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ASSESSMENT OF HEAVY METAL CONTAMINATION IN FISH AND WATER SAMPLES FROM BABBAN WUYA MADACHI RIVER: IMPLICATIONS FOR HUMAN HEALTH AND ENVIRONMENTAL SUSTAINABILITY

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ABSTRACT

This manuscript investigates the presence and concentration of heavy metals, namely zinc (Zn), copper (Cu), lead (Pb), and cadmium (Cd), in water and two commonly consumed fish species (Tilapia and Catfish) from the Babban Wuya Madachi River. Heavy metal contamination poses significant risks to both human health and environmental sustainability. The study employs Atomic Absorption Spectroscopy (AAS) to analyze heavy metal concentrations in water and fish samples collected from ten different points along the river. The mean concentration of Zn, Cu, Pb, and Cd in the Tilapia fish, Catfish and water are 50.85 ± 0.22, 2.84 ± 0.27, 7.89 ± 0.78, 0.80 ± 0.02 mg/kg; 33.87 ± 1.08, 1.49 ± 0.10, 3.74 ± 0.42, 0.33 ± 0.01mg/kg; and 0.07 ± 0.00, 0.09 ± 0.00, 0.05 ± 0.02, BDL mg/L respectively. Results indicate that water concentrations generally fall below World Health Organization (WHO) standards, while the concentrations of certain heavy metals in fish samples exceed WHO limits, notably Zn, Pb, and Cd. Moreover, concentration of Cu in fish samples is within the standard WHO limit of 2.25 mg/kg and in water its concentration is below the standard limit of 2mg/L. It has been reported that, heavy metals such as Zinc, Cd and Pb has a unique behavior that once absorbed by man it retained in the body system for long and accumulate to cause kidney problems and born demineralization through direct bone damage or indirect through renal dysfunction. The findings underscore the necessity of continued monitoring and regulatory efforts to safeguard both human health and environmental integrity in regions affected by heavy metal pollution.

Keywords: Heavy metals, WHO, River, AAS, Fish, Water

INTRODUCTION

Rivers are globally crucial freshwater resources, yet face escalating threats to their quality, quantity, and accessibility due to burgeoning human development, industrialization, and population expansion (UN Water, 2018). The ingress of toxic chemicals and heavy metals into river systems arises predominantly from industrial and anthropogenic activities in urban settlements surrounding river basins (Eruteya et al., 2024). Anthropogenic activities in adjacent farmlands heavily influence the types of pollutants introduced into aquatic ecosystems (Adamu et al., 2023; Idris et al., 2019). Notably, mining and smelting operations, untreated effluent disposal, metal chelates from industries, and indiscriminate use of heavy metal-containing fertilizers and pesticides in agriculture represent significant sources of heavy metal contamination (Abubakar et al., 2015; Bashir et al., 2023; Zhang et al., 2023). These activities deteriorate water quality, altering both its physicochemical and biological parameters, rendering it unsuitable not only for domestic purposes but also for various other uses. Consequently, habitat degradation occurs, prompting species migration and endangering reproductive capabilities, these and many other factors are the challenges that prompted this research to determine the level of heavy metal contamination in water and fish tissue within the study area.. Heavy metal pollution in aquatic environments has emerged as a global concern due to the indestructible nature and toxic effects of these contaminants on aquatic organisms, animals, and humans (JECFA/WHO, 2011). Metals, as environmental pollutants, warrant particular attention owing to their intensive effects on ecosystems, toxicity, and propensity to bioaccumulate in aquatic ecosystems and organisms' body tissues and organs (Bashir et al., 2023; Rinklebe et al., 2019). While certain heavy metals like copper, iron, chromium, and nickel are essential and play crucial roles in biological systems, non-essential metals such as cadmium and lead exhibit toxicity even in trace amounts (Ren et al., 2022). Some heavy metals, notably chromium, lead, cadmium, arsenic, and mercury, pose severe health risks to both humans and aquatic life, including liver and kidney ailments, and act as genotoxic carcinogen (Guo et al., 2010; Jeyakumar et al., 2023; Sarala & Vidya, 2013).

