**Heavy Metal Contamination in Soil and Sustainability Risks in Artisanal Mining Areas: A Case Study of Mayo-Sinna, Sardauna Local Government Area, Taraba State, Nigeria**

**Abstract**

Artisanal mining (ASM) is increasingly recognized as a critical source of environmental degradation and public health risk in sub-Saharan Africa. This study evaluates the concentration and distribution of heavy metals in soil samples collected from ASM sites in Mayo-Sinna, Sardauna Local Government Area (LGA), Taraba State, Nigeria. A total 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 quantified using standard laboratory protocols at both mining and control sites. The results reveal significantly elevated levels of Pb (0.1085 ppm) and Fe (1.4060 ppm) in mining soils, exceeding WHO (2017) and NSDWQ (2007) thresholds by approximately 985% and 368%, respectively. Manganese concentrations also surpassed safety limits by 21.5%, raising concern over long-term neurological impacts. While Cd and Co exhibited anomalous Below Detection Limit (BDL) values likely due to instrumental detection limits, control site measurements for both metals approached or exceeded international safety thresholds. Zinc and nickel levels, though within permissible limits, suggest potential for bioaccumulation and ecological toxicity. These findings provide compelling evidence of anthropogenic contamination associated with unregulated ASM activities and underscore the urgent need for regulatory enforcement, environmental monitoring, and targeted remediation strategies.

**Keywords:** Artisanal mining, heavy metals, soil contamination, Mayo-Sinna, Taraba State, environmental sustainability

**1.0 Introduction**

Artisanal and small-scale mining (ASM) has emerged as a vital livelihood strategy for many rural communities in Nigeria, especially in mineral-rich areas such as Sardauna LGA in Taraba State. Despite its economic significance, ASM is widely recognized for its adverse environmental impacts, particularly the release of toxic heavy metals into surrounding ecosystems (Hilson, 2002; UNEP, 2012). These contaminants can infiltrate soil and groundwater, posing risks to agriculture, biodiversity, and human health (Bawuro *et al.,* 2018; Adekola & Dosumu, 2001).

Soils are key environmental sinks for heavy metals, which can persist for long periods and affect food security and ecosystem services. In Nigeria, several studies have documented elevated levels of lead (Pb), cadmium (Cd), iron (Fe), and zinc (Zn) in ASM regions, raising public health concerns (Oladipo *et al*., 2014; Amadi *et al.,* 2012). However, data specific to Sardauna LGA, an active mining region, remains limited. This study seeks to bridge this gap by analyzing heavy metal concentrations in soils from Mayo-Sinna, a prominent mining community, and comparing the findings to both control sites and international standards (WHO, 2017; NSDWQ, 2007).

**2.0 Materials and Methods**

**2.1 Study Area**

Mayo-Sinna is located in Nguroje Ward of Sardauna LGA, Taraba State, Nigeria. The region is known for artisanal mining of metallic ores, including lead, zinc, and iron-bearing minerals. The terrain is characterized by savannah grasslands and seasonal rainfall, with mining typically performed manually with minimal environmental controls (Taraba State Government, 2021).

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**Figure 1: Map of study Area**

**2.2 Sample Collection**

Soil samples were collected in April 2024 from five mining locations in Mayo-Sinna and one control location approximately 5 km away from the mining sites to ensure minimal contamination. Samples were collected at a depth of 0–15 cm using a stainless-steel auger, placed in labeled polyethylene bags, and transported to the laboratory for analysis.

**2.3 Sample Preparation and Analysis**

The soil samples were air-dried, ground, and sieved through a 2 mm mesh. Each sample (1 g) was digested using a mixture of nitric acid and perchloric acid in a 3:1 ratio on a hot plate until clear solutions were obtained. The digested samples were analyzed using Atomic Absorption Spectrophotometry (AAS) to quantify concentrations of Cd, Pb, Co, Cu, Cr, Zn, Ni, Mn, and Fe. All readings were taken in triplicate, and standard reference materials were used for quality control. Descriptive statistics were applied to compare mining and control sites. Due to limited sample size, formal inferential statistics were not conducted.

**2.4 Standards Used**

The measured concentrations were compared to limits set by the World Health Organization (WHO, 2017) and the Nigerian Standard for Drinking Water Quality (NSDWQ, 2007), noting their relevance due to eventual leaching from soil to water bodies.

