ISRG Journal of Arts, Humanities and Social Sciences (ISRGJAHSS)

ISRG PUBLISHERS
Abbreviated Key Title: ISRG J Arts Humanit Soc Sci
ISSN: 2583-7672 (Online)
Journal homepage: https://isrgpublishers.com/isrgjahss
Volume – III Issue -III (May-June) 2025
Frequency: Bimonthly

Assessment and Percentage Change of Heavy Metals Contamination in Water Sources Near Mining Sites in Gashaka L.G.A., Taraba State, Nigeria

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| **Received:** 03.06.2025 | **Accepted:** 09.06.2025 | **Published:** 11.06.2025

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Abstract

Artisanal and small-scale mining (ASM) remains a pervasive source of heavy metal pollution in aquatic environments, particularly in low- and middle-income countries with limited environmental oversight. This study provides a spatial assessment of heavy metals contamination in water resources surrounding four active ASM sites Lambangudu, Maijankasa, Gidankara, and Quentygate, in Gashaka Local Government Area, Taraba State, Nigeria. Concentrations of nine heavy metals including cadmium (Cd), lead (Pb), cobalt (Co), copper (Cu), chromium (Cr), zinc (Zn), nickel (Ni), manganese (Mn), and iron (Fe) were identified and quantified using Atomic Absorption Spectrophotometry (AAS) following standardized analytical protocols. Contamination levels were evaluated through percentage change analysis relative to WHO and Nigerian Standard for Drinking Water Quality (NSDWQ) guideline values. The results indicated spatial heterogeneity in metal concentrations across the study sites. Iron (Fe) exhibited the highest mean percentage increase (+272.75%), indicative of intense geochemical mobilization potentially driven by oxidative weathering of mineralized substrates. Conversely, Cd, Cu, and Zn showed consistent negative percentage changes (e.g., Cd: –246.67%, Cu: –99.90%, Zn: –97.09%), possibly reflecting site-specific dilution or hydrogeological dynamics. Lead (Pb) demonstrated significant spatial variability, ranging from a +200% increase at Lambangudu to a –110% decline at Quentygate, suggesting localized point-source inputs, likely from lead-bearing mining waste. Other metals, including Co, Cr, Ni, and Mn, exhibited moderate decreases yet remained within ranges that may pose ecological and human health risks. This study highlights ASM as a significant and spatially diffuse contributor to heavy metal loading in both surface and groundwater systems.

Keywords: *Assessment, Percentage, heavy metals, contamination, water sources, Gashaka, Taraba State, Nigeria*

DOI: 10.5281/zenodo.15638858

1. Introduction

Heavy metal pollution in freshwater ecosystems has emerged as a pressing global concern, particularly in areas impacted by mining activities. These pollutants are characterized by their persistence, non-biodegradability, bioaccumulation, and toxicity at even trace concentrations, posing serious ecological and human health risks (WHO, 2017; Tchounwou *et al*., 2012). In aquatic environments, heavy metals can disrupt biological functions, impair water quality, and make water sources unsafe for human consumption and agricultural use (Jaishankar *et al*., 2014).

In many developing countries, particularly within sub-Saharan Africa, artisanal and small-scale mining (ASM) has proliferated due to its economic importance. However, the sector often operates without formal environmental oversight, leading to the unregulated release of mine tailings, smelting by-products, and metal-rich effluents into nearby water bodies (Hilson, 2006; Obiri *et al*., 2016). These uncontrolled practices frequently result in the mobilization of toxic elements such as lead (Pb), cadmium (Cd), iron (Fe), chromium (Cr), and copper (Cu) into both surface and groundwater systems.

In Nigeria, the environmental consequences of ASM are well documented in regions like Zamfara, Niger, and Plateau States, where groundwater contamination and lead poisoning outbreaks have raised national concern (UNEP, 2013; Balarabe *et al*., 2020). However, there remains a notable data gap in northeastern Nigeria, particularly in Taraba State, where small-scale mining is expanding, but environmental surveillance remains weak.

Gashaka Local Government Area (LGA) in Taraba State is one such region, with artisanal mining activities concentrated in Lambangudu, Maijankasa, Gidankara, and Quentygate. These communities rely heavily on shallow wells, boreholes, and nearby streams for domestic and agricultural water use. Despite this reliance, there is limited empirical data on the spatial distribution and intensity of heavy metal contamination in these water sources.

The present study seeks to quantify the spatial variability and percentage change in concentrations of selected heavy metals (Cd, Pb, Co, Cu, Cr, Zn, Ni, Mn, Fe) across water sources located near four mining sites in Gashaka LGA. The analysis aims to provide a robust baseline for environmental quality assessment and to support evidence-based public health and regulatory interventions in a region experiencing unregulated mineral exploitation.

