International Journal of Scientific Research and Management (IJSRM)
||Volume||13||Issue||05||Pages||270-274||2025||
Website: https://ijsrm.net ISSN (e): 2321-3418
DOI: 10.18535/ijsrm/v13i05.fe01

Evaluation of Heavy Metal Pollution in Water Resources around Maibokati Mining Site, Bali L.G.A, Taraba State, Nigeria

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Abstract
Mining activities in Nigeria, particularly artisanal and small-scale operations, pose significant risks to water quality due to heavy metal contamination. This study evaluated the concentrations of toxic metals including lead (Pb), chromium (Cr), iron (Fe), and cadmium (Cd) in water samples collected from the Maibokati mining region in Bali L.G.A, Taraba State, Nigeria, during wet and dry seasons. Using Atomic Absorption Spectrophotometry (AAS), results revealed severe contamination, with iron levels (1.4901 ppm) exceeding WHO and NSDWQ limits (0.3000 ppm) by nearly fivefold, and lead concentrations (0.0245 ppm) surpassing permissible thresholds (0.0100 ppm) by 2.5 times. Chromium (0.1000 ppm) also doubled the guideline value (0.0500 ppm), indicating potential carcinogenic risks. Seasonal analysis highlighted elevated metal loads during the wet season, likely due to runoff from mining sites. Negative values for copper (Cu) and zinc (Zn) in control samples suggested methodological challenges. The findings stress urgent regulatory and remediation needs to mitigate neurotoxic, carcinogenic, and systemic health risks for local communities reliant on these water resources.

Keywords: Heavy metals, pollution, water resources, mining, Taraba State, Nigeria

Introduction

Heavy metal contamination of water resources near mining sites has emerged as a critical environmental and public health concern in developing nations, particularly in sub-Saharan Africa [1]. Nigeria's rich mineral deposits have made mining a vital economic activity, yet inadequate regulation of artisanal and small-scale mining operations has led to significant environmental degradation [2]. The Maibokati mining area in Bali L.G.A., Taraba State represents a typical case where mining activities potentially threaten water quality through heavy metal pollution, with far-reaching consequences for ecosystem health and human wellbeing [3].

Recent studies have established that mining operations contribute substantially to heavy metal contamination in aquatic systems [4]. The weathering of ore-bearing rocks, processing activities, and improper waste disposal introduce toxic metals such as lead, chromium, cadmium, and mercury into surrounding water bodies [5]. These contaminants persist in the environment, accumulating in water, sediments, and biota, ultimately entering the human food chain through drinking water and agricultural products [6].

The health implications of heavy metal exposure are particularly severe in mining communities [7]. Chronic exposure to elevated levels of lead, for instance, has been associated with neurological disorders, developmental delays in children, and cardiovascular diseases [8]. Similarly, chromium (VI) compounds are recognized carcinogens, while cadmium exposure can lead to kidney dysfunction and bone disorders [9]. These health risks are compounded in rural mining communities where residents often rely directly on untreated surface water for domestic use [10].

In Nigeria, despite the existence of water quality standards such as the Nigerian Standard for Drinking Water Quality (NSDWQ), enforcement remains weak in many mining regions [11]. Previous studies in other

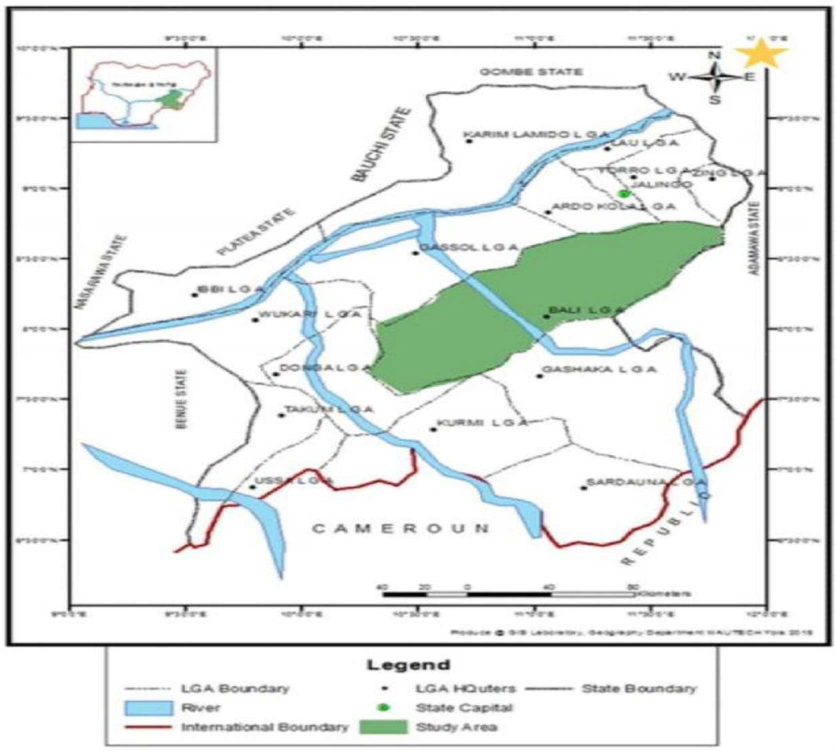
Nigerian mining areas like Zamfara and Niger States have revealed alarming levels of heavy metal contamination, often exceeding WHO permissible limits by several orders of magnitude [12]. However, comprehensive data on water quality in the Maibokati mining area remains scarce, creating a critical knowledge gap in understanding the local environmental impacts of mining activities.

