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ASSESSING ECOLOGICAL HEALTH: THE IMPACT OF HEAVY METAL CONTAMINATION IN LUHU DAM, ADAMAWA STATE

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ABSTRACT

Water is an essential resource covering 75% of Earth's surface, providing habitat for various organisms and facilitating gas exchange and nutrient transport. However, human activities around Luhu Dam in the Michika Local Government Area of Adamawa State, Nigeria, have increased the presence of heavy metals, which pose significant ecological threats due to bioaccumulation and biomagnification. This study aimed to assess the concentrations of seven heavy metals-iron (Fe), zinc (Zn), cadmium (Cd), lead (Pb), chromium (Cr), manganese (Mn), and copper (Cu)-in the surface water and sediments of Luhu Dam over six months (July 2025 to January 2026). Water and sediment samples were collected biweekly from three stations and analyzed using Atomic Absorption Spectrophotometry. The results revealed distinct spatial variations in metal concentrations. In water samples, significant differences in cadmium (0.01-0.04 mg/l) and manganese (0.057-0.166 mg/l) were observed ($p<0.05$), while iron, zinc, lead, chromium, and copper showed no significant variations. Mean concentrations of cadmium, lead, and iron exceeded FMEnv and WHO permissible limits, indicating potential health concerns. Sediment samples contained substantially higher metal concentrations, particularly at station 3, where iron (188.3-283.4 mg/kg), zinc (26.41-48.6 mg/kg), and manganese (16.88-30.83 mg/kg) were most prevalent. Significant spatial differences ($p<0.05$ to $p<0.01$) in cadmium, zinc, lead, and chromium suggest localized pollution from agricultural runoff and domestic activities. These findings highlight the urgent need for regular monitoring and pollution control strategies to safeguard the ecological integrity of Luhu Dam and the health of local communities.

Keywords: Heavy metals, Water quality, Sediment contamination, Luhu Dam, Pollution assessment, Adamawa State

INTRODUCTION

Water is a crucial resource, essential for sustaining life on Earth and for everyday human activities (Fabian *et al.,* 2023). The two primary sources of water are surface water (lakes, streams, and rivers) and groundwater (boreholes, wells, and springs). About 75% of Earth's surface is covered by water, resulting in a vast volume that comprises the hydrosphere, defined as the water present on Earth's surface (Adjarho *et al.,* 2013). Water is indispensable to all living organisms, and inadequate water quality or quantity can have a profound impact on sustainable development (Taiwo *et al.,* 2012). Additionally, water serves not only as a habitat for various living organisms but also as a medium for gas exchange and nutrient transport (Taiwo *et al.,* 2012).

Rising environmental pollution with toxic substances is an escalating issue in Nigeria and globally (Ezemonye and Enuneku, 2005). Various pollutants are continually released into aquatic ecosystems, largely driven by increased industrialization, technological advancement, population growth, oil exploration and extraction, and runoff from agricultural and household waste (Lima *et al.*, 2008).

Heavy metals pose a considerable threat as serious environmental pollutants, primarily due to their inherent toxicity, long-lasting presence in ecosystems, potential for bioaccumulation in living organisms, and biomagnification through the food web (Ozturk *et al.,* 2006). While these metals are normally found in trace amounts in aquatic environments, their concentrations have been significantly elevated by anthropogenic activities, leading to severe ecological consequences in freshwater bodies such as lakes (Ntakirutimana *et al.*, 2013).

Heavy metals can enter aquatic systems from various sources. Natural processes, such as rock weathering, soil erosion, and the dissolution of naturally occurring salts, contribute to their presence. However, human activities greatly exacerbate this issue. For instance, agricultural practices often lead to runoff containing fertilizers and pesticides, which may introduce heavy metals into nearby waterways. Additionally, residential and industrial waste products, including sewage and heavy-metal-laden debris from manufacturing processes, further increase metal concentrations in aquatic environments (Joshi *et al.*, 2026).

Once released, heavy metals undergo complex transport mechanisms, during which they can distribute between the dissolved aqueous phase and particulate suspended sediments. This distribution process not only affects their bioavailability—how easily they can be absorbed by living organisms—but also influences their environmental persistence and potential for entering the food chain, which can have detrimental effects on biodiversity and human health.

Heavy metals are non-biodegradable and cannot be removed from water through self-purification processes. Once they are discharged into water bodies, they tend to be adsorbed onto sediment particles, accumulating in lakes and rivers, and eventually entering the food chain (Loska and Wiechula, 2003). Sediments, as fundamental components of aquatic environments, play a crucial role in elemental cycling and transport significant amounts of pollutants and nutrients. They serve as important sinks for various pollutants, including heavy metals and pesticides. Aquatic sediments can accumulate persistent and toxic chemicals to levels that are many times higher than the concentration found in the water column (Milenkovic *et al.*, 2005).

