# EVALUATION OF THE IMPACT OF GOLD MINING ON THE SOIL OF ALAGBEDE DABA COMMUNITY MORO LOCAL GOVERNMENT AREA, KWARA STATE

BY


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## CERTIFICATION

This is to certify this project was carried out by **TOHEEB ALADE AJAGBE (HND/23/MNE/FT/0034)** and submitted to the Department of Mineral and Petroleum Resources Engineering Technology, Institute of Technology, Kwara State Polytechnic, Ilorin in partial fulfillment of the requirements for the award of Higher National Diploma (HND) in Mining Engineering Technology.

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## DEDICATION

This research work is dedicated to the glory of Almighty Allah, AJAGBE TOHEEB ALADE and Mr. Odediran Olatunbosun Ayorinde

## ACKNOWLEDGMENTS

I give glory and gratitude to Almighty Allah, while I also wish to express my sincere appreciation to my supervisor, Mr. Odediran O.A, whose guidance, constructive criticism, and constant support made this research a reality. Your time, effort, and encouragement are deeply appreciated.

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## ABSTRACT

*This study investigated the impact of gold mining activities on soil quality in Alagbede Daba by analyzing selected heavy metals and physico-chemical parameters. Soil samples were collected from ten different locations within the mining site and subjected to laboratory analysis using Atomic Absorption Spectrophotometry (AAS) for heavy metals such as cadmium (Cd), chromium (Cr), nickel (Ni), lead ($Pb^{2+}$), and manganese ($Mn^{2+}$). Physico-chemical properties including pH, soil temperature, electrical conductivity (EC), and total dissolved solids (TDS) were also measured.The results revealed varying concentrations of heavy metals across the sample sites. Cadmium levels in some samples exceeded the WHO permissible limit of 0.3 mg/kg, while nickel concentrations were elevated in several locations but remained below international thresholds. Lead levels were consistently low, suggesting limited contamination from this metal. The pH of the soil samples ranged from slightly acidic to neutral, with some locations showing acidity likely influenced by mining residues. Elevated EC and TDS values in specific sites indicated increased ionic content, possibly from ore processing and tailings runoff.Overall, the findings demonstrated that artisanal gold mining had negatively affected the soil quality in the study area. The presence of elevated heavy metal concentrations and altered soil properties highlighted the need for continuous environmental monitoring, regulation of mining practices, and the implementation of soil remediation strategies to mitigate ecological and human health risks.*

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# CHAPTER ONE

## 1.0 Introduction

### 1.1 Location and Accessibility

Alagbede Daba is a rural settlement found in the Moro Local Government Area of Kwara State, Nigeria. The village lies roughly 25 kilometers northwest of Malete—a town that is home to Kwara State University—and is approximately 60 kilometers from Ilorin, the state capital. The most common access route is through Ilorin-Shao-Malete to Alagbede Daba, and the journey typically takes between one to two hours, depending on road conditions. Geographically, the community is positioned at a coordinate of Longitude 4.520120E and Latitude 8.886579°N, standing at an average elevation of about 260 meters (853 feet) above sea level. Because of the area's rural setting, public transport is often scarce; therefore, personal vehicles are highly recommended, particularly in the rainy season when the roads can become difficult to navigate.

### 1.2 Climate and Vegetation

The area falls under the tropical savanna climatic zone, which is marked by alternating rainy and dry seasons. This pattern of rainfall significantly affects the land, especially when mining operations remove the natural plant cover. The vegetation in Kwara State is mainly guinea savanna, characterized by tall grasses and sparsely distributed trees. These plant species play an important role in shielding the soil from erosion and in maintaining moisture and nutrient balance. When such vegetation is cleared for gold mining, the land becomes prone to degradation, erosion, and reduced fertility.

Hence, climate and vegetation are critical to understanding the environmental impact of gold mining, as they influence both the extent of soil damage and the capacity of the land to regenerate (Oladele, 2023). Average daytime temperatures range from 30°C to 35°C, while nighttime temperatures drop to between 18°C and 22°C. The hottest months span from March to May, while December and January tend to be the coolest due to the harmattan season. Humidity levels typically remain moderate, with abundant sunshine, particularly in the dry season.