Human exposure to heavy metals occurs through various pathways, including ingestion via the food chain, direct ingestion, dermal contact, inhalation of fumes, and ingestion of particles through the mouth and nose (Alzahrani et al., 2023). In surface water environments, ingestion and dermal absorption represent primary exposure routes. Water quality assessment encompasses evaluating the chemical, physical, and biological characteristics of water, considering natural quality, human impacts, and intended uses, particularly those affecting human health and aquatic ecosystems (Idris et al., 2019; U.S. Environmental Protection Agency, 2011). Water quality standards, tailored to specific environmental conditions, ecosystems, and intended uses, vary significantly for surface waters like lakes, rivers, and oceans (JECFA/WHO, 2011). These standards aim to safeguard human health, ecosystem integrity, and recreational activities, especially concerning fisheries and endangered species. Furthermore, recent research revealed that, there is prevalent increase in kidney related problems within Hadejia Emirate, and Babban Wuya River have been the source of water and fish for the community within the study area. Therefore, the objective of this study is to assess the levels of selected heavy metal contamination in water and fish tissues from Babban Wuya Madachi River using Atomic Absorption Spectroscopy (AAS).

MATERIALS AND METHODS

Description of the Study Area

Madachi village is situated in the Kiri Kasamma Local Government Area of Jigawa State, Nigeria, at geographical coordinates 12°34'27.9"N (12.575601 North) and 10°12'19.6"E (10.205350 East). Babban Wuya Madachi River has been extensively utilized by the local populace for various purposes including domestic use, transportation, agricultural activities, plantation irrigation, and small-scale fishing.

Water Sample Collection

The water samples were collected using the grab sampling technique, where samples were manually collected by directly submerging the bottle into the water. To minimize the risk of contamination, polyethylene sampling bottles were utilized for sample collection and accurately labeled. Prior to sample collection, the sampling bottles were pre-conditioned with 5% nitric acid and thoroughly rinsed with distilled deionized water. Upon reaching the sampling site, the polyethylene sampling bottles underwent three rinses before sampling commenced. These pre-cleaned bottles were then submerged approximately 10cm below the water surface, and approximately 0.5L of water sample was collected at each sampling site. To preserve the samples, they were acidified with 10% HNO_3, placed in an ice bath for temperature control, and promptly transported to the laboratory for analysis.

Fish Sample Collection

The samples of Tilapia and Catfish were purchased at the riverbank of Babban Wuya River after being caught by a fisherman using fishing net. Fish samples were promptly placed in bags and preserved on ice to maintain freshness before undergoing heavy metals analysis, ensuring compliance with the required analytical holding times. The fish samples were collected at 3 different location within the riverbank of the study area to ensure spatial validity of the study.

Water Sample Digestion

About 100 mL of the water sample was measured using a measuring cylinder, and 5 mL of concentrated hydrochloric acid (HCl) was added to it. The solution was then transferred into a conical flask and heated on a hot plate for approximately one hour and thirty minutes at 100°C. After reducing the volume to 25 mL, it was transferred into a 100 mL volumetric flask, and distilled water was added to fill it up to the mark. The solution was then filtered using a 0.45 µm filter and transferred into a pre-cleaned sample bottle for further analysis using Atomic Absorption Spectrometry (AAS).

