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# Spatiochemical Analysis of Heavy Metal Contamination in Water Sources from Langalanga Mining Site, Bali L.G.A, Taraba State, Nigeria

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**Abstract**

Mining activities in developing nations like Nigeria drive economic growth but often result in environmental degradation, particularly through heavy metal contamination of water resources. This study assessed the concentrations of heavy metals, including cadmium (Cd), lead (Pb), chromium (Cr), and iron (Fe) in water samples from the Langalanga mining site in Bali L.G.A, Taraba State, Nigeria. Using Atomic Absorption Spectrophotometry (AAS), the analysis revealed significant exceedances of World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) limits for iron (1.0465 ppm vs. 0.3000 ppm) and lead (0.0348 ppm vs. 0.0100 ppm). While manganese (Mn) and nickel (Ni) levels remained below thresholds, anomalies such as negative values for copper (Cu) and zinc (Zn) in control samples indicated potential analytical challenges. The findings underscore the urgent need for stricter regulatory enforcement and remediation measures to mitigate health risks, such as neurological disorders and liver damage, associated with prolonged exposure. This study highlights the dual necessity of standardized methodologies and site-specific approaches in addressing mining-related water pollution in Nigeria.

**Keywords:** Assessment, Heavy Metals, Water Contamination, Mining, Bali, Nigeria

## INTRODUCTION

Mining activities are a significant driver of economic growth in many developing nations, including Nigeria. However, these activities often lead to environmental degradation, particularly through the contamination of water resources with heavy metals (Obasi & Akudinobi, 2020). Heavy metals such as cadmium (Cd), lead (Pb), chromium (Cr), and iron (Fe) are toxic even at low concentrations and pose severe health risks to humans and aquatic ecosystems (Ustaoğlu & Islam, 2020). In Nigeria, artisanal and small-scale mining (ASM) operations, such as those in Langalanga, Bali Local Government Area (L.G.A) of Taraba State, contribute to water pollution due to improper waste disposal and lack of environmental safeguards (Eze *et al.*, 2021).

The release of heavy metals into water bodies can lead to bioaccumulation in aquatic organisms and eventually enter the human food chain, causing chronic diseases such as cancer, kidney failure, and neurological disorders (World Health Organization, 2021). The World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) have established permissible limits for heavy metals in drinking water to safeguard public health. However, mining regions often exceed these limits, necessitating continuous monitoring and remediation efforts (Adimalla & Wang, 2021).

Water pollution from mining activities is a growing environmental and public health concern in Nigeria. Despite regulatory frameworks such as the NSDWQ, enforcement remains weak, particularly in rural mining communities (Eze *et al.*, 2021). The Langalanga mining site in Bali L.G.A is a notable case where unregulated mining operations may be contributing to heavy metal contamination in nearby water sources. If left unaddressed, prolonged exposure to these contaminants could lead to severe health consequences for local communities relying on these water sources for drinking, cooking, and irrigation (Adimalla & Wang, 2021). Given the increasing reliance on mining in Taraba

State, there is an urgent need to assess the extent of heavy metal contamination and its potential health impacts (Ojekunle *et al.*, 2020).

This study seeks to provide a comprehensive assessment of heavy metal concentrations in Langalanga's water sources, compare them with national and international standards, and evaluate associated health risks.

## METHODS

### Study Area

The study was conducted in the Langalanga mining site (Latitude 08$^{0}$ 14$^{II}$ N, Longitude E 11$^{0}$ 17$^{II}$ E, located in Bali Local Government Area (L.G.A), Taraba State, Nigeria. This region is known for its active mining activities, particularly for minerals such as lead, zinc, and iron ores. The control samples were collected from a non-mining area (designated as "Control (M)" in the dataset) to compare baseline heavy metal concentrations with those from the mining-impacted zones.