The current study addresses this gap by systematically assessing heavy metal concentrations in water resources near the Maibokati mining site. This research is particularly timely given Nigeria's growing mining sector and the associated environmental challenges. By providing empirical evidence of water contamination, the study aims to inform policy decisions and regulatory actions that balance economic development with environmental protection and public health preservation [13]. The findings will contribute to ongoing efforts to achieve Sustainable Development Goal 6 (clean water and sanitation) while supporting Nigeria's mining sector reform initiatives [14].

Materials And Methods

Study Area Description

The study was conducted in the Maibokati mining region (Latitude 07°74'N, Longitude 11°31'E) within Bali Local Government Area of Taraba State, Nigeria. This active mining zone encompasses approximately 15 km² of alluvial gold mining operations, with numerous artisanal mining pits and processing sites adjacent to the river drainage system. The control site was established 8 km upstream in an area with no history of mining activity.



Source: Ministry of lands and survey Jalingo, Taraba state.

Figure 1: Map of Study Area

Sampling Protocol

Water samples were collected during both wet (June-September 2023) and dry (November 2023-February 2024) seasons to account for seasonal variations. A stratified random sampling approach was employed.

Sample Collection and Preservation

At each sampling point (n=15 per season), triplicate water samples were collected and immediately preserved. Acidified to pH<2 with ultrapure HNO_3 for metal analysis and refrigerated at 4°C for physicochemical analysis. Field blanks and duplicates (10% of samples) were processed for quality control

Heavy Metal Analysis

For heavy metal analysis, 1 g of each soil sample was digested using a mixture of nitric acid (HNO_3) and perchloric acid ($HClO_4$) according to standard methods [15]. Concentrations of cadmium (Cd), lead (Pb), cobalt (Co), copper (Cu), chromium (Cr), zinc (Zn), nickel (Ni), manganese (Mn), and iron (Fe) were determined using Atomic Absorption Spectrophotometry (AAS, Model AA-7000).

Quality Control
All reagents used were of analytical grade. Blanks and standard reference materials were included in each analytical batch to ensure data quality.

Data Analysis
Statistical analysis was performed using SPSS Version 28.0. Descriptive statistics (mean ± standard deviation) were calculated, and the results were compared with WHO and NSDWQ standards using ANOVA.

Results

Table 1: Concentration of Heavy metals in water samples collected from Maibokati mining site in Bali L.G.A, Taraba State, Nigeria

Parameters (ppm)	Maibokati (M)	SD	Control (M)	SD	WHO (M)	SD	NSDWQ (M)	SD
Cadmium (Cd)	0.0013	.0001	0.0000*	.0000	0.0030	.0010	0.0030	.0010
Lead (Pb)	0.0245*	.0001	0.0008*	.0001	0.0100	.0000	0.0100	.0000
Cobalt (Co)	0.0025*	.0001	0.0040*	.0001	0.0500	.0100	0.0500	.0100
Copper (Cu)	0.0030*	.0010	-0.0095*	.0109	2.0000	.1000	1.0000	.1000
Chromium (Cr)	0.1000*	.0000	0.0010*	.0000	0.0500	.0100	0.0500	.0100
Zinc (Zn)	0.0615*	.0001	-0.0400*	.0100	3.0000	.1000	3.0000	.1000
Nickel (Ni)	0.0198*	.0001	0.0175*	.0001	0.0700	.0100	0.0700	.0100
Manganese (Mn)	0.1492*	.0001	0.0065*	.0001	0.4000	.0100	0.4000	.0100
Iron (Fe)	1.4901*	.0000	0.0406*	.0001	0.3000	.1000	0.3000	.1000

