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ASSESSMENT OF HEAVY METALS PRESENT IN SOIL SAMPLES OBTAINED FROM GOLD MINING VILLAGES IN SELECTED AREAS WITHIN ATAKUMOSA WEST LGA OF OSUN STATE, NIGERIA

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ABSTRACT

Artisanal gold mining in Nigeria is a lucrative industry, yet it poses serious health risks and environmental pollution by releasing toxic metals into the environment. The research aimed to determine the concentrations and distributions of selected heavy metals, including chromium, cadmium, copper, lead, zinc, mercury, and arsenic, in soil samples. Soil samples were collected from 5 mining villages: Ibodi, Fadugba, Igila, Gbodo-araromi, and Itagunmodi. The soil samples were prepared by removing unwanted materials and digested with aqua-regia. The digested samples were heated at 95°C for 3–4 hours in a fume cupboard until the solution was clear, allowed to cool, and then 20 ml of deionized water was added, filtered, and taken for analysis by atomic absorption spectroscopy. The results show significant mercury pollution in Igila (1.211±0.004 ppm) and Ibodi (1.154±0.002 ppm), and cadmium in Ibodi (1.142±0.002 ppm), Fadugba (1.141±0.002 ppm), and Gbodo-araromi (1.832±0.002 ppm). They were above the permissible limit set by the World Health Organization (WHO). These villages need urgent intervention from the State Government to prevent these metals from entering the food chain; solutions such as remediation and environmental clean-up are suggested to keep the villagers safe from cadmium and mercury poisoning.

Keywords: Aqua-regia; Cadmium; Mercury; Mining; Poisoning.

1.0. Introduction

Artisanal gold mining has been a significant economic driver in many developing countries, particularly in sub-Saharan Africa (Hilson, 2009). In Nigeria, it supports local income and industrial development; however, heavy metals in soils and sediments pose a major environmental threat due to their persistence, non-biodegradability, and toxicity (Adewumi & Laniyan, 2020). The extraction and processing of gold often involve substances such as mercury (Hg) and cyanide, along with inherent metals such as arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), and zinc (Zn), which can accumulate in soil, water, and plants near mining zones. Over time, these contaminants endanger ecosystems and communities relying on regional resources (Adewumi & Olaniyi, 2019).

Heavy metals are elements with metallic characteristics and high atomic masses, typically greater than 20, and densities exceeding 5g/cm³ (Alloway, 2013). These metals are dense and harmful or toxic at low concentrations. Unlike organic contaminants, they resist degradation and can linger in environments for decades (Alloway, 2013). When mining disrupts mineral-rich geological layers, it releases heavy metals that can build up in nearby soils, water bodies, and sediments. For example, mercury (Hg) and arsenic (As) are commonly linked to gold minerals and are used in amalgamation and mineral processing. Extended contact with these metals through breathing, consumption, or skin absorption can cause serious health conditions such as neurological problems, kidney damage, cancer, and developmental defects (Jaishankar et al., 2014).

Globally, the environmental impacts of gold mining have been thoroughly examined in Ghana, Tanzania, and Zimbabwe; studies have shown that mining communities face high levels of lead, mercury, and arsenic in their water supplies and food sources (Hilson & Pardie, 2006). In Nigeria, the Zamfara lead poisoning crisis in northwest Nigeria, when ore processing spread lead dust in villages such as Dareta and Bagega, was responsible for more than 400 children's deaths and hundreds of cases in which blood lead was more than 100 µg/dL (Tirima et al., 2018).

Even today, the use of mercury in Zamfara's Anka area still threatens miners, as a survey in 2021 showed that mercury poisoning had caused symptoms such as tremors and kidney problems for half of the miners investigated (Basu et al., 2015). In Niger State, activities in Minna and Shiroro had led to the loss of 30% of the forest and to mercury entering the Mariga River. This resulted in neurological problems for people and caused problems with local farmers (Eludoyin et al., 2017). The Osun River has been reported to be contaminated with mercury, severely damaging farming and water use in the area and causing health problems such as skin rashes and increased social conflict. In response, Ilesha communities now use sand and charcoal filtration to reduce waterborne illnesses. (Awogbami et al., 2024).