Fish Sample Digestion

Prior to analysis, glassware was soaked in diluted nitric acid for 24 hours and then rinsed with distilled deionized water. Muscle tissue from the dorsal muscle of fish was selected for this study, as it is the primary target tissue for metal storage and is the most edible part of the fish. The scales, fins, and head were removed, and the fish tissue was cut and oven-dried at 110°C until a constant weight was achieved. Furthermore, a wet digestion method, following analytical methods for Atomic Absorption Spectrometry, was employed. A 5g dry weight sample was placed into a 50 mL beaker with 5 mL of HNO_3 and 5 mL of H_2SO_4. Once the fish tissues ceased reacting with HNO_3 and H_2SO_4, the beaker was placed on a hot plate and heated at 60°C for 30 minutes. After cooling, 10 mL of HNO_3 was added, and the beaker was slowly heated on the hot plate to 100°C until the sample turned black. Upon reaching this point, the beaker was removed from the hot plate, allowed to cool, and then treated with H_2O_2 until the sample became clear. The contents of the beaker were transferred into a 50 mL volumetric flask and diluted with ultra-pure water (deionized water). All procedures were conducted in a fume hood for safety, following the guidelines outlined by Abubakar et al. (2015) and the analytical methods for AAS as reported by Siva (2015).

RESULTS AND DISCUSSION

Water sample

Table 1: Mean concentration of heavy metals in water samples with WHO standard limit in mg/kg

Samples	Heavy metal (mg/kg)			
	Zn	**Cu**	**Pb**	**Cd**
A	0.056 ± 0.001	0.262 ± 0.002	BDL	BDL
B	0.049 ± 0.002	0.022 ± 0.003	BDL	BDL
C	0.095 ± 0.001	0.125 ± 0.002	0.063 ± 0.026	BDL
D	0.090 ± 0.001	0.053 ± 0.004	0.048 ± 0.019	BDL
E	0.075 ± 0.000	0.050 ± 0.003	0.022 ± 0.011	BDL
F	0.050 ± 0.001	0.250 ± 0.003	0.080 ± 0.021	BDL
G	0.068 ± 0.001	0.275 ± 0.003	0.007 ± 0.015	BDL
H	0.060 ± 0.001	0.058 ± 0.001	0.110 ± 0.023	BDL
I	0.057 ± 0.001	0.046 ± 0.004	0.049 ± 0.032	BDL
J	0.068 ± 0.001	0.038 ± 0.006	0.020 ± 0.027	BDL
WHO	3.00	2.00	0.01	0.03

Note: BDL = Below detection limit, WHO = World Health Organization.