### 1.3 Relief and Drainage

The topography and drainage characteristics of Alagbede Daba significantly influence the effects of mining activities on soil stability and quality. The landscape is generally gently rolling with occasional hills and shallow valleys, which affect how water flows across the surface. These slopes can intensify erosion when the land is disturbed, especially during heavy rainfall. The act of removing vegetation and the top layer of soil for mining purposes often results in rapid runoff and the erosion of nutrient-rich soil layers, sometimes forming gullies.

The area is drained mainly by seasonal streams and minor tributaries that are active only during the wet season. These water channels are particularly vulnerable to pollution and sediment deposits from poorly managed mining waste. Without effective drainage systems, areas near mining sites may suffer from waterlogging or severe erosion, both of which degrade the soil. Moreover, excavation and mining pits often interfere with the natural flow of water, disrupting the ecological balance and reducing the soil's capacity to hold moisture and nutrients.

## 1.4 Aim and Objectives

The primary goal of this research is to assess how gold mining activities have influenced soil characteristics in Alagbede Daba, a community in the Moro Local Government Area of Kwara State.

The specific objectives of the study are to:

i. determine the concentrations of heavy metals and other environmental contaminants within the soil.
ii. determine if the impact of pollutants on humans and the environment.

## 1.5 Statement of the Problem

In recent times, gold mining operations have expanded rapidly in Alagbede Daba, bringing about growing environmental concerns, especially in relation to soil quality and land degradation. Activities such as vegetation clearing, soil excavation, and the poor handling of mining waste have triggered soil erosion, loss of fertility, and contamination from hazardous substances including heavy metals.

This research seeks to offer vital scientific data to inform both the local community and relevant authorities about the present soil condition and the likely long-term consequences if these mining activities persist without regulation. By clarifying the link between mining operations and soil deterioration, the findings can support the development of effective interventions—such as adopting improved mining methods, promoting waste control, restoring damaged land, and implementing tree planting initiatives. Additionally, the outcomes can serve as a basis for enforcing environmental protection laws, supporting better land-use planning, and enhancing sustainable livelihoods for affected residents, particularly those dependent on farming and natural water sources.

Overall, this study aims to provide a balanced approach to reconciling the economic benefits of gold mining with environmental preservation and community health.

## 1.6 Justification

Gold mining has emerged as a major source of income and employment for residents of Alagbede Daba. However, concerns are rising about its detrimental effects on soil health and land usability. Soil is a critical natural resource in the area, supporting agriculture, vegetation growth, and water retention. Negative consequences of mining such as soil erosion, nutrient depletion, contamination by heavy metals, and disruption of natural drainage pose threats to food production, environmental integrity, and public health.

Because of the unique environmental characteristics of the community, the effects of mining could be more pronounced compared to other regions, making a detailed investigation both timely and necessary. This study is therefore significant as it will generate empirical data on the extent of soil degradation due to mining. It will also raise awareness among both locals and policymakers about the environmental dangers of unregulated mining, promote the formulation of sustainable land-use practices, and contribute to better environmental stewardship in Alagbede Daba.

## 1.7 Scope and Limitations

This study is concentrated on the effects of gold mining on soil quality within Alagbede Daba community in Moro Local Government Area, Kwara State. The research encompasses field visits, soil sampling, laboratory testing, and interactions with local residents to gather relevant data in the selected study zone.

While the study aims to provide meaningful insights, it is subject to several limitations:

- **Dependence on Local Testimonies:** Some of the information was gathered through oral interviews, which may reflect personal opinions rather than verifiable facts.
- **Access and Safety Issues:** Certain mining sites were challenging or unsafe to reach due to active operations, rough terrain, or security risks.
- **Time Constraints:** The duration allocated for conducting this research was limited, affecting the depth and breadth of data collection and analysis.
- **Geographical Limitation:** The study only covers a specific portion of the community, which may affect how applicable the findings are to the broader region.
- **Resource Limitations:** The research was constrained by limited funding, manpower, equipment, and materials, which is often a challenge in rural environmental studies.

## CHAPTER TWO

## 2.0 Literature Review

### 2.1 Overview of Gold Mining

Gold mining is the process through which gold is extracted from the earth's crust, either through surface mining or underground operations. It has historically been a major contributor to economic growth in many regions, particularly in countries rich in mineral resources. The extraction methods used in gold mining vary depending on the geological features of the area, the mining scale, and available technology. Regardless of the method, the core objective is to separate gold from the surrounding material through physical, chemical, or manual techniques.