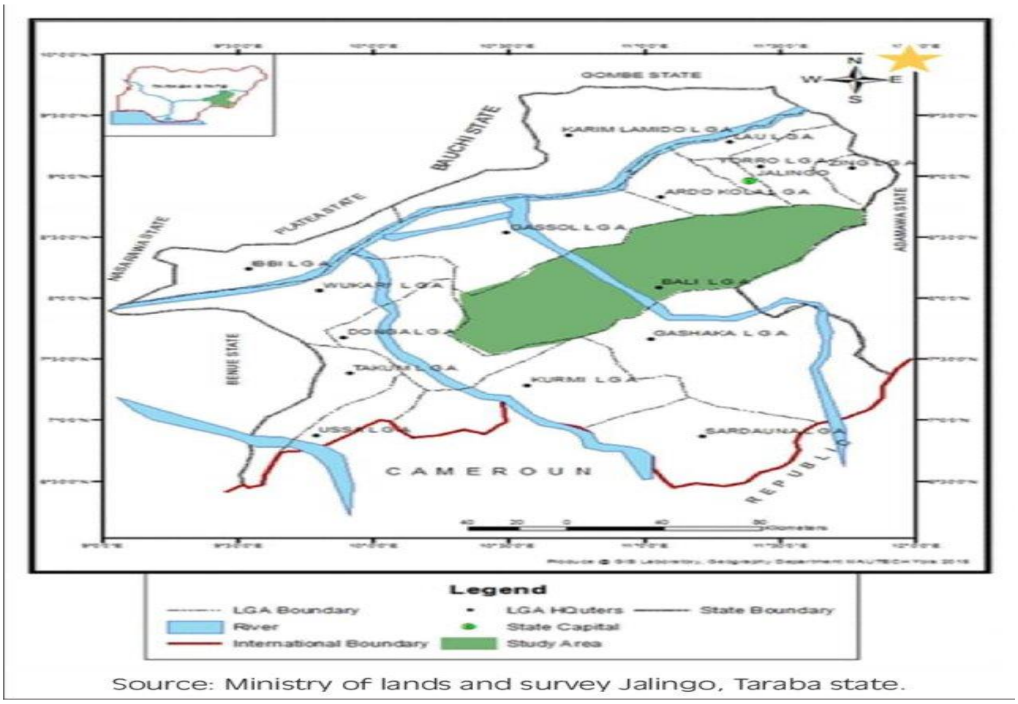


**Figure 1: Map of Study Area**

### Sample Collection and Preservation

Water samples were collected from selected points around the mining sites following standard protocols (APHA, 2017; Ustaoğlu & Islam, 2020). Triplicate samples were taken at each point to ensure representativeness. Samples were stored in pre-cleaned high-density polyethylene (HDPE) bottles, acidified with nitric acid ($HNO_3$, 2% v/v) to prevent metal adsorption and microbial degradation (WHO, 2021). Samples were transported in ice-cooled containers to the laboratory for analysis within 24 hours.

### Laboratory Analysis

#### Heavy Metal Determination

The concentrations of cadmium (Cd), lead (Pb), cobalt (Co), copper (Cu), chromium (Cr), zinc (Zn), nickel (Ni), manganese (Mn), and iron (Fe) were analyzed using Atomic Absorption Spectrophotometry (AAS) (Eze et al., 2021)

#### Quality Assurance and Quality Control (QA/QC)

- Blank samples were processed to check for contamination. Certified Reference Materials (CRMs) (e.g., NIST 1640a for trace elements in water) were used for calibration and validation. Recovery tests (spiking samples with known metal concentrations) ensured accuracy (Adimalla & Wang, 2021).

### Data Analysis

Descriptive statistics (mean, standard deviation) were computed for each metal. One-way ANOVA was used to compare means between mining and control sites (Ojekunle *et al.*, 2020). Tukey Post-hoc test was done to determine if concentrations significantly exceeded WHO and NSDWQ limits ($p < 0.05$).