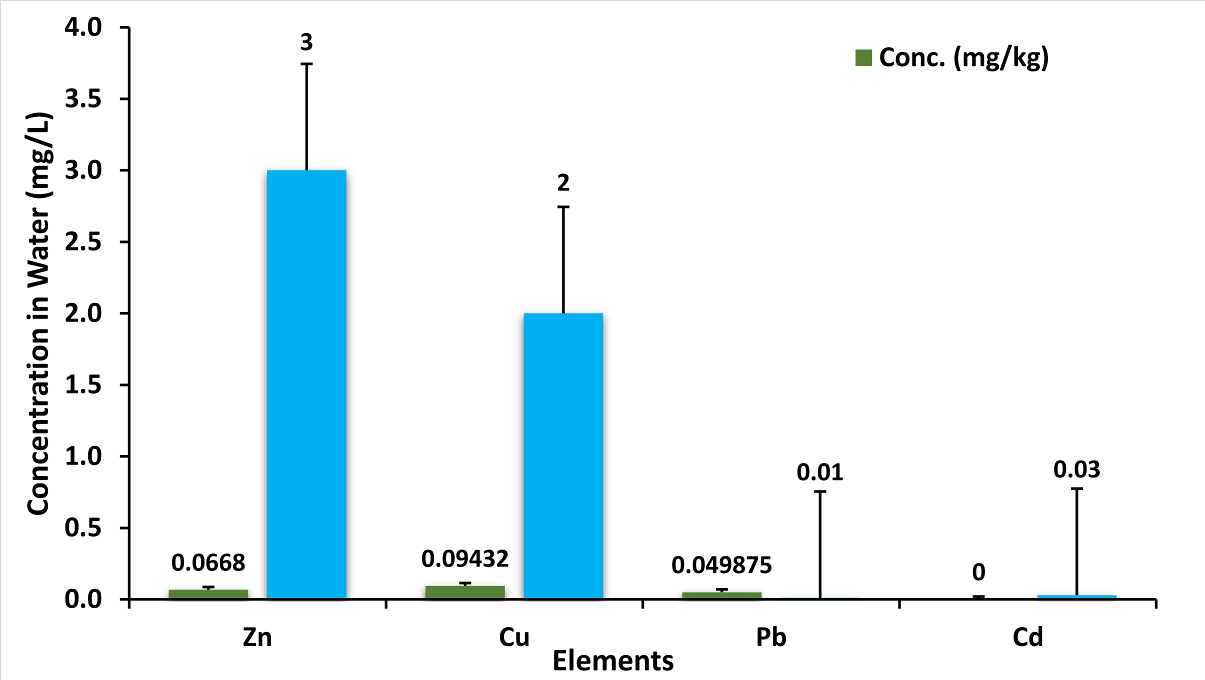

Figure 1: Concentration of Heavy Metals in Water in mg/L

Tilapia Fish

Table 2: Mean concentration of heavy metals in Tilapia fish samples with WHO standard limit in mg/kg

Samples	Heavy metal (mg/kg)			
	Zn	Cu	Pb	Cd
A	56.15 ± 0.38	2.96 ± 0.12	8.40 ± 0.17	0.89 ± 0.02
B	45.54 ± 0.05	2.71 ± 0.42	7.37 ± 1.38	0.70 ± 0.02
Mean	50.85 ± 0.22	2.84 ± 0.27	7.89 ± 0.78	0.80 ± 0.02
WHO	5.00	2.25	0.01	0.01