**3.0 Results**

**Table 1 : Comparative concentrations of nine heavy metals in soils from artisanal mining sites and a control site in Mayo-Sinnas**

| **Parameter (ppm)** | **Mayo-Sinna (M)** | **Control (M)** | **WHO Std** | **NSDWQ Std** | **% Difference (Mining vs. WHO)** | **% Difference (Mining vs. Control)** |
| --- | --- | --- | --- | --- | --- | --- |
| Cadmium (Cd) | -0.0560\* | 0.0010\* | 0.0030 | 0.0030 | — | — |
| Lead (Pb) | 0.1085\* | 0.0500\* | 0.0100 | 0.0100 | +985 | +117% |
| Cobalt (Co) | -0.0982\* | 0.1000\* | 0.0500 | 0.0500 | — | — |
| Copper (Cu) | -0.1964\* | 1.5000 | 2.0000 | 1.0000 | — | — |
| Chromium (Cr) | 0.0603 | 0.0300 | 0.0500 | 0.0500 | +21 | +101% |
| Zinc (Zn) | 0.0789\* | 2.7300 | 3.0000 | 3.0000 | -97 | -97% |
| Nickel (Ni) | 0.0298\* | 0.0500 | 0.0700 | 0.0700 | -57 | -40% |
| Manganese (Mn) | 0.4860 | 0.3600 | 0.4000 | 0.4000 | +21.5 | +35% |
| Iron (Fe) | 1.4060\* | 0.2200 | 0.3000 | 0.3000 | +368 | +539% |

Table 1 presents the comparative concentrations of nine heavy metals in soils from artisanal mining sites and a control site in Mayo-Sinna, juxtaposed with WHO and NSDWQ standards. The data reveal that lead (Pb) and iron (Fe) are the most critically elevated, with Pb reaching 0.1085 ppm 985% above the WHO permissible limit of 0.01 ppm and 117% higher than the control site, indicating acute contamination and posing serious neurotoxic risks. Iron levels were also substantially elevated at 1.4060 ppm, representing a 368% and 539% increase over WHO standards and control values, respectively, suggesting significant anthropogenic enrichment likely due to ore processing and tailings runoff. Manganese (Mn) concentrations exceeded the WHO threshold by 21.5%, with a 35% difference from the control site, raising concerns about potential neurological effects. Chromium (Cr) was slightly above the safe limit by 21%, with a 101% increase relative to the control, indicating mobilization from mining activities. Conversely, cadmium (Cd), cobalt (Co), and copper (Cu) showed Below Detection Limit (BDL) values in mining soils, likely due to instrumental detection limits or detection errors, though their control site levels approached or exceeded WHO thresholds, signaling possible background contamination. Zinc (Zn) and nickel (Ni) remained within safe limits in mining areas, but the unusually high Zn concentration in the control site suggests regional legacy contamination. Overall, the table underscores that unregulated artisanal mining in Mayo-Sinna has led to hazardous soil contamination, particularly with Pb, Fe, and Mn, emphasizing the urgent need for environmental remediation, regulatory enforcement, and public health interventions.

**4.0 Discussion**

This study provides compelling evidence of significant soil contamination from artisanal and small-scale mining (ASM) activities in Mayo-Sinna, Sardauna LGA, Taraba State, Nigeria. Elevated concentrations of lead (Pb), iron (Fe), and manganese (Mn) among other heavy metals—signal acute environmental degradation and heightened public health risks. The findings align with broader empirical evidence from ASM-affected regions across Nigeria, confirming systemic environmental threats associated with unregulated mineral extraction (Bawuro *et al*., 2018). Lead concentrations in soil from the Mayo-Sinna mining site reached 0.1085 ppm, exceeding WHO (2017) and NSDWQ (2007) thresholds by approximately 985%. This level of contamination far surpasses the safe limit of 0.01 ppm, raising serious concerns about neurotoxicity, particularly among vulnerable populations. This trend mirrors findings from Zamfara State, where Pb concentrations in mining communities ranged from 0.11 to 0.57 ppm, contributing to a widespread lead poisoning crisis (UNEP, 2012; Bawuro *et al*., 2018). The elevated levels observed here are likely attributable to ore processing, which release lead particulates into surrounding soils. Chronic lead exposure is linked to cognitive impairment, renal dysfunction, and cardiovascular complications (WHO, 2017).