The selected sites are located in the Atakumosa West Local Government Area (LGA) of Osun State, South-West Nigeria, which is known for its abundant gold reserves and long-standing gold mining activities. This resource has drawn miners for years, notably in areas such as Itagunmodi, Ibodi, and Igila, which have become centres of informal gold operations. Although these efforts boost local earnings and jobs, the ecological consequences have raised alarm among scientists, health officials, and policymakers (Oladipo et al., 2020). This axis has provided a vital example for understanding the effects of small-scale gold mining on environmental quality in south-western Nigeria.

The topography, water flow, and geological setting of the area make it prone to metal leaching and sediment movement. Rainfall patterns promote surface runoff, which carries metal remnants into nearby streams and rivers, affecting aquatic systems and community water supplies. Gradually, the bioaccumulation of these metals in flora and fauna may introduce toxic levels into the food chain, creating long-term effects (Taiwo & Awomeso, 2017).

Mining activities in Atakumosa West LGA. are predominantly informal and unregulated, often leading to improper waste disposal, heavy metal leaching into the environment, and contamination of the soil and water. The primary aim of this research is to determine the concentrations of selected heavy metals, including chromium, cadmium, copper, lead, zinc, mercury, and arsenic, in soil samples from the gold mining site within the Atakumosa West LGA of Osun State, Nigeria.

2.0. Materials And Methods

2.1. Description of the Study Area

The investigation was conducted in five selected villages, namely ibodi, Fadugba, Gbodo-araromi, itagunmodi and igila, all within the Atakumosa

West LGA. in Osun State, south-west Nigeria, they are known for their rich gold deposits and active informal mining operations.

2.2.Sampling Locations and Coordinates

Five principal gold-mining villages or locations were chosen for this study to capture a range of mining intensities and environmental conditions within Atakumosa West L.G.A. Their coordinates were obtained using a Global Positioning System (GPS) device, as presented in Table 1 below.

Table 1.0: Global Positioning System of the various sampling sites

S/N	Sampling Site/ villages	Latitude (°N)	Longitude (°E)
1	Itagunmodi	7.542336	4.669324
2	Ibodi	7.581959	4.674359
3	Igila	7.579451	4.658164
4	Fadugba,	7.598227	4.657849
5	Gbodo-araromi	7.585937	4.655039

Each location was selected based on proximity to active or recently abandoned gold mining operations. Soil samples were collected from the top 0–15 cm layer, where surface pollution is typically concentrated.

2.3. Sample Collection Procedure

Systematic sampling was used to collect representative soil samples from each site. At each location, five sub-samples were taken within a 20 m radius and thoroughly mixed to form a composite sample of about 500 g. Samples were collected with clean stainless-steel augers and stored in well-labelled polythene bags (USEPA, 2002). To prevent cross-contamination, all tools were thoroughly cleaned after each use. Samples were then transported to the chemistry laboratory at Osun State College of Technology, Esa-Oke, Osun State, for analysis.

2.4. Sample Preparation

Soil samples were air-dried at room temperature for five days to remove moisture and debris, then sieved through a 2 mm mesh to obtain a homogeneous fine powder for analysis. A 5 g portion of each sample was accurately weighed using an analytical balance (Mettler Toledo AB104-S) (Jones, 2001).

2.4.1. Digestion Procedure

Digestion reagents were concentrated nitric acid (HNO_3) and hydrochloric acid (HCl), analytical grade (99.8% purity). A 200 mL aqua regia solution (150 mL HNO_3: 50 mL HCl; 3:1 v/v), a strong oxidizing mixture that dissolves most metals, was prepared. A 5 g soil sample was placed in a 250 mL beaker, and the aqua regia was added gradually. The beaker was heated on a hot plate in a fume cupboard at 95°C for 3–4 h until the solution became clear, indicating complete digestion. After cooling, 20 mL deionized water was added and mixed. The solution was filtered through Whatman No. 42 filter paper, and the filtrate was collected in a pre-cleaned 50 mL bottle, labelled, and stored for Atomic Absorption Spectrometry (AAS) analysis (ISO, 1995).