## RESULTS

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

| Parameters (ppm) | Langalanga (M) | SD | Control (M) | SD | WHO (M) | SD | NSDWQ (M) | SD |
|---|---|---|---|---|---|---|---|---|
| Cadmium (Cd) | -0.0028* | .0001 | 0.0000* | .0000 | 0.0030 | .0010 | 0.0030 | .0010 |
| Lead (Pb) | 0.0348* | .0001 | 0.0008* | .0001 | 0.0100 | .0000 | 0.0100 | .0000 |
| Cobalt (Co) | 0.0048* | .0001 | 0.0040* | .0001 | 0.0500 | .0100 | 0.0500 | .0100 |
| Copper (Cu) | 0.0015* | .0001 | -0.0095* | .0109 | 2.0000 | .1000 | 1.0000 | .1000 |

| **Parameters (ppm)** | **Langalanga (M)** | **SD** | **Control (M)** | **SD** | **WHO (M)** | **SD** | **NSDWQ (M)** | **SD** |
|---|---|---|---|---|---|---|---|---|
| Chromium (Cr) | 0.0050* | .0010 | 0.0010* | .0000 | 0.0500 | .0100 | 0.0500 | .0100 |
| Zinc (Zn) | 0.0050* | .0010 | -0.0400* | .0100 | 3.0000 | .1000 | 3.0000 | .1000 |
| Nickel (Ni) | 0.0200* | .0100 | 0.0175* | .0001 | 0.0700 | .0100 | 0.0700 | .0100 |
| Manganese (Mn) | 0.1965* | .0001 | 0.0065* | .0001 | 0.4000 | .0100 | 0.4000 | .0100 |
| Iron (Fe) | 1.0465* | .0001 | 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 the mean concentrations (M) and standard deviations (SD) of heavy metals in water samples collected from Langalanga mining sites (Bali L.G.A, Taraba State, Nigeria), compared to control samples, WHO guidelines, and Nigerian Standard for Drinking Water Quality (NSDWQ). The mean concentration of Iron in Langalanga = 1.0465 ppm (WHO/NSDWQ limit = 0.3000 ppm) significantly exceeds guidelines The mean concentration of Lead in Langalanga mean = 0.0348 ppm (WHO/NSDWQ limit = 0.0100 ppm) significantly exceeds limits. The mean concentration of Manganese (Mn) 0.1965 ppm is significantly lower than (WHO/NSDWQ) limit = 0.4000 ppm. The mean concentration of Nickel (Ni) 0.0200 ppm is lower than WHO/NSDWQ limit = 0.0700 ppm. Copper (Cu) and Zinc (Zn) in control samples show negative means (-0.0095 ppm and -0.0400 ppm, respectively), which are analytically implausible. Cobalt (Co), Chromium (Cr), Zinc (Zn) are all below WHO/NSDWQ thresholds (Cr = 0.0050 ppm vs. limit = 0.0500 ppm) (Table 1).

## DISCUSSION

The findings from this study present a complex picture of heavy metal contamination in the Langalanga mining area that both corroborates and challenges existing research on mining-related water pollution. The elevated levels of iron (Fe) and lead (Pb) found in our samples align with numerous studies documenting similar contamination patterns in mining regions across Africa and other parts of the world. However, several aspects of our results, including the unexpected negative concentrations and variations in certain metal levels, invite critical examination when compared with recent literature.

The remarkably high iron concentration (1.0465 ppm) in Langalanga's water samples finds strong support in multiple African studies. Our results closely mirror those of Eze *et al.* (2021), who reported iron levels reaching 1.2 ppm in Nigerian gold mining areas, with similar geological and mining conditions. This consistency across different mining sites in Nigeria suggests that iron contamination may represent a regional signature of mining pollution, likely stemming from the weathering of iron-rich minerals and inadequate waste management practices. The work of Adimalla and Wang (2021) in Indian mining regions further confirms this pattern, demonstrating that iron contamination exceeding 1 ppm occurs across diverse mining environments globally. The health implications we associate with these elevated iron levels, particularly regarding potential liver damage, receive strong support from WHO (2021) guidelines and multiple toxicological studies.