2. Materials and Methods

2.1 Study Area

The study was conducted in Gashaka Local Government Area, located in the southeastern part of Taraba State, Nigeria. This region lies within the coordinates 7.3167° N and 11.6167° E and is characterized by a tropical climate with distinct wet and dry seasons. The area is underlain by Precambrian basement complex rocks and hosts numerous artisanal mining activities, particularly in Lambangudu, Maijankasa, Gidankara, and Quentygate, each identified as a high-impact site for small-scale mineral extraction. These mining sites are typically adjacent to surface water bodies and hand-dug wells, which serve as the primary sources of drinking and domestic water for surrounding communities.

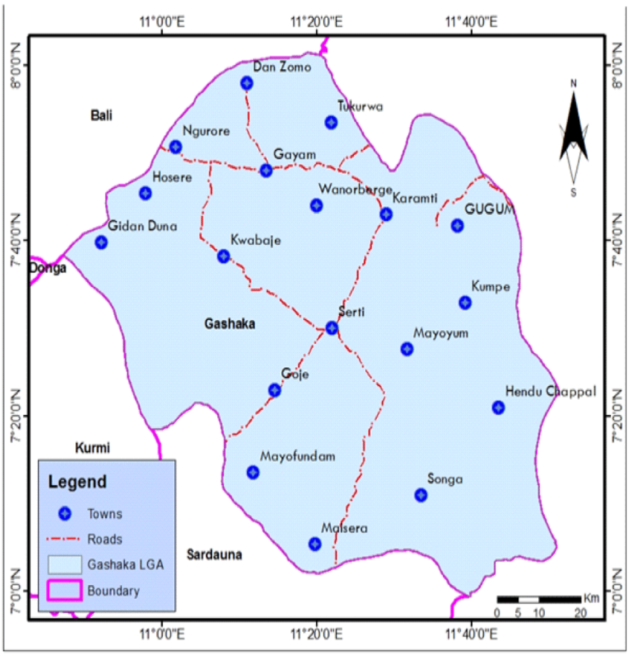

Figure 1: Map of Study Area

2.2 Sampling Strategy

Water samples were collected from four distinct mining-impacted locations: Lambangudu, Maijankasa, Gidankara, and Quentygate. At each site, triplicate samples were taken from both surface water (streams) and shallow groundwater (wells) to account for variability and ensure statistical reliability. Sampling was carried out during the dry season (January–March 2024) to reduce dilution effects caused by rainfall and to capture peak contamination levels.

2.3 Sample Collection and Preservation

Samples were collected using acid-washed high-density polyethylene (HDPE) bottles (1L capacity). Prior to collection, all containers were rinsed three times with the sample water. Samples were filtered on-site using 0.45 µm Whatman membrane filters to remove suspended particulates. For metal analysis, samples were acidified to pH <2 using ultrapure nitric acid (HNO_3) to prevent precipitation and adsorption of metals to container walls.

All samples were stored at 4°C in an insulated cooler and transported to the laboratory for analysis within 24 hours.

2.4 Analytical Methods

Heavy metal concentrations were determined using Atomic Absorption Spectrophotometry (AAS) (PerkinElmer AAnalyst 400). The metals analyzed included Cadmium (Cd), Lead (Pb), Cobalt (Co), Copper (Cu), Chromium (Cr), Zinc (Zn), Nickel (Ni), Manganese (Mn) and Iron (Fe). Instrument calibration was carried out using certified standard solutions of each metal, and calibration curves were constructed with R^2 values ≥ 0.995. Quality control was maintained through the analysis of blanks, duplicates, and standard reference materials (SRMs). Analytical precision was kept within ±5% relative standard deviation.

2.5 Data Analysis

Percentage change in metal concentrations was calculated relative to baseline or control values. These baseline values were obtained from previously reported regional reference concentrations or background levels in unaffected upstream water bodies. The percentage change was computed using the following formula:

Percentage Change = ((C_sample - C_reference) / |C_reference|) × 100

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Where:

C_sample is the measured concentration at the mining site

C_reference is the baseline or control concentration

Descriptive statistics, including mean and standard deviation, were calculated using IBM SPSS Statistics v27. Spatial variation and pattern analysis were visualized using OriginPro 2023 and QGIS 3.28.