2.5. Calculation of the contamination factor and the pollution load index.

The contamination factor (CF) is an index used to assess environmental pollution; it compares a

sample with a reference value. CF is calculated for each metal using the formulae below

$$CF = Csample \div Creference$$

Where CF is the contamination factor, and C_{sample} is the concentration of the sample, and $C_{reference}$ is the concentration of the reference sample

$$PLI = (CF1 \times CF2 \times CF3 \times CF4 \times CF5 \times CF6 \times CF7)\ \Delta^{1/7}$$

PLI = pollution load index (PLI), Where CF_1, CF_2, CF_3, CF_4, CF_5, CF_6, CF_7 = contamination factor for each metal

3.0.Results and Discussion

Table 2: Heavy metal concentration (Cr, Cd, Cu, Pb, Zn, Hg, As) in ppm of different soil samples

Ibodi village							
Readings	**Cr**	**Cd**	**Cu**	**Pb**	**Zn**	**Hg**	**As**
1st	2.301	1.142	0.079	0.098	0.229	1.155	1.226
2nd	2.284	1.139	0.076	0.091	0.235	1.151	1.229
3rd	2.311	1.147	0.082	0.101	0.221	1.158	1.221
Std. dev	0.01365	0.00404	0.003	0.00513	0.00702	0.00351	0.00404
Mean	2.29866	1.14266	0.079	0.09666	0.22833	1.15466	1.22533
SEM	0.00788	0.002	0.00173	0.00296	0.00405	0.00203	0.00233
Fadugba village							
1st	1.208	1.136	3.100	1.515	1.132	0.064	0.055
2nd	1.199	1.146	3.098	1.519	1.127	0.068	0.059
3rd	1.191	1.141	3.089	1.511	1.135	0.061	0.051
Std dev	0.0085	0.05	0.00585	0.004	0.00404	0.00351	0.004
Mean	1.1993	1.141	3.09566	1.515	1.13133	0.06433	0.055
SEM	0.00491	0.0028	0.00338	0.0023	0.00233	0.00202	0.0023
Gbodo –araromi village							
1st	0.088	1.832	0.216	1.426	0.075	0.037	0.092
2nd	0.085	1.836	0.212	1.429	0.071	0.033	0.095
3rd	0.079	1.829	0.219	1.422	0.079	0.039	0.099
Std dev	0.00458	0.00351	0.00351	0.00351	0.004	0.00305	0.00351
Mean	0.084	1.83233	0.21567	1.42566	0.075	0.03633	0.09533
SEM	0.00264	0.00202	0.00203	0.00202	0.00231	0.00176	0.00202
Itagunmodi village							
1st	2.713	0.088	0.231	0.109	0.133	0.105	1.365
2nd	2.701	0.085	0.237	0.106	0.138	0.101	1.369
3rd	2.719	0.082	0.239	0.102	0.131	0.108	1.364
Std dev	0.0092	0.003	0.00416	0.00351	0.00361	0.00351	0.00265
Mean	2.711	0.085	0.23567	0.105667	0.134	0.10467	0.96262
SEM	0.00529	0.00173	0.0024	0.00203	0.00208	0.00203	0.00153
Igila village							
1st	1.279	0.091	1.522	1.707	0.094	1.22	1.008
2nd	1.285	0.089	1.517	1.701	0.091	1.211	1.004
3rd	1.272	0.094	1.529	1.711	0.089	1.204	1.001
Std dev	0.00651	0.00252	0.00603	0.00503	0.00252	0.00802	0.0035

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Mean	1.2787	0.09133	1.5226	1.70633	0.09133	1.21166	1.00433
SEM	0.003756	0.00145	0.00348	0.00291	0.00145	0.00463	0.00203

Table 3: Mean concentration and range of heavy metal concentration (ppm) in soil samples.

Location	Chromium (Cr)	Cadmium (Cd)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Mercury (Hg)	Arsenic (As)
Ibodi	2.298±0.007	1.142±0.002	0.079±0.001	0.096±0.002	0.228±0.004	1.154±0.002	1.225±0.002
Fadugba	1.199±0.004	1.141±0.002	3.096±0.003	1.515±0.002	1.131±0.002	0.064±0.002	0.055±0.002
Gbodo-araromi	0.084±0.002	1.832±0.002	0.215±0.002	1.425±0.002	0.075±0.002	0.036±0.001	0.095±0.002
Itagunmodi	2.711±0.005	0.085±0.001	0.235±0.002	0.105±0.002	0.134±0.002	0.104±0.002	1.366±0.001
Igila	1.278±0.003	0.091±0.001	1.522±0.003	1.706±0.002	0.0913±0.001	1.211±0.004	1.004±0.002
Permissible limit (WHO)	50.0	1.0	50.0	50.0	150.0	0.5	10.0