Gold mining operations generally fall into two categories: industrial-scale miningand artisanal and small-scale gold mining (ASGM)**.** Large-scale mining is typically conducted by well-capitalized companies that utilize advanced machinery and are subject to regulatory oversight. These operations aim to minimize environmental harm through modern methods and compliance with environmental standards.

On the other hand, ASGM is more widespread in developing nations and is often practiced informally using simple tools and outdated techniques. In countries like Nigeria, Ghana, and Burkina Faso, ASGM is a primary livelihood for many rural communities (Adebayo *et al.,* 2021). In Nigeria specifically, ASGM is prevalent in areas where gold deposits are near the surface. Despite its economic benefits, this form of mining is commonly unregulated and can cause severe environmental degradation, especially affecting soil quality and the general landscape (Ibrahim and Lawal, 2020).

Gold mining, particularly when done without adequate safeguards, can disturb soil composition, reduce fertility, and introduce harmful substances such as mercury or cyanide into the soil. These changes disrupt the soil's pH balance and lead to long-lasting environmental and health problems (Ogunleye *et al.,* 2019).

#### 2.1.1 Meaning and Categories of Gold Mining

Gold mining refers to the activities undertaken to extract gold-bearing minerals from the earth using a combination of mechanical, chemical, and physical processes. It begins with identifying gold-rich sites, followed by removal of top layers (overburden) and subsequent processing to isolate the gold. Depending on the deposit's nature—whether found in riverbeds, alluvial zones, or hard rock formations—different techniques are applied (Aliyu *et al.,* 2020).

Gold mining is broadly divided into:

- **Industrial (Large-Scale) Mining**, and
- **Artisanal and Small-Scale Gold Mining (ASGM).**

### 2.1.2 Industrial (Large-Scale) Gold Mining

This form of mining requires substantial capital investment, high-tech equipment, and skilled labor. Usually undertaken by international or corporate entities, it involves systematic exploration, drilling, and extraction, often with government-issued licenses. These operations are generally expected to follow environmental laws, which include waste treatment, land reclamation, and pollution control (Adebayo *et al.,* 2021).

### 2.1.3 Artisanal and Small-Scale Gold Mining (ASGM)

ASGM is carried out by individuals or small groups using traditional and manual tools. It has become increasingly popular in less-developed economies due to its low startup cost and the immediate income it provides. However, most ASGM activities are conducted without proper regulation, which raises concerns about worker safety and environmental degradation. Techniques like manual panning and mercury amalgamation are commonly used, which release harmful chemicals into the soil and surrounding ecosystems (Eze and Akinola, 2019).

In West Africa, illegal or informal mining—often called “galamsey” or “illegal gold rush”—is a major issue. Although similar to ASGM, these operations typically violate mining and environmental laws, causing erosion, toxic runoff, and land degradation (Okafor and Bello, 2022).

Understanding both legal and illegal forms of gold mining is key to evaluating their environmental effects. While regulated industrial mining offers some control, unregulated ASGM remains a significant source of soil degradation and pollution in Nigeria and beyond.

## 2.2 Artisanal Gold Mining in Nigeria

ASGM is common in Nigeria, particularly in gold-bearing states such as Zamfara, Kebbi, Osun, and Niger. In these areas, many residents turn to gold mining as a viable alternative to farming or other low-income occupations (Adebayo *et al.,* 2021). The informal nature of ASGM makes it difficult to regulate, leading to widespread use of mercury for gold extraction. This process, while effective and affordable, produces toxic vapors and contaminates the environment.

Aside from mercury, ASGM often leads to the destruction of soil structure due to constant digging and washing. Heavy metals like lead (Pb), cadmium (Cd), and nickel (Ni) are frequently introduced into the soil, which not only affects agricultural productivity but also poses long-term health risks to humans and animals (Aliyu *et al.,* 2020).

### 2.3 Methods and Practices in Gold Mining

Gold mining comprises a series of processes tailored to extract gold from mineral deposits. The techniques used differ based on whether the gold is found in surface alluvial deposits or deeper rock layers, as well as whether the operation is industrial or artisanal in scale.

In industrial mining, the process begins with exploration and site development. This is followed by the removal of ore through open-pit or underground mining methods. Open-pit mining, which involves stripping large amounts of surface rock and soil, is suitable for shallow deposits but causes extensive environmental disruption (Aliyu *et al.,* 2020). Underground mining is preferred for deeper veins and generally causes less surface damage but is costlier and more technically demanding.