Heavy metals tend to bond with organic matter, Fe/Mn oxides, sulfides, and clay within sediments, forming several reactive compounds that are harmful to the environment. Sediments are always regarded as potential reservoirs for

heavy metals and play a vital role in the adsorption of dissolved heavy metals (Praveena *et al*., 2010). Under various physical and chemical conditions, heavy metals in sediments can leach back into the water column as free ions. Consequently, polluted sediments can also serve as sources of heavy metals when they are released into lake or river water. The concentration of heavy metals in lake or river water is a good indicator of pollution levels in these bodies of water (Praveena *et al*., 2010).

Polluted sediments pose a threat to benthic organisms, exposing them to hazardous concentrations of toxic heavy metals. Some types of polluted sediments can kill benthic organisms, thereby reducing the food supply for larger animals such as fish (Abida *et al*., 2009).

Human activities in and around Luhu Dam, such as industrial discharges, agricultural runoff, and urban development, have the potential to adversely affect water and sediment quality and to disrupt the ecological balance of indigenous species in the area. Despite its importance, there is a notable lack of comprehensive data regarding the concentration of heavy metals in the waters of Luhu Dam. Consequently, this study aims to systematically evaluate the heavy metal concentrations within the dam, providing crucial insights into the health and sustainability of its aquatic ecosystem. This assessment will help to identify the levels of pollution and the associated stressors impacting the local environment, which is vital for informing conservation strategies and mitigating anthropogenic impacts.

MATERIALS AND METHODS

Study Area

The study site is Luhu Dam, positioned in Michika LGA of Adamawa state. The dam is situated at precisely latitude 10.610 N and longitude 13.380 E. Luhu Dam is a man-made dam for aquaculture, particularly for recharging the fishponds. It covers an appraised area of about 3320sq meters with a rough depth of about 6 meters, with its sources from the mountains of Wambirmi and the nearby farmlands.

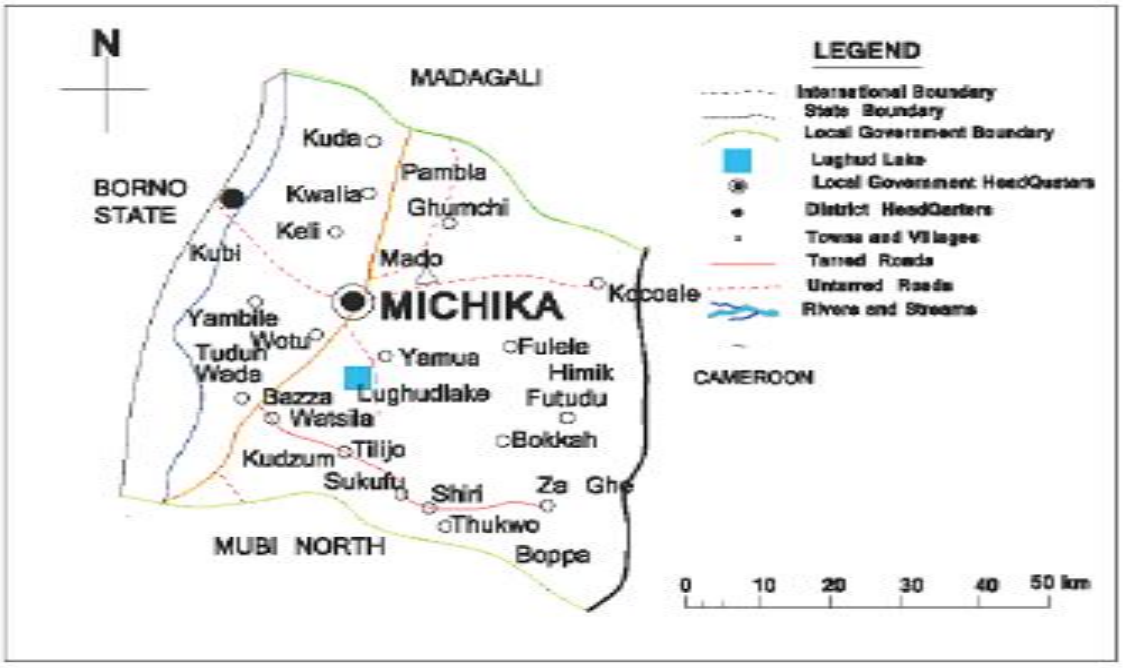

Figure 1: Map Showing Luhu Dam, Michika Local Government, Adamawa State, Nigeria (Adebayo and Tukur, 2010)

Sampling

Three sampling stations were chosen based on the objective of the study. Samples were collected fortnightly for a period of six months between the hours of 8 am and 11 am from July 2025 to January 2026. Sampling usually began in stations 1,2 and 3 in that order.

Water samples for analysis of the heavy metals were collected in 1-litre plastic bottles, which were prewashed, rinsed, and dried. The collection was done by immersing the plastic bottle in the water body, and when it was filled, it was corked and labeled appropriately and then kept in ice boxes before analysis.

Sediment samples were collected from the study area using a Van Veen grab of 0.6 M^2, which was lowered into the bottom of the reservoir with the aid of strong ropes attached to it, on the top of a canoe. On board, the grab was opened above a plastic bucket, and the sample was gently removed. (Davide and Marco, 2010)

Determination of Heavy Metals in Water Samples

Water samples were filtered with Whatman No. 42 filter paper and diluted to 50 ml with distilled water for analysis using a Buck Scientific Atomic Absorption Spectrophotometer. For digestion, 100 ml of each sample received 4 ml of perchloric acid, 20 ml of concentrated nitric acid, and 2 ml of concentrated sulfuric acid. The solution was heated until white fumes emerged, then cooled and transferred to a 100 ml volumetric flask, filled with distilled water, and mixed. After letting it stand overnight to separate insolubles, the solution was filtered through a 0.45 µm Millipore filter.

The heavy metals analyzed included iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), chromium (Cr), cadmium (Cd), and lead (Pb). The AAS was set to specific wavelengths for each metal, with distilled deionized water used between readings. Absorbance readings stabilized after 1-2 minutes, and each sample was analyzed in triplicate. Metal concentrations were determined using a standard calibration plot (Chen and Ma, 2001).

Extraction of Heavy Metals in Sediment Samples

Heavy metals were extracted from sediment using the Double Acid Extraction Method. First, 100 grams of dried sediment were digested with 4 milliliters of perchloric acid, 20 milliliters of concentrated nitric acid, and 2 milliliters of concentrated sulfuric acid in an aluminum block digester model 110.

The formation of a white crystalline mixture confirmed complete digestion. After cooling, the mixture was filtered with Whatman filter paper No. 541, and the filtrate was analyzed for heavy metals (iron, manganese, zinc, copper, chromium, cadmium, and lead) using a Solaar 969 Unicam Series Atomic Absorption Spectrometer (AAS).

Data Analysis

The values of data obtained would be subjected to analysis of variance (ANOVA), mean and standard deviation.

RESULTS AND DISCUSSION

Mean Variation of Heavy Metals in the Surface Water of the Michika Dam

Table 1: Mean Variation of Heavy Metals in the Surface Water of Michika Dam

Parameters	Station 1	Station 2	Station 3		Standard	
	$\bar{X} \pm S.E$ (Min-Max)	$\bar{X} \pm S.E$ (Min-Max)	$\bar{X} \pm S.E$ (Min-Max)	p-Value	FMEnv. Permissible Limit	WHO Permissible Limit
Iron (mg/l)	0.96±0.14 (0.34-1.57)	0.68±0.121 (0.25-1.44)	1.53±0.353 (0.33-3.83)	P > 0.05	1	0.3
Zinc (mg/l)	0.34±0.06 (0.1-0.62)	0.20±0.034 (0.09-0.41)	0.51±0.112 (0.13-1.06)	P > 0.05	5	5.0
Cadmium (mg/l)	0.02 ± 0.005^{AB} (0.00-0.04)	0.01 ± 0.003^{A} (0.00-0.02)	0.04 ± 0.011^{B} (0.01-0.09)	P < 0.05	0.01	0.005
Lead (mg/l)	0.03±0.006 (0.00-0.06)	0.02±0.008 (0.00-0.07)	0.06±0.0167 (0.01-0.17)	P > 0.05	0.05	0.01
Chromium (mg/l)	0.027±0.005 (0.01-0.05)	0.020±0.005 (0.00-0.05)	0.04±0.009 (0.01-0.09)	P > 0.05	0.05	0.05
Manganese (mg/l)	0.087 ± 0.022^{A} (0.03-0.24)	0.057 ± 0.014^{A} (0.01-0.14)	0.166 ± 0.061^{A} (0.04-0.63)	P < 0.05	0.05-0.5	-
Copper (mg/l)	0.04±0.008 (0.01-0.09)	0.027±0.008 (0.01-0.08)	0.07±0.019 (0.02-0.19)	P > 0.05	0.1	0.05 – 1.5

NOTE: p<0.01 – Highly Significant Difference; p<0.05 – Significant Difference; p>0.05 – No Significant Difference; Similar Superscripts Row-wise – No Significant Difference using Duncan Multiple Range Tests (DMRT)
Where X Mean, SE Standard Error, Min. = Minimum value, and Max. = Maximum values

Table 2: Heavy Metals in Sediments of Michika Dam

Parameters	Station 1	Station 2	Station 3	p-value
	$\bar{X} \pm S.E$ (Min-Max)	$\bar{X} \pm S.E$ (Min-Max)	$\bar{X} \pm S.E$ (Min-Max)	
Iron (mg/kg)	208.09±19.69 (111.30-286.90)	188.3±26.86 (119.30-392.00)	283.4±37.47 (110.90-444.50)	P > 0.05
Copper (mg/kg)	6.29±0.955 (1.22-9.93)	3.99±1.193 (0.86-10.60)	8.69±1.517 (1.91-15.60)	P > 0.05
Cadmium (mg/kg)	4.05 ± 0.789^{A} (0.35-8.34)	1.99 ± 0.560^{A} (0.73-5.43)	8.98 ± 2.304^{B} (0.32-18.00)	P < 0.05
Zinc (mg/kg)	33.54 ± 2.467^{AB} (23.90-44.80)	26.41 ± 5.435^{A} (8.71-55.4)	48.6 ± 7.103^{B} (16.00-79.60)	P < 0.05
Chromium (mg/kg)	4.30 ± 0.615^{A} (0.74-6.58)	2.53 ± 0.821^{A} (0.62-7.59)	8.76 ± 1.705^{B} (1.41-15.50)	P < 0.01
Lead (mg/kg)	4.66±0.819 (0.60-9.30)	2.16±0.741 (0.00-6.52)	8.95±2.149 (0.84-19.40)	P < 0.05
Manganese (mg/kg)	21.16±1.853 (12.30-30.30)	16.88±3.411 (8.24-37.20)	30.83±4.008 (12.40-49.10)	P > 0.05

NOTE: p<0.01 – Highly Significant Difference; p<0.05 – Significant Difference; p>0.05 – No Significant Difference; Similar Superscripts Row-wise – No Significant Difference using Duncan Multiple Range Tests (DMRT) where X= Mean, SE= Standard Error, Min. = Minimum value and Max. = Maximum value

Heavy Metals in Water

The study examined metal levels in water samples from different stations. - Iron *(mg/l)* levels varied from 0.68 mg/l at Station 2 to 1.53 mg/l at Station 3, with no significant differences between stations. – Zinc *(mg/l)* levels ranged from 0.20 mg/l at Station 2 to 0.51 mg/l at Station 3, also showing no significant differences. Cadmium*(mg/l)* levels showed a significant difference, with values of 0.01 mg/l at Station 2 and 0.04 mg/l at Station 3. Lead *(mg/l)* levels ranged from 0.02 mg/l at Station 2 to 0.06 mg/l at Station 3, with no significant differences noted. Chromium*(mg/l)* levels ranged from 0.020 mg/l at Station 2 to 0.04 mg/l at Station 3, with no significant differences. Manganese*(mg/l)* levels showed significant differences, ranging from 0.057 mg/l at Station 2 to 0.166 mg/l at Station 3. Copper*(mg/l)* levels ranged from 0.027 mg/l at Station 2 to 0.07 mg/l at Station 3, with no significant differences. Overall, the study found differences in cadmium and manganese levels, while the other metals did not show significant variations across the stations.

Heavy Metal in Sediment

Iron (Fe): Concentrations ranged from 188.3±26.86 mg/l at Station 2 to 283.4±37.48 mg/l at Station 3, with no significant differences (p> 0.05) between stations. Copper (Cu): Values varied from 3.99±1.19 mg/l at Station 2 to 8.69±1.52 mg/l at Station 3, also showing no significant differences (p> 0.05). Cadmium (Cd): Ranged from 1.993±0.56 mg/l at Station 2 to 8.98±2.30 mg/l at Station 3, exhibiting significant differences (p<0.05) across stations. 4. Zinc (Zn): Measured from 26.41±5.44 mg/l at Station 2 to 48.5±7.10 mg/l at Station 3, with significant differences (p< 0.05) noted. Chromium (Cr): Concentrations ranged from 2.53±0.82 mg/l at Station 2 to 8.76±1.71 mg/l at Station 3, showing highly significant differences (p< 0.01). Lead (Pb): Varied from 2.16±0.74 mg/l at Station 2 to 8.95±2.15 mg/l at Station 3, also with significant differences (p <0.05). 7. Manganese (Mn): Ranged from 16.88±3.41 mg/l at Station 2 to 30.83±4.01 mg/l at Station 3, revealing no significant differences (p> 0.05). Overall, the study highlights variations in metal concentrations across stations and seasons, with cadmium, zinc, chromium, and lead showing significant differences, indicating potential environmental concerns.

Five of the heavy metals analyzed were not significantly different (P > 0.05) in values across the three stations. Only Cadmium (Cd) and manganese were significantly different (P < 0.01 and 0.05, respectively) across the stations sampled for water samples (see Table 1). The highest mean concentrations for heavy metals were found at Station 3. Fe (1.5289mg/l), Cu (0.0679mg/l), Cd (0.0437mg/l), Zn (0.5100), Cr (0.0404mg/l), Pb (0.0556mg/l), and Mn (0.1656mg/l). The lowest mean concentration for all the metals was found in Station 2. Fe (0.6811mg/l), Cu (0.0277mg/l), Cd (0.0124mg/l), Zn (0.2011mg/l), Cr (0.0147mg/l), Pb (0.0204mg/l), and Mn (0.0571mg/l). Like most tropical water bodies, the heavy metal concentration of the three stations showed a seasonal pattern of variation.

Water samples taken at Station 1 ranked second in mean values, as shown in Table 1. From Table 1, Fe > Zn > Mn > Cu > Pb > Cr > Cd. The mean values of Cadmium, Lead and Iron were above the permissible limits (Federal Ministry of Environment Limits) in water samples across the stations, while Zinc and Chromium fell below maximum permissible limits.

Dissolved heavy metal concentrations are generally greater during periods when the inflow of water is low, during drought months, because the decrease in water volume decreases dilution effects, and the decrease in suspended sediment concentration decreases the metal scavenging process (Chiarelli *et al*., 2011).

Results showed that heavy metal values in water are comparatively lower than corresponding values in the sediment, an observation reported by Bashir *et al*. (2013).

In the sediment, the highest mean concentration for all heavy metals studied was found at Station 3. Fe (283.4111mg/kg), Cu (8.6900mg/kg), Cd (8.9800mg/kg), Zn (48.5778), Cr (8.7611mg/kg), Pb (8.9522mg/kg), and Mn (30.8333mg/kg). The lowest mean concentration for all the metals was found in Station 2. Fe (188.3444mg/kg), Cu (3.9944mg/kg), Cd (1.9933mg/kg), Zn (26.4122mg/kg), Cr (2.5300mg/kg), Pb (2.1567mg/kg) and Mn (16.8767mg/kg).

Sediment samples taken at Station 1 were ranked second in mean values, as shown in Table 2. From the table, Fe> Zn > Mn > Cu > Pb > Cr > Cd. The levels of all the metals in sediments at station 3 could be the result of runoff and domestic activities that occur at the location. The increased levels of Pb, Mn, Zn and Fe could be a result of bush burning and other agricultural practices taking place in the stations. Ogaga *et al*. (2015) reported the burning of gasoline and fossil fuels as a source of Lead in urban aerosols and roadside dust, which gets flushed into the aquatic environment through flood run-off and atmospheric precipitation. From table 2, Fe, Cu and Mn showed no significant difference (P > 0.05) across the three stations, while Cd, Zn and Pb showed significant difference (P < 0.05) across stations. Only Cr was highly significantly different (P < 0.01).

CONCLUSION

In conclusion, the alarming rise of heavy metals in aquatic ecosystems poses a serious threat to environmental balance and human health, driven by human activities such as industrial waste discharge, toxic agricultural runoff, and rapid urban development, all contributing to the pollution of vital freshwater bodies like Luhu Dam. Heavy metals bind to sediments, leading to persistent bioaccumulation and biomagnification within the food web, which endangers aquatic life and the larger species that rely on them. Furthermore, the significant lack of comprehensive data on heavy metal concentrations in Luhu Dam highlights a pressing need for rigorous assessment and monitoring. Addressing this urgent challenge is essential for protecting aquatic ecosystems and promoting sustainable development. By prioritizing targeted research and implementing effective management strategies, we can mitigate pollution and safeguard the health of both the environment and the communities that depend on these vital water resources, ensuring a more sustainable future for all.

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