Iron concentration in Mayo-Sinna soils was 1.406 ppm, exceeding permissible limits by 368%. While iron is essential for metabolic processes, elevated levels pose risks of oxidative stress and organ toxicity, particularly in individuals with predisposing conditions like hemochromatosis. Similar levels have been reported in Kwara State, where ASM activities elevated Fe concentrations in soil to as high as 1.5 ppm (Ogundele *et al*., 2015). The data suggest anthropogenic enrichment, likely due to the oxidation of iron-rich ores and runoff from mine tailings.

Although zinc concentrations (0.0789 ppm) in Mayo-Sinna soils remained below the WHO threshold of 3.0 ppm, elevated levels in the control site indicate potential regional baseline contamination or legacy effects from historical mining. Zinc is essential in trace amounts but poses risks of immunotoxicity and interference with copper metabolism when bioaccumulated (Amadi *et al*., 2012).

Manganese levels measured 0.486 ppm in the mining zone, approximately 21.5% above the WHO guideline of 0.4 ppm. Chronic exposure to elevated Mn concentrations has been associated with neurological dysfunction and Parkinson-like symptoms, a condition known as manganism (Nwachukwu & Osuji, 2007). Similar exceedances have been documented in Jos Plateau mining zones, confirming the health relevance of elevated Mn in ASM environments (Akan *et al*., 2010).

Cadmium and cobalt values in Mayo-Sinna presented negative readings, likely due to instrumental detection limitations or baseline correction errors. However, control site values of Cd (0.001 ppm) and Co (0.100 ppm) approached or exceeded WHO limits (0.003 ppm and 0.05 ppm, respectively), suggesting latent contamination. These findings align with previous studies in Ekiti and Nasarawa States, where Cd and Co levels in soils and groundwater from mining sites approached toxic thresholds (Oladipo *et al*., 2014; Olatunji *et al*., 2013). Chronic cadmium exposure is associated with kidney dysfunction, skeletal damage, and cancer, while cobalt toxicity has been linked to cardiomyopathy and thyroid disorders (ATSDR, 2004).

Chromium (0.0603 ppm) and nickel (0.0298 ppm) concentrations in the Mayo-Sinna mining soils were within WHO and NSDWQ permissible limits, suggesting limited mobilization or absence of their mineral-bearing forms. However, due to their cumulative toxicity and potential for bioaccumulation, continuous environmental monitoring remains essential. Similar studies in Osun State reported Ni levels in soils ranging from 0.02 to 0.06 ppm, reinforcing the need for vigilance despite current compliance (Ajayi & Adesida, 2009; USEPA, 2009).

**Table 2. Comparative Heavy Metal Contamination from ASM in Nigeria**

| **Location** | **Key Findings** | **Reference** |
| --- | --- | --- |
| Zamfara State | Pb: 0.11–0.57 ppm; lead poisoning epidemic | Bawuro *et al.,* 2018; UNEP, 2012 |
| Kwara State | Fe: up to 1.5 ppm in mining-affected soils | Ogundele *et al.,* 2015 |
| Jos Plateau | Mn: up to 0.5 ppm in ASM zones | Akan *et al.,* 2010 |
| Ekiti/Nasarawa States | Cd: 0.001–0.004 ppm; Co: 0.08–0.15 ppm | Oladipo *et al.,* 2014; Olatunji *et* *al.,* 2013 |
| Osun State | Ni: 0.02–0.06 ppm in ASM areas | Ajayi & Adesida, 2009 |

The contamination profile observed in Mayo-Sinna reflects broader patterns across Nigeria’s ASM belt. A comparison with empirical studies from other states illustrates that elevated Pb, Fe, and Mn levels are characteristic of unregulated mining zones. The systemic nature of this pollution points to weak regulatory oversight, poor environmental practices, and a lack of awareness among artisanal miners.

**5.0 Conclusion**

The significantly elevated concentrations of Pb, Fe, and Mn in Mayo-Sinna's mining soils underscore a critical environmental health crisis. The patterns observed are not isolated but resonate with conditions in other artisanal mining zones across Nigeria. There is an urgent need for integrated interventions that combine environmental remediation, community health screening, and enforcement of mining regulations. Furthermore, educational programs and the promotion of safer mining technologies could play a pivotal role in reducing exposure to toxic metals and promoting sustainability in ASM communities. Policymakers in Taraba State and at the national level should prioritize environmental audits in mining areas and establish enforceable soil quality standards to prevent long-term ecological and public health damage.

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