3. Results

3.1 Percentage Change of Heavy Metals

Parameter (ppm)	Lambangudu (%)	Maijankasa (%)	Gidankara (%)	Quentygate (%)	Average (%)
Cadmium (Cd)	-200.00	-243.33	-360.00	-183.33	-246.67
Lead (Pb)	200.00	-52.50	0.00	-110.00	5.63
Cobalt (Co)	-65.50	-140.00	-71.00	-92.00	-83.92
Copper (Cu)	-99.72	-99.92	-101.48	-100.40	-99.90
Chromium (Cr)	-92.00	-98.00	-90.00	-70.00	-74.00
Zinc (Zn)	-96.04	-98.97	-98.27	-98.13	-97.09
Nickel (Ni)	-69.29	-70.71	-81.43	-71.86	-74.57
Manganese (Mn)	-53.12	-50.55	-43.38	-51.82	-49.93
Iron (Fe)	385.83	368.60	312.57	297.77	272.75

The table presents the percentage change in heavy metal concentrations across four mining sites in Gashaka L.G.A., Taraba State, Nigeria, relative to baseline levels. Iron (Fe) showed the highest mean increase (+272.75%), peaking at +385.83% in Lambangudu, indicating significant geochemical mobilization due to mining activities. Lead (Pb) exhibited spatial variability, with a sharp increase (+200%) in Lambangudu but declines in other sites, suggesting localized contamination from mining waste. Conversely, cadmium (Cd), copper (Cu), and zinc (Zn) displayed consistent negative percentage changes (e.g., Cd: -246.67%, Cu: -99.90%, Zn: -97.09%), which may reflect adsorption, dilution, or low natural abundance. Other metals like cobalt (Co), chromium (Cr), nickel (Ni), and manganese (Mn) showed moderate decreases but could still pose ecological and health risks.

4. Discussion

The findings of this study on heavy metal contamination in Gashaka L.G.A. reveal critical insights that both align with and diverge from recent research on mining-related water pollution. The observed spatial variability, particularly the elevated levels of iron (Fe) and lead (Pb), stress the complex interplay of geochemical and anthropogenic factors in artisanal mining regions. One of the most striking agreements with contemporary studies is the pronounced increase in iron concentrations, which averaged +272.75% across the sampled sites. This finding resonates with the work of Balarabe *et al*. (2020), who documented similar Fe mobilization in Nigerian mining areas, attributing it to the oxidative weathering of mineralized substrates. The peak value of +385.83% at Lambangudu further supports the notion that disturbed soils and exposed lithologies in mining zones significantly contribute to Fe loading in water systems. Recent research by Nnorom *et al*. (2022) corroborates this, emphasizing that Fe-rich effluents from artisanal mining are a pervasive issue in sub-Saharan Africa, often leading to secondary contamination through co-precipitation with other metals.

The spatial variability of lead contamination also aligns with recent literature. The sharp increase of +200% at Lambangudu, contrasted with declines at other sites, mirrors findings by Eze *et al*. (2021), who identified localized Pb hotspots near mining waste dumps in Nigeria. The study's emphasis on Pb's neurotoxic risks, particularly for vulnerable populations, is consistent with the conclusions of Orisakwe *et al*. (2020), who highlighted the absence of safe exposure thresholds and the disproportionate impact on children in mining communities. These parallels reinforce the urgency of targeted interventions in high-risk areas like Lambangudu.

However, the study's interpretation of negative percentage changes for metals like cadmium (Cd), copper (Cu), and zinc (Zn) invites some disagreement. While the authors suggest these declines may reflect natural attenuation or dilution, recent work by Okeke *et al*. (2023) cautions against overreliance on percentage change metrics without absolute concentration data. Their research argues that even sub-threshold levels of these metals can persist in ecosystems, posing long-term risks through bioaccumulation. For instance, the extreme decline of -360% for Cd at Gidankara, while statistically significant, may obscure the presence of residual contamination that could still exceed safety guidelines.

5. Conclusion

This study reveals pronounced spatial heterogeneity in heavy metal contamination across artisanal mining sites in Gashaka Local Government Area, Taraba State, Nigeria. Notably, iron (Fe) and lead (Pb) exhibited elevated concentrations—particularly at Lambangudu—indicating localized hotspots of contamination likely driven by mining-related geochemical processes and anthropogenic inputs. While negative percentage changes in some metals (e.g., cadmium, copper, zinc) may reflect geochemical retention or dilution, they do not preclude potential ecological or health risks, especially in the context of chronic exposure.

The findings underscore the need for site-specific monitoring frameworks and evidence-based remediation strategies to address contamination at its source. Special attention should be directed toward high-risk communities, such as those near Lambangudu, where elevated exposure to neurotoxic metals poses a critical threat to public health. Future policies must integrate environmental risk assessment, community engagement, and sustainable mining practices to mitigate the long-term impacts of heavy metal pollution in the region's water resources.

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6. Recommendations

i. Based on the findings of this study, we therefore recommend the following;
ii. Establish periodic water quality monitoring programs.
iii. Implement low-cost remediation solutions (e.g., phytoremediation, biochar filters).
iv. Raise community awareness of contamination risks and alternative water sources.
v. Enforce environmental regulations in artisanal mining operations.

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DOI: 10.5281/zenodo.15638858