near polluted canal area in Kichha town, Uttarakhand, India. *International Journal of Recent Scientific Research*, *5*, 362-368.

Lu, S.-Y., Zhang, H.-M., Sojinu, S. O., Liu, G.-H., Zhang, J.-Q., & Ni, H.-G. (2015). Trace elements contamination and human health risk assessment in drinking water from Shenzhen, China. *Environmental monitoring and assessment*, *187*, 1-8.

Mandour, R., & Azab, Y. (2011). The prospective toxic effects of some heavy metals overload in surface drinking water of Dakahlia Governorate, Egypt. *Int J Occup Environ Med (The IJOEM)*, *2*(4 October).

Mirzabeygi, M., Abbasnia, A., Yunesian, M., Nodehi, R. N., Yousefi, N., Hadi, M., & Mahvi, A. H. (2017). Heavy metal contamination and health risk assessment in drinking water of Sistan and Baluchistan, Southeastern Iran. *Human and Ecological Risk Assessment: An International Journal*, *23*(8), 1893-1905.

DOI: 10.56892/bima.v8i4B.1165

Momodu, M., & Anyakora, C. (2010). Heavy metal contamination of ground water: The Surulere case study. *Res J Environ Earth Sci*, *2*(1), 39-43.

Musa, J. J., & Ahanonu, J. (2013). Quality Assessment of Shallow Groundwater in Some Selected Agrarian Communities in Patigi Local Government Area, Nigeria.

Niknejad, H., Ala, A., Ahmadi, F., Mahmoodi, H., Saeedi, R., Gholami-Borujeni, F., & Abtahi, M. (2023). Carcinogenic and non-carcinogenic risk assessment of exposure to trace elements in groundwater resources of Sari city, Iran. *Journal of Water and Health*, *21*(4), 501-513.

Nouri, J., Mahvi, A., Babaei, A., Jahed, G., & Ahmadpour, E. (2006). Investigation of heavy metals in groundwater.

Omotoriogun, T. C., Uyi, O. O., & Egbon, I. N. (2012). The physicochemical characteristics of Ibiekuma River Ekpoma, Nigeria.

Prashanth, L., Kattapagari, K. K., Chitturi, R. T., Baddam, V. R. R., & Prasad, L. K. (2015). A review on role of essential trace elements in health and disease. *Journal of Dr. YSR University of Health Sciences*, *4*(2), 75-85.

Reynolds, K. A., Mena, K. D., & Gerba, C. P. (2008). Risk of waterborne illness via drinking water in the United States. *Reviews of environmental contamination and toxicology*, 117-158.

Rezaei, H., Zarei, A., Kamarehie, B., Jafari, A., Fakhri, Y., Bidarpoor, F., Karami, M. A., Farhang, M., Ghaderpoori, M., & Sadeghi, H. (2019). Levels, distributions and health risk assessment of lead, cadmium and arsenic found in drinking groundwater of Dehgolan's villages, Iran. *Toxicology and environmental health sciences*, *11*, 54-62.

Squitti, R. (2012). Copper dysfunction in Alzheimer's disease: from meta-analysis of biochemical studies to new insight into genetics. *Journal of Trace Elements in Medicine and Biology*, *26*(2-3), 93-96.

Tepanosyan, G., Maghakyan, N., Sahakyan, L., & Saghatelyan, A. (2017). Heavy metals pollution levels and children health risk assessment of Yerevan kindergartens soils. *Ecotoxicology and environmental safety*, *142*, 257-265.

Turdi, M., & Yang, L. (2016). Trace elements contamination and human health risk assessment in drinking water from the agricultural and pastoral areas of Bay County, Xinjiang, China. *International journal of environmental research and public health*, *13*(10), 938.

Ukah, B., Egbueri, J., Unigwe, C., & Ubido, O. (2019). Extent of heavy metals pollution and health risk assessment of groundwater in a densely populated industrial area, Lagos, Nigeria. *International Journal of Energy and Water Resources*, *3*(4), 291-303.

Wu, C., Fang, C., Wu, X., & Zhu, G. (2020). Health-risk assessment of arsenic and groundwater quality classification using random Forest in the Yanchi region of Northwest China. *Exposure and Health*, *12*, 761-774.

Zakir, H., Sharmin, S., Akter, A., & Rahman, M. S. (2020). Assessment of health risk of heavy metals and water quality indices for irrigation and drinking suitability of waters: a case study of Jamalpur Sadar area, Bangladesh. *Environmental advances*, *2*, 100005.

Zhang, Q.-H., Wei, Y.-Z., Cao, J.-H., & Yu, S. (2018). Heavy metal pollution of the drinking water sources in the Liujiang River Basin, and related health risk assessments. *Huan jing ke xue= Huanjing kexue*, *39*(4), 1598-1607.