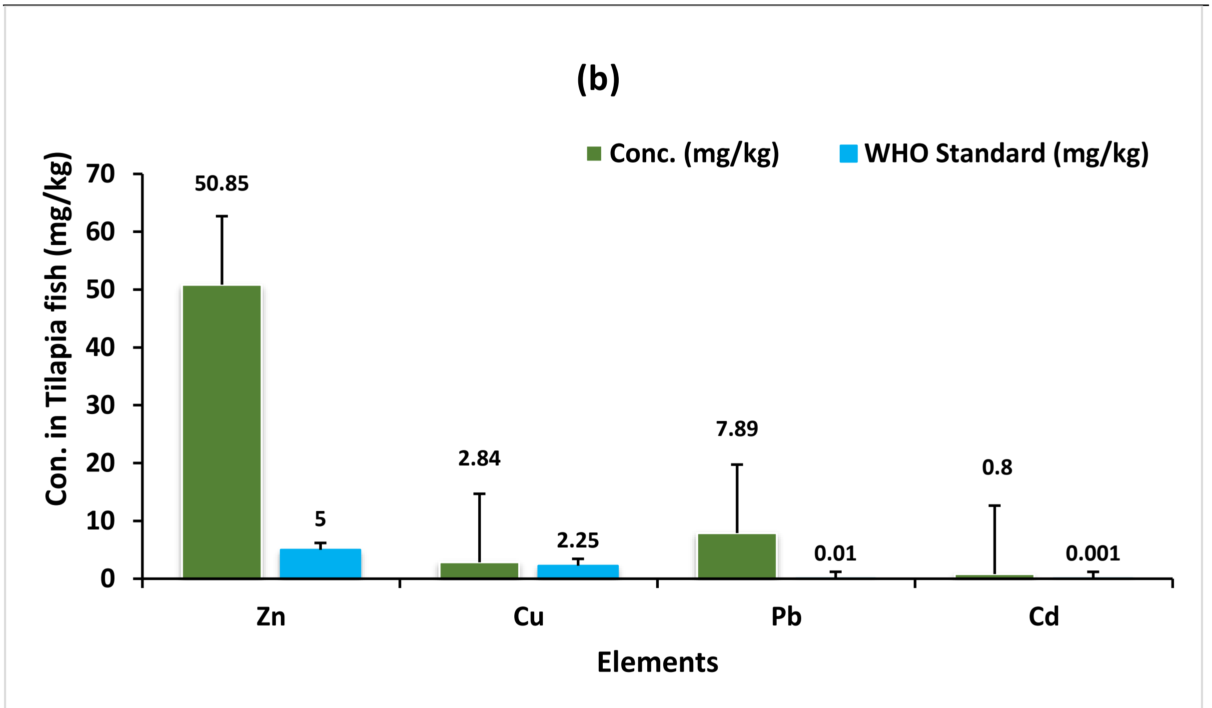

Figure 2: Concentration of Heavy Metals in Tilapia Fish in mg/kg

Catfish

Table 3: Mean Concentration of Heavy Metals in Catfish Samples with WHO standard limit in mg/kg

Samples	Heavy metal (mg/kg)			
	Zn	Cu	Pb	Cd
C	33.28 ± 0.59	2.31 ± 0.11	4.59 ± 0.50	0.44 ± 0.01
D	34.46 ± 1.56	0.67 ± 0.08	2.89 ± 0.33	0.21 ± 0.03
Mean	33.87 ± 1.08	1.49 ± 0.10	3.74 ± 0.42	0.33 ± 0.02
WHO	5.00	2.25	0.01	0.01

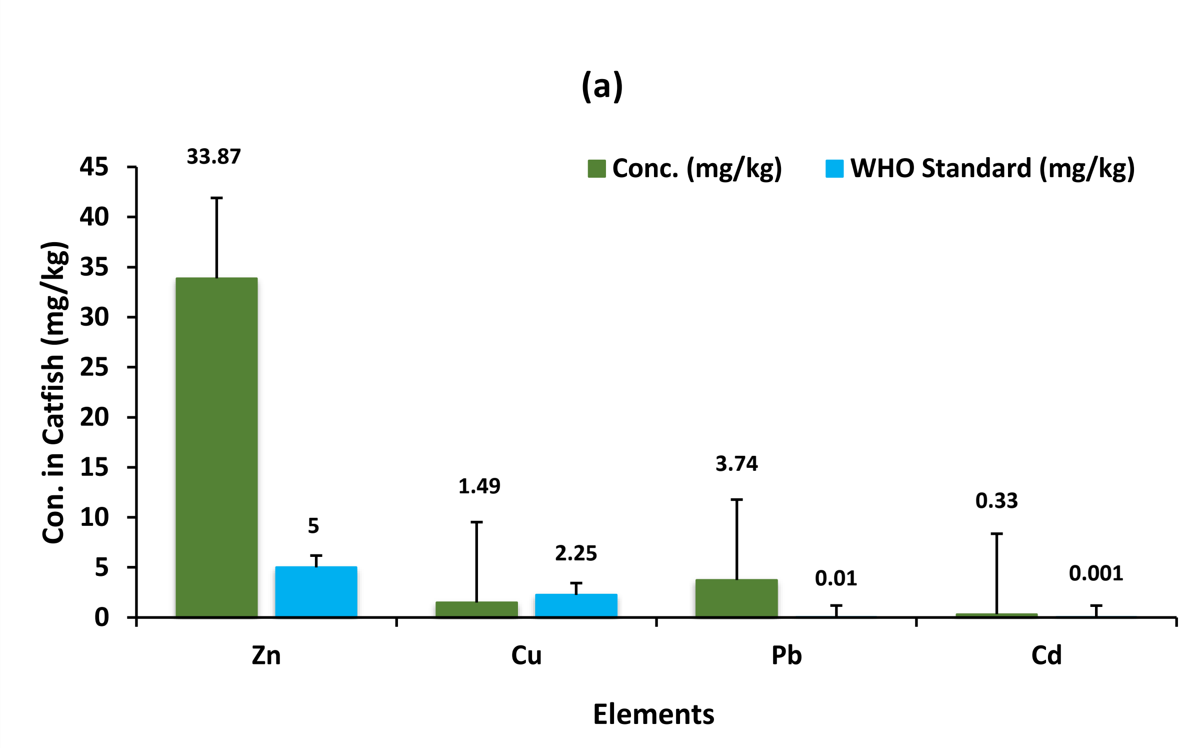

Figure 3: Concentration of Heavy Metals in Catfish Fish in mg/kg

Discussion

Table 1 shows the concentration of heavy metals in the water samples in mg/L. concentration of Zn is found to be 0.056, 0.049, 0.095, 0.090, 0.075, 0.050, 0.068, 0.060, 0.057 and 0.068 mg/kg respectively for all the samples, which is far below the standard limit set by WHO of 3 mg/kg. Similarly, concentration of Cu was revealed to be 0.262, 0.022, 0.125, 0.053, 0.050, 0.250, 0.275, 0.058, 0.046 and 0.038 mg/kg respectively in all the samples is below the WHO standard limit of 2 mg/kg. However, concentration of Pb in sample A & B are not detected, Similarly, concentration in other samples are reported to be above the WHO standard limit of 0.01 mg/kg as 0.063, 0.048, 0.022, 0.080, 0.0110, 0.049 and 0.020 mg/kg for samples C, D, E, F, H, I and J respectively, except for sample H as 0.007 mg/L which is almost in line with the standard. Moreover, Cd is not detected in all samples as re[ported in Table 1 and this can all be seen in figure 1.

Table 2 and 3 shows the total extractable concentration of heavy metals in fish samples (Tilapia and Catfish) in mg/kg. for Table 2, the result shows that the concentration of Zn for samples A and B are 56.15 and 45.54 mg/kg respectively, which is far above the World Health Organization (WHO) standard of 5.00mg/kg and this can also be seen in figure 2, it was reported by () that, Zinc poisoning may results in constipation, abdominal pain, headache and loss of appetite. Similarly, for Table 3, the result is 33.28, 34.46 for samples A and B respectively and this presented in figure 3. Furthermore, concentration of Cu in both samples is within WHO standard limit of 2.25mg/kg, except for sample D which is Catfish with concentration of 0.67mg/kg which is below the standard limit this can be seen from figure 3. Lead and Cadmium were also detected in both samples of Tilapia as 8.40 and 7.37 mg/kg for Pb and 0.89 and 0.70 mg/kg for Cadmium. Similarly, 4.59 and 2.89 was reported for Pb and 0.44 and 0.21 mg/kg for Cadmium in Catfish respectively and this exceeded WHO standard limits of 0.01 mg/kg and 0.01 mg/kg respectively, this can be observed in figure 2 and figure 3. Cadmium as a byproduct of zinc, it has a unique behavior that once absorbed by man it retained in the body system for long and accumulate to cause kidney problems and born demineralization through direct bone damage or indirect through renal dysfunction. However, Pb poisoning is as a result of consistent absorption over time and it can cause loss of memory, weakness and tingling in feet and hands.

CONCLUSION

This study was carried out to provide information on heavy metal concentration in water and fish which can cause health risk to the human beings that consume them. The level of heavy metals in fish tissue indicates the presence of the heavy metals in fishes from Babban Wuya Madachi River.

The Concentration of Zinc (Zn), Lead (Pb), and Cadmium (Cd) exceeded respective maximum limits, while concentration of Copper (Cu) is within the standard in all fish samples. Whereas the concentration of Zn, and Cu in water are below the limits with exception Pb that exceeded the limit,

Cd that is not detected in all water samples. The result further indicated that the fishes highly contaminated by heavy metals and exceeded WHO recommended limit. Meanwhile the water is safe.
Consequently, implementing stricter regulations on industrial discharges, promoting sustainable agricultural practices to minimize runoff, or implementing community-based initiatives for water quality management is highly recommended.

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