After extraction, the ore is crushed and ground (comminution) into fine particles. Chemical processing then follows, typically using cyanide leaching. In this method, cyanide dissolves the gold from the ore, and the gold is recovered from the solution. While efficient, this method poses serious environmental risks if the cyanide is not carefully managed (Okafor and Bello, 2022).

In contrast, artisanal mining follows a more manual approach. Miners dig and crush ore by hand, then separate gold using panning, sluicing, or mercury amalgamation. The latter is the most common in ASGM due to its low cost. Miners mix mercury with the crushed ore, forming an amalgam that is heated to release mercury vapor, leaving behind gold. This method is highly dangerous to human health and contributes to mercury accumulation in ecosystems (Eze and Akinola, 2019).

Dry-washing is another technique used in drier regions. Here, miners use air and mechanical vibrations to separate gold from the soil. While it conserves water, it is often inefficient and accelerates land degradation when used excessively.

A serious concern across both large-scale and ASGM operations is the mismanagement of mine tailings—the waste material left after gold has been extracted. These tailings often contain cyanide, mercury, and heavy metals, which can leak into surrounding soil and groundwater, leading to severe ecological damage over time (Adebayo *et al.,* 2021).

## 2.4 Environmental Consequences of Gold Mining

Though gold mining provides significant economic benefits, it also brings numerous environmental challenges—many of which can be quite harmful, especially when carried out without appropriate oversight or ecological protections. Key negative outcomes include land degradation, water pollution, deforestation, biodiversity loss, and air contamination. These impacts are most evident in regions where artisanal and small-scale gold mining (ASGM) is widespread and typically unregulated, lacking any formal environmental controls (Okafor and Bello, 2022).

Among the most severe consequences is soil degradation and pollution. Mining operations frequently strip away vegetation and the upper layers of soil, leaving the ground exposed and prone to erosion. Hazardous chemicals like mercury and cyanide, commonly used during gold processing, further deteriorate soil quality. When these substances are mishandled or dumped improperly, they seep into the soil and introduce toxic heavy metals such as lead (Pb), cadmium (Cd), and arsenic (As), which not only harm plant life but can linger in the environment for many years (Adebayo *et al.*, 2021).

Water contamination is another pressing concern. During mining—whether large-scale or artisanal—wastewater from ore washing and chemical treatment is often released untreated into nearby rivers and streams. This results in mercury, cyanide, and other pollutants entering both surface and underground water sources, leading to ecological damage, unsafe drinking water, and public health risks via food chain contamination (Aliyu *et al.,* 2020).

Forest clearing and habitat loss are also common in gold mining zones. Vast stretches of woodland are removed to access gold deposits, especially in tropical climates. This not only leads to tree loss but also disrupts wildlife habitats and natural ecosystems. In parts of Nigeria, mining has been directly associated with deforestation and the destruction of farmland, reducing local food production (Ibrahim and Lawal, 2020).

Air quality also suffers due to mining. In small-scale mining, the burning of mercury emits toxic vapors into the atmosphere, which can travel over long distances and later settle into ecosystems where they are converted to methylmercury, a harmful neurotoxin that builds up in aquatic life and eventually in humans. Similarly, dust generated from blasting and excavation machinery affects the respiratory health of nearby populations (Eze and Akinola, 2019).

Beyond immediate environmental damage, mining contributes to global warming by releasing greenhouse gases during land clearing and machine operations. The disruption of vegetation and soil also disturbs the natural carbon storage of the land, further accelerating climate change (Olowu *et al.,* 2021).

Moreover, gold mining poses substantial threats to the environment, especially when not properly managed. While it provides livelihood opportunities, its environmental toll—especially regarding land and water quality—must be tackled through sustainable practices and effective regulation to safeguard affected communities.

### 2.4.1 Effects on Soil Quality

Soil plays a crucial role in supporting agriculture, maintaining ecological balance, and filtering water. Unfortunately, gold mining—particularly when conducted with inadequate environmental practices—seriously damages soil health. Both industrial-scale and informal mining lead to various forms of soil degradation that negatively impact the land's productivity, public well-being, and environmental stability.

A primary concern is the buildup of harmful heavy metals in the soil. Chemicals like mercury, lead, cadmium, and chromium used in gold extraction contaminate surrounding lands. As these toxins accumulate, they alter the soil's natural chemistry, reduce its fertility, and pose risks to human and animal health. In parts of Nigeria, researchers have recorded dangerously high levels of cadmium and lead in soils near mining areas, making them unfit for cultivation (Adebayo *et al.,* 2021; Aliyu *et al.,* 2020).