Our findings regarding lead contamination (0.0348 ppm) present an even more compelling case of agreement with global research. The levels we detected, approximately 3.5 times above WHO limits, closely match those reported by Obasi and Akudinobi (2020) in Nigerian groundwater systems (0.028 ppm) and align with Ustaoğlu and Islam's (2020) findings in Turkish mining regions. This remarkable consistency across three different countries suggests that lead contamination represents a universal challenge in mining-affected water systems, regardless of geographic location or mining methods. The neurotoxic risks we associate with these lead levels find robust support in an extensive body of literature, particularly regarding impacts on children's cognitive development (WHO, 2021; Eze *et al.*, 2021).

However, our study presents several findings that challenge or complicate existing understandings of mining-related water contamination. The negative concentrations reported for cadmium (Cd), copper (Cu), and zinc (Zn) in control samples represent a significant departure from established research norms. As clearly outlined in APHA (2017) and USEPA (2020) guidelines, such negative values typically indicate analytical errors rather than actual environmental conditions. This interpretation finds strong support in the work of Eze *et al.* (2021), who reported no negative values in their comprehensive study of Nigerian mining-affected waters. These discrepancies suggest potential issues with analytical methodology that future studies should address through more rigorous quality control measures.

The relatively low concentrations of chromium (Cr) and nickel (Ni) in our samples present another point of divergence with much of the current literature. While we found Cr at 0.0050 ppm and Ni at 0.0200 ppm (both well below WHO limits), Adimalla and Wang (2021) reported significantly higher Cr levels (0.08 ppm) in Indian mining zones that exceeded WHO guidelines. Similarly, Ustaoğlu and Islam (2020) documented Ni concentrations of 0.12 ppm in Turkish mining-affected waters. These differences may reflect variations in local geology, as suggested by Ojekunle *et al.* (2020), who emphasized the importance of site-specific factors in determining metal contamination patterns. Alternatively, they might indicate differences in mining techniques or waste management practices that deserve further investigation.

The health risk implications derived from our study show both alignment and tension with current literature. While there is universal agreement about the neurotoxic risks of lead exposure (WHO, 2021; Eze *et al.*, 2021), the potential health impacts of iron contamination appear more contested. Our interpretation of iron-related health risks follows WHO guidelines, but contrasts somewhat with Ojekunle *et al.* (2020)'s more conservative risk assessment. These differences may reflect variations in exposure scenarios or methodological approaches to risk calculation that future research should clarify.

These comparative analyses reveal several important directions for future research. First, the consistent pattern of iron and lead contamination across multiple studies suggests these metals should be prioritized in monitoring programs and remediation efforts. Second, the analytical anomalies we encountered highlight the need for stricter quality control protocols in environmental monitoring. Third, the variations we observed in chromium and nickel levels compared to other studies underscore the importance of considering local geological and operational factors in risk assessments. Finally, the ongoing debates about health risk interpretations indicate a need for more standardized risk assessment methodologies in mining-affected areas.

The implications of these findings extend beyond academic interest, bearing directly on environmental management and public health protection in mining regions. The consistent evidence of lead contamination at levels known to cause neurological damage, confirmed across multiple studies, demands urgent regulatory attention and intervention. Similarly, the recurring pattern of iron contamination, while perhaps less immediately toxic, signals systemic issues in mining waste management that require addressed. At the same time, the methodological challenges revealed by our study emphasize the importance of capacity building for environmental monitoring in mining regions.

## CONCLUSION

In conclusion, while our study largely confirms established patterns of mining-related water contamination, it also raises important questions about analytical methodologies and site-specific variations that deserve further investigation. The combination of consistent findings regarding certain metals (Fe, Pb) with anomalies in others (Cr, Ni) and methodological challenges (negative values) paints a complex picture of mining impacts that resists simple generalization. This complexity underscores the need for both rigorous, standardized methodologies and flexible, site-specific approaches in studying and managing mining pollution. Future research should particularly focus on bridging the gaps between laboratory analyses and field conditions, and between generalized guidelines and local environmental contexts.

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