Table 4: Table of Contamination Factor and pollution load index

Location	Chromium (Cr)	Cadmium (Cd)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Mercury (Hg)	Arsenic (As)	PLI
Ibodi	0.046	1.142	0.0016	0.0019	0.0015	2.308	0.1225	0.0353
Fadugba	0.0239	1.141	0.061	0.0303	0.0075	0.128	0.0055	0.0429
Gbodo-araromi	0.0017	1.832	0.0043	0.0285	0.0005	0.072	0.0095	0.0145
Itagunmodi	0.054	0.085	0.0047	0.0021	0.0008	0.208	0.1366	0.0194
Igila	0.02556	0.091	0.0304	0.0341	0.0018	2.422	0.1004	0.0523

From results Table 2 and 3; heavy metal was detected in all the sample site, Chromium (Cr) highest concentration was observed in Itagunmodi (2.711±0.005ppm) and lowest value was observed in Gbodo - Araromi (0.084±0.002ppm), Cadmium (Cd) recorded lowest concentration in Itagunmodi (0.085±0.001) and highest in in Gbodo - Araromi (1.832±0.002ppm) which is a little bit above permissible limit, Fadugba recoded highest concentration of copper (3.036±0.003ppm) while Ibodi recorded lowest (0.079±0.001ppm), highest concentration of lead (Pb) was observed in Igila (1.706±0.002ppm) and lowest concentration was observed in Ibodi (0.096±0.002ppm), lowest concentration of Zinc (Zn) observed Gbodo - Araromi (0.075±0.002ppm), highest concentration of Arsenic was observed in Itagunmodi (1.366±0.001ppm) and lowest. All of these are within limits and pose little risk, except for mercury. Mercury (Hg) concentrations in Igila (1.211±0.004 ppm) and Ibodi (1.154±0.002 ppm) were recorded as the highest, exceeding the WHO permissible limit. The lowest mercury concentration was observed in Gbodo-Araromi (0.036±0.001 ppm), as reported by Odukoya et al.

(2021). These findings indicate a significant concentration of mercury in these areas, which may pose a serious health risk to both humans and other aquatic animals due to the high level of Hg in the environment.

The variation observed in heavy metal concentrations in these villages can also be attributed to natural and other anthropogenic activities. Basically, rocks, soils, and water contain heavy metals that are elements of the earth's crust. Heavy metals can be introduced into the environment through erosion, soil leaching, biological processes, surface winds, volcanic activities, and other natural geological processes; all of which contribute to the concentration of heavy metals in those villages. (Ali et al., 2019; Jomova et al., 2024)

In Table 4, the contamination factor clearly shows that Gbodo-araromi, Fadugba, and Ibodi are contaminated with cadmium, while Ibodi and Igila are contaminated with mercury. The overall assessment of pollution was based on the pollution load index. The PLI value was well below 1, indicating a low pollution index. However, the presence of mercury and cadmium above the recommended limit poses a serious health risk to communities and their environs, and the State Government must urgently respond to clean up the environment. The high concentration of mercury observed in Ibodi and Igila may be related to their use for gold mining and the extraction of their ore. Mercury can be released into the environment from gold amalgamation and tailings processing. Mercury is a highly toxic element and can affect human health via inhalation, ingestion, or dermal absorption. (Odukoya *et al.,* 2021).

Mitigation and management of heavy metal pollution require a combination of prevention, treatment, and remediation strategies to remove or minimize the risk to humans, the environment, and ecosystems.

i. Prevention strategies like effective waste management, proper waste disposal, and control should be encouraged. This will help minimize the risk of heavy metal pollution.
ii. Chemical methods; strategies such as ion-exchange, adsorption, chemical immobilization, and precipitation methods can be used to remove heavy metal pollution in the affected area.

4.0. Conclusions

The results from the analyzed samples indicate moderate heavy metal pollution in some of the studied soil samples, especially mercury, at Igila and Ibodi. This study analysed the concentrations of seven heavy metals in five gold-mining villages in Atakumosa West Local Government: Cr, Cd, Cu, Pb, Zn, Hg, and As. The findings revealed that the concentrations of these elements in the samples varied. Mercury and cadmium concentrations were above the WHO-recommended threshold of 0.5 and 1.0 mg/kg, respectively. The high concentration of these metals can cause significant health problems such as cancer, skin irritation, respiratory problems, and organ damage. This study confirms that artisanal gold mining contributes to soil contamination and pollution; it should be discouraged due to adverse consequences for health, the environment, and ecosystems.

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