Physical degradation is another issue. The repeated use of heavy equipment, excavation, and digging compacts the soil, limiting air and water flow. This depletes the land's capacity to support vegetation. In small-scale mining, the constant washing of ore further removes nutrients and organic material, leaving the soil barren and prone to erosion (Okafor and Bello, 2022).

Moreover, topsoil—rich in nutrients and crucial for plant growth—is often stripped away during mining. The exposed subsoil is typically less fertile and more susceptible to erosion and runoff. These conditions not only hinder farming but also increase the likelihood of contaminants reaching nearby water sources (Eze and Akinola, 2019).

One long-term concern is that soil contamination tends to persist. Unlike pollutants in water, which may be diluted or washed away over time, toxins in the soil can remain in place for decades unless remedial action is taken. This ongoing contamination threatens future land use, food security, and the overall health of communities living in mining regions (Ibrahim and Lawal, 2020).

By and large, the degradation of soil due to gold mining is extensive, affecting agriculture, ecosystems, and human health. Addressing these problems calls for stronger regulation, public awareness campaigns, and restoration projects to recover damaged lands.

### 2.4.2 Effects on Water Resources

Gold mining poses a serious threat to water systems, especially in regions where environmental control is lacking. Water bodies near mining activities are frequently polluted with runoff carrying toxic chemicals, heavy metals, and sediments from extraction processes. These pollutants contaminate rivers, streams, and underground water, endangering ecosystems and the health of surrounding communities (Okafor and Bello, 2022).

In small-scale mining, mercury is a commonly used substance for extracting gold. However, mercury often finds its way into rivers and lakes, where it eventually transforms into methylmercury—a dangerous compound that accumulates in fish and enters human diets, causing neurological damage and developmental issues (Eze and Akinola, 2019).

Large-scale operations contribute as well, particularly through the use of cyanide in processing. While effective at isolating gold, cyanide is lethal to aquatic organisms. Accidents such as tailings dam failures can release large quantities of polluted water, triggering widespread ecological harm (Aliyu *et al.,* 2020).

Another impact is sedimentation. Mining disturbs the land and removes vegetation, which causes loose soil to be washed into rivers during rainfall. This increases water cloudiness (turbidity), limits sunlight reaching aquatic plants, disrupts fish habitats, and can even shorten the life of dams and reservoirs due to the buildup of silt (Ibrahim and Lawal, 2020).

Additionally, mining operations consume vast amounts of water—for cooling, processing, and dust control—which places pressure on already scarce water supplies. This can reduce water availability for farming, drinking, and industrial use, especially in arid or semi-arid regions (Adebayo *et al.,* 2021).

In essence, gold mining significantly degrades water quality and availability. Mitigating these impacts demands strict regulation, improved waste management practices, and the promotion of environmentally friendly mining alternatives.

## 2.5 Soil Contamination and the Presence of Heavy Metals

The contamination of soil resulting from mining operations represents a serious ecological challenge, especially in areas where gold extraction—particularly through artisanal and small-scale mining (ASM)—is widespread. When soils are polluted, their structural integrity and biochemical functions are disrupted, leading to long-term damage to ecosystems and a decline in agricultural viability. A major factor contributing to soil degradation in mining environments is the introduction of heavy metals—metallic elements characterized by their high density and toxicity even at trace levels. These contaminants are typically released into the soil through activities such as ore crushing, processing, and the improper disposal of tailings. Unlike organic waste, heavy metals do not decompose, meaning they accumulate and remain in the soil for extended periods, posing hazards to flora, fauna, and human populations (Adebayo *et al.,* 2021). The problem is particularly acute in developing nations, where informal mining practices are common, and environmental oversight is minimal. In such regions, the lack of waste management practices and the use of hazardous substances like mercury and cyanide lead to the leaching of dangerous metals into surrounding soils (Okafor and Bello, 2022). Over time, these pollutants not only alter soil biochemistry and harm beneficial microorganisms but also bioaccumulate in crops, creating food safety risks for nearby communities (Aliyu *et al.,* 2020). As such, a comprehensive understanding of heavy metal dynamics in soils is essential for gauging the environmental footprint of gold mining and guiding appropriate remediation strategies.

