

Assessment of Some Selected Heavy Metals (Zn, Cu, Pb, and Cd) Contamination in Kafin Hausa River using Atomic Absorption Spectroscopy

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Abstract

Water is the most crucial resource available on Earth's surface and subsurface, yet the presence of heavy metals diminishes its usability. This study aimed to evaluate the presence and levels of selected heavy metals in the Kafin Hausa River, Jigawa State. Three water samples were collected from various sites along the river, and four metals (Zn, Pb, Cd, and Cu) were chosen for testing. After digestion, the samples were analyzed using atomic absorption spectroscopy. The concentrations of metals detected in the water followed this order: Zn (ranging from 0.049 to 0.67 mg/L) > Cd (0.022 to 0.080 mg/L) > Pb (0.007 to 0.080 mg/L), with Cu undetectable (0.0 mg/L). Results indicated that Cu was absent, while Pb and Zn levels were below the standard thresholds, but Cd concentrations exceeded the acceptable limits. The calculated Nemerow's Pollution Index revealed that Cd accounted for approximately 77% of pollution, followed by Pb at 22%, and Zn at 1%. Therefore, Cd poses a threat to individuals consuming the water, necessitating action from responsible authorities to reduce contaminant levels. Further research and monitoring of these sites are imperative, conducted by researchers and biomedical experts, to uncover the precise adverse effects of heavy metal contamination on humans, especially among vulnerable populations such as children.

Keywords: AAS, Contamination, Kafin Hausa, River, WHO.

1. Introduction

Water, the essential life-sustaining resource on Earth, is increasingly threatened by pollution, diminishing its potability and suitability for various purposes. Human activities such as industrialization, urbanization, and population growth have imposed significant pressures on water resources, affecting their quality, quantity, and accessibility (Öztürk et al., 2008; Vasistha and Ganguly, 2022). Heavy metals, originating from industrial and anthropogenic sources like mining, smelting, and agricultural practices, infiltrate rivers, deteriorating water quality and altering its physiochemical and biological parameters (Adesiyan et al., 2018). This pollution not only renders water unsuitable for domestic use but also disrupts habitats, leading to species migration and extinction (Peters and Meybeck, 2000).

Pollution, defined as the release of harmful substances into the environment in quantities detrimental to health or the environment itself, has intensified with the expanding usage of chemicals in industry and agriculture. This increase in environmental pollution, particularly from heavy metals, poses a threat to ecosystems, evident in streams, lakes, and groundwater (Mensah et al., 2021; Adamu et al., 2023; El-Amier et al., 2023). Several authors had investigated and reported the accumulation of toxic compounds in soils and water systems further exacerbates environmental degradation, impacting overall quality of life (Idris et al., 2019; Mensah et al., 2021; Bashir et al., 2023; El-Amier et al., 2023).

Heavy metal contamination in aquatic environments poses direct threats to aquatic organisms and humans alike. While some heavy metals like copper, zinc, iron, manganese, and chromium are essential in biological systems, others such as lead, arsenic, cadmium, and mercury are highly toxic, even in minute concentrations (Son, 2007; EPA, 2009; Ahmad Alin Baffa, 2022). The toxic effects of these metals, including liver and kidney problems and genotoxic carcinogenesis, underscore the urgent need for assessment and management of heavy metal levels in water bodies.

Thus, this study aims to evaluate selected heavy metal (Zn, Pb, Cd, and Cu) concentrations in the Kafin Hausa River using Atomic Absorption Spectroscopy (AAS) and Nemerow's pollution index to estimate and interpret the contamination levels.

2. Materials and Methods

2.1 Description of the Study Area

Kafin Hausa Local Government Area is situated within Jigawa State, Nigeria, at geographic coordinates 12°34'27.9" N (12.575601 North) and 10°12'19.6" E (10.205350 East). The Kafin Hausa River, a vital resource for the local community, serves various purposes including domestic use, transportation, agriculture, plantation irrigation, and small-scale fishing. Figure 1 illustrates the geographical layout of the study area.

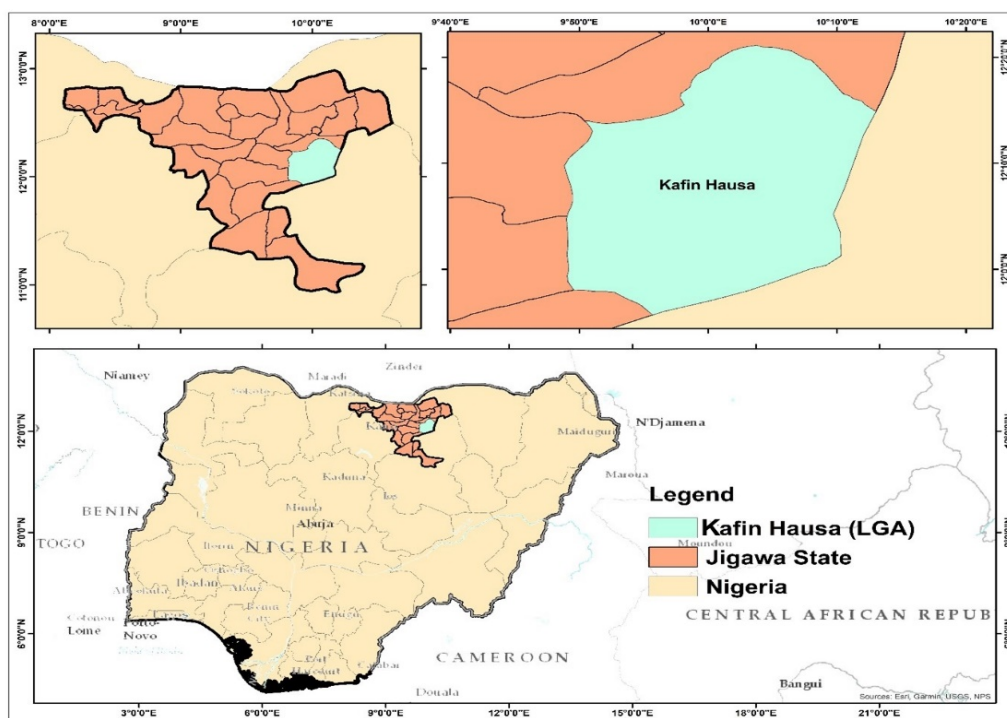


Figure 1: Map of the study area (Source: Bashir et al., 2023).

2.2 Sample collection, Preparation and characterization analysis

The water samples were collected using the grab sampling technique, which involved manually submerging the sampling bottles directly into the water. To prevent contamination, polyethylene sampling bottles were employed and accurately labeled. These bottles were pre-conditioned with 5% nitric acid and thoroughly rinsed with distilled deionized water before use. At each sampling site, the polyethylene bottles underwent a rinsing process at least

three times prior to sample collection. Positioned approximately 10 cm below the water surface, the pre-cleaned sampling bottles were used to collect 0.5 L of water sample.

Upon collection, the samples were acidified with 10% HNO₃, placed in an ice bath, and promptly transported to the laboratory. A measured 100 ml of the water sample was then mixed with 5ml of concentrated hydrochloric acid (HCl). The resulting solution was transferred to a conical flask and heated on a hot plate for approximately one hour and thirty minutes at 100 °C to reduce its volume to 25 ml. Subsequently, the solution was transferred to a 100 ml volumetric flask, where distilled water was added to reach the mark. This solution was then filtered through a 0.45 µm filter and transferred into pre-cleaned sample bottles for further analysis using Atomic Absorption Spectrometry (AAS).

All the steps above procedures were performed in the fume hood for safety. Moreover, the above procedures in this section followed the guidelines from the analytical methods for atomic absorption spectroscopy as reported by Idris et al. (2019).

2.3 Nemerow’s Pollution Index Theory

Nemerow’s Pollution Index provides insights into the pollution levels of specific pollutants within a sampled area, comparing them to established standard values. The average pollution index (NPI_{avg}) is mathematically represented as follows (Idris et al., 2019):

$$NPI_{avg} = \frac{1}{n} \sum_{i=1}^n NPI_i, \tag{1}$$

where $NPI = \frac{C_{sample}}{C_p}$, C denotes the sample concentration, and C_p signifies the permissible limit with reference

to the element. Notably, each calculated NPI value reflects the relative contribution of a single parameter to pollution at each sampling site (Idris et al. 2019). According to Nemerow's Pollution Index the four basis standard water quality classification are as follows: Good condition 0 < NPI < 1; slightly polluted ranges from 1 < NPI < 5; moderately contaminated 5 < NPI < 10 and heavily (strongly) contaminated is NPI > 10 (Idris et al. 2019). Therefore, the ideal NPI_{avg} should ideally equal or be less than one.

3. Results and Discussion

Table 1 displays the concentration of heavy metals in the water samples, measured in mg/L. The concentration of Zn in all samples is well below the standard limit set by the World Health Organization (WHO) of 3 mg/L. Similarly, the concentration of Cd in all samples falls below the WHO standard limit of 2 mg/L. However, in sample A, Pb is not detected, while in other samples, it exceeds the WHO standard limit of 0.01 mg/L, except for one sample which registers 0.007 mg/L, nearly meeting the standard. Furthermore, Cu is not detected in any of the samples, as depicted in Figure 1 (a) and (b).

Table 1. Mean Concentration of Heavy Metals in Water Samples with WHO Standard Limit in mg/L

Heavy metal (mg/L)	Element Symbol	Samples			WHO Standard Limit (mg/L)
		A1	A2	A3	
Zinc	Zn	0.67 ± 0.001	0.049 ± 0.002	0.060 ± 0.001	3.00
Lead	Pb	BDL	0.007 ± 0.015	0.080 ± 0.021	0.01
Cadmium	Cd	0.080 ± 0.021	0.022 ± 0.011	0.049 ± 0.032	0.005
Copper	Cu	BDL	BDL	BDL	1.00

BDL= below detection limit, WHO= World health organization (Idris et al., 2019).

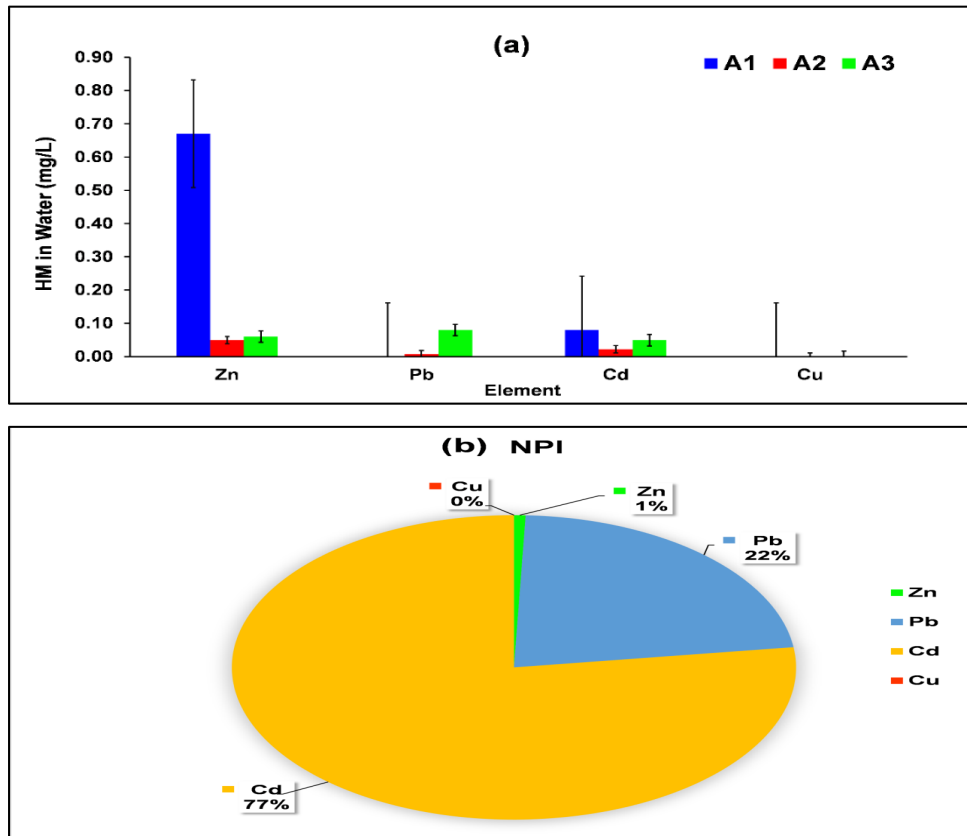


Figure 1: (a) Mean Concentration of Heavy Metals in Water Samples with WHO Standard Limit in mg/L and (b) average Nemerov's pollution index.

Table 2. Results of Nemerov's pollution index (NPI) and average NPI.

Sample location	NPI			
	Zn	Pb	Cd	Cu
A1	0.22	0.00	16.00	BDL
A2	0.02	0.70	4.40	BDL
A3	0.02	8.00	9.80	BDL
NPI_{avg}	0.09	2.90	10.07	0.00

Table 2 summarizes the findings of the NPI analysis. It is notable that Cd exhibits the highest concentration, comprising about 77% of the total, followed by Pb at 22%, and Zn at 1%. Copper is undetectable, registering a concentration of zero. Based on the NPI classification, samples are considered heavily (strongly) contaminated if $NPI > 10$, with Cd, and slightly polluted if $1 < NPI < 5$, with Pb. Additionally, sample A1 is heavily contaminated, followed by A3 and A2, while sample A2 is in good condition compared to others. These results are consistent with prior research conducted by Idris et al. (2019).

4. Conclusion

This study was carried out to provide information on heavy metal concentration in water which can cause health risk to the human beings that consume it. The level of heavy metals in water indicates the presence of the heavy

metals in fishes from Kafin Hausa River. The Concentration of Zn, Pb, and Cd were above respective maximum limits, while concentration of Cu is within the standard in all fish samples. On the other hand, the concentration of Zn, and Cd in water are below the limits with exception Pb that exceeded the limit in sample A2 and A3, respectively. Cu that is not detected in all water samples. Based on NPI, the result further indicated Cd exhibits the highest concentration, comprising about 77% of the total, followed by Pb at 22%, and Zn at 1%. While Cu is undetectable. Meanwhile the water is safe.

Recommendation

We recommend assessing other factors that were not examined, such as pH, turbidity, and geoaccumulation index, and comparing the results with relevant regulatory standards.

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References

- Adamu, Suleiman Bashir, Faragai, Inuwa Aliyu, Yalwa, Lawan Musa, Kayode, Katibi Kamil, Oladeji, Amoo Afeez, Chiromawa, Idris Muhammad, Mikailu, Abdullahi, Rabi, Tafida, Garba, Ibrahim Shitu, Durumin-iya, Sani Garba, Ojonugwa, Daniel Thomas, & Yusuf, Yusuf Yakubu. (2023). Quantification of Pollution Index of Selected Heavy Metals in Agricultural Soils in Kafin Hausa Area , Northwest Nigeria. *UMYU Scientifica*, 2(4), 150–60.
- Adesiyani, I. M., Bisi-Johnson, M., Aladesanmi, O. T., Okoh, A. I., & Ogunfowokan, A. O. (2018). Concentrations and human health risk of heavy metals in rivers in Southwest Nigeria. *Journal of Health and pollution*, 8(19), 180907.
- Ahmad Alin Baffa. (2022). Physico-chemical assessment of hand pump borehole water samples: A case study of some schools in Gashua Town, Bade LGA, Yobe State. *International Journal of Science and Technology Research Archive*, 3(1), 148–54.
- Bashir, Adamu Suleiman, Faragai, Inuwa Aliyu, Yalwa, Lawan Musa, Kayode, Katibi Kamil, Chiromawa, Idris Muhammad, Mikailu, Abdullahi, Abubakar, Tafida Rabi, Shitu, Ibrahim Garba, Muhammad, Aminu, Iya, Sani Garba Durumin, & Yusuf, Yusuf Yakubu. (2023). Assessment and quantification of heavy metals in cultivated soils in Kafin Hausa Jigawa State Nigeria using Nigerian research reactor-1. *Environmental Quality Management*, 00, 1–15.
- El-Amier, Yasser A., Bonanomi, Giuliano, & Abd-ElGawad, Ahmed M. (2023). Assessment of heavy metals contamination and ecological risks in coastal sediments of the Mediterranean seashore. *Regional Studies in Marine Science*, 63, 103017.
- El-Moselhy, K. M., Othman, A. I., Abd El-Azem, H., & El-Metwally, M. E. A. (2014). Bioaccumulation of heavy metals in some tissues of fish in the Red Sea, Egypt. *Egyptian journal of basic and applied sciences*, 1(2), 97-105.
- EPA, United States Environmental Protection Agency. (2009). *National Primary Drinking Water Regulations*. United States Environmental Protection Agency.
- Idris, M. C., Adamu, S. B., & Ibrahim, G. S. (2019). Determination of Physico-Chemical Parameters of Drinking Water in Kafin-Hausa: an Index Analysis Approach. *African Journal of Earth and Environmental Sciences*, 1(2), 150–9.
- Mensah, Albert Kobina, Marschner, Bernd, Antoniadis, Vasileios, Stemm, Eric, Shaheen, Sabry M., & Rinklebe, Jörg. (2021). Human health risk via soil ingestion of potentially toxic elements and remediation potential of native plants near an abandoned mine spoil in Ghana. *Science of the Total Environment*, 798, 149272.
- Öztürk, M., Özözen, G., Minareci, O., & Minareci, E. (2008). Determination of heavy metals in fish, water and sediments of Avsar Dam Lake in Turkey. *Journal of Environmental Health Science & Engineering*, 6(2), 73-80.

- Peters, N. E., & Meybeck, M. (2000). Water quality degradation effects on freshwater availability: impacts of human activities. *Water International*, 25(2), 185-193.
- Son. (2007). *Nigerian Standard for Drinking Water Quality* (Issue 52).
- Tripathi, J.A, Taylor, C.G, Weiler, H.A. (2007). Marginal Zinc deficiency exacerbate bone lead accumulation and high zinc attenuates lead accumulation at the growing rats. *Toxicol Science Journal* 9(2): 286-294.
- Vasistha, P., & Ganguly, R. (2022). Water quality assessment in two lakes of Panchkula, Haryana, using GIS: case study on seasonal and depth wise variations. *Environmental Science and Pollution Research*, 29(28), 43212-43236.