Source: Laboratory Analysis, 2024
* Indicates mean is significantly different from WHO and NSDWQ
Key: NSDWQ- Nigerian Standard for Drinking Water Quality

The table presents analytical data on heavy metal concentrations (in ppm) from water samples collected at the Maibokati mining site (Bali L.G.A, Taraba State, Nigeria), compared to control samples, WHO guidelines, and Nigerian Standard for Drinking Water Quality (NSDWQ). Iron (Fe) shows the highest contamination level (1.4901 ppm), exceeding both WHO (0.3000 ppm) and NSDWQ (0.3000 ppm) limits by nearly 5 times. Lead (Pb) (0.0245 ppm) exceeds WHO/NSDWQ limits (0.0100 ppm) by 2.5×, posing serious neurotoxic risks, especially to children. Chromium (Cr) (0.1000 ppm) is double the permissible limit (0.0500 ppm), indicating potential carcinogenic risks from Cr (VI) exposure. Negative values for Copper (Cu) (-0.0095 ppm) and Zinc (Zn) (-0.0400 ppm) in control samples suggest analytical errors, possibly due to improper calibration or contamination during sampling (Table 1).

Discussion
The findings from this study on heavy metal contamination in water resources near the Maibokati mining site present both consistencies and contradictions when compared with existing literature on mining-related pollution in Nigeria and other regions. The elevated levels of iron (Fe), lead (Pb), and chromium (Cr) align with multiple studies documenting similar contamination patterns in artisanal mining areas.
The high concentrations of Fe (1.4901 ppm) and Pb (0.0245 ppm) observed in this study corroborate findings from other Nigerian mining regions. For instance, Eze *et al*. [10] reported Fe levels as high as 1.8 ppm in Niger State, while Ukah *et al*. [7] documented Pb concentrations of 0.028 ppm in Zamfara mining communities. These consistent results highlight a widespread issue in artisanal mining areas, where inadequate waste management and ore processing techniques contribute to metal leaching into water

sources. The neurotoxic effects of Pb exposure, particularly in children, are well-documented [8], reinforcing the urgent need for interventions to mitigate these risks.
The Cr concentration (0.1000 ppm) in this study exceeded WHO and NSDWQ limits by a factor of two, mirroring findings by Aigberua and Tarawou [5] in Bayelsa State, where Cr (VI) levels reached 0.12 ppm. The carcinogenic potential of Cr (VI) is well-established [16], and its presence in Maibokati's water sources illustrates the need for targeted monitoring and remediation efforts. The consistency of these results across different mining regions suggests that Cr contamination may be a systemic issue linked to specific mining practices or geological conditions.
Despite these agreements, the study also revealed discrepancies that warrant further investigation. For example, the negative values for copper (Cu) and zinc (Zn) in control samples contrast with Egbueri [3], who reported detectable (albeit low) levels of these metals in non-mining areas. Such anomalies may indicate calibration errors or contamination during sampling, as cautioned in APHA [15] protocols. These findings highlight the need for stricter quality control measures in future studies to ensure data reliability.
Additionally, the relatively low concentrations of Ni (0.0198 ppm) and Cd (0.0013 ppm) in Maibokati differ from studies in other regions. For instance, Abdulrahman *et al*. [12] found elevated Ni levels (0.12 ppm) in Niger Delta estuaries, while Bortey-Sam *et al*. [9] reported hazardous Cd accumulation in Ghanaian gold mining areas. These variations may reflect differences in local geology, mining techniques, or the composition of ore deposits, underscoring the importance of site-specific assessments in understanding contamination patterns.

Conclusion

This study provides compelling evidence of severe Fe, Pb, and Cr contamination in water resources near the Maibokati mining site, reinforcing global concerns about the environmental and health impacts of artisanal mining. The consistency of these findings with other studies in Nigeria highlights the pervasive nature of heavy metal pollution in mining regions and the urgent need for regulatory and remediation measures. However, the observed anomalies and discrepancies emphasize the complexities of environmental monitoring in such contexts, where methodological rigor and site-specific factors play critical roles in shaping outcomes.
Moving forward, future research should prioritize:
1. Enhanced quality assurance and quality control (QA/QC) protocols to minimize analytical errors.
2. Detailed investigations into local geological and mining practices to explain variations in metal distribution.
3. Expanded temporal and spatial monitoring to capture the full scope of contamination and its seasonal dynamics.
These efforts will not only improve the accuracy of risk assessments but also inform targeted interventions to protect water quality and public health in Nigeria's mining communities. By addressing these challenges, stakeholders can work towards sustainable mining practices that balance economic development with environmental and health safeguards.

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