### 2.5.1 Definition and Traits of Heavy Metals

Heavy metals are naturally occurring metallic elements that possess high atomic masses and densities, typically at least five times that of water. While some—like iron (Fe), zinc (Zn), and copper (Cu)—are beneficial in small doses for biological functions, others such as cadmium (Cd), lead (Pb), chromium (Cr), nickel (Ni), and manganese (Mn) can become hazardous even in minimal quantities (Okafor and Bello, 2022).

Their danger lies in their environmental persistence. These elements do not undergo natural degradation and can remain in the environment indefinitely. Once deposited into the soil, their mobility and bioavailability are influenced by environmental factors such as pH, soil composition, and organic matter content. Due to these characteristics, heavy metals are readily absorbed by plant roots, making their way into food systems and potentially harming both wildlife and human health (Eze and Akinola, 2019).

### 2.5.2 Predominant Heavy Metals Found in Mining Areas (Cd, Cr, Ni, Pb, Mn)

Soils in and around gold mining sites are frequently contaminated with specific heavy metals due to the composition of the ores and the methods used in extraction:

- **Cadmium (Cd):** Commonly found with zinc-containing ores, cadmium is highly toxic and accumulates in the soil through mining byproducts. It disrupts microbial ecosystems and poses risks to human renal and skeletal health.
- **Chromium (Cr):** Found in certain rock types, chromium can exist in trivalent [Cr(III)] or hexavalent [Cr(VI)] forms, the latter being particularly toxic and carcinogenic. Mining processes tend to elevate Cr(VI) concentrations.
- **Nickel (Ni):** Although present naturally, nickel levels spike near mining zones. High concentrations inhibit root development and impact soil microbial populations.
- **Lead (Pb):** Lead, often introduced during smelting, is a long-lasting pollutant affecting both soil functionality and human neurological health, especially in children.
- **Manganese (Mn):** Though vital in small quantities, high levels from runoff can unbalance soil chemistry and reduce crop yields (Aliyu et al., 2020; Adebayo *et al.,* 2021).

### 2.5.3 Impacts of Heavy Metals on Soil and Human Health

The intrusion of heavy metals into soil systems disrupts multiple soil functions. One of the foremost impacts is the decline in soil fertility, as these metals interfere with the nutrient absorption capabilities of plants and reduce microbial activity essential for organic matter breakdown (Ibrahim and Lawal, 2020).

Crops grown on contaminated land often exhibit poor growth, leaf discoloration, or may fail to sprout. Even more alarming is their tendency to absorb metals, which then enter the human food chain and contribute to serious health complications (Adebayo *et al.,* 2021).

Prolonged exposure to polluted soils also affects biodiversity. Beneficial organisms such as earthworms and nitrogen-fixing bacteria are especially sensitive to toxic environments. Their absence further degrades the soil's structural and biological health. Given the enduring nature of heavy metals, these effects can last decades without targeted remediation (Okafor and Bello, 2022).

## 2.6 Review of Empirical Studies

Numerous studies have examined the influence of gold mining on soil contamination, particularly focusing on the accumulation of heavy metals. For example, Musa and Idris (2020) studied heavy metal levels in soils from artisanal mining communities in Zamfara State, Nigeria. Using a random sampling approach, they collected ten samples from five locations and analyzed them using the Aqua Regia digestion technique and Atomic Absorption Spectrometry (AAS). Results showed elevated levels of cadmium, lead, and nickel that surpassed WHO and FAO safety thresholds. Their findings emphasized the need for stronger mining regulations and soil rehabilitation efforts—relevant to this current research in terms of methodology and thematic alignment.

Another notable investigation by Boateng and Mensah (2019) in Tarkwa, Ghana, employed a mixed-method design combining geochemical testing with stakeholder interviews. Using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), they analyzed twenty soil samples and found significantly elevated levels of chromium, cadmium, and lead in mining zones compared to control areas. The study also observed pH changes, suggesting a decline in soil quality and fertility. Their conclusion warned of the health and agricultural implications of small-scale mining and called for better environmental management—reinforcing the findings applicable to this present study.

In Ilesha, Nigeria, Adebayo and Ojo (2021) carried out research to evaluate the environmental effects of gold mining on local soils and vegetation. Employing stratified sampling, they gathered thirty samples from mining and non-mining zones. Analytical results showed higher concentrations of heavy metals in mining areas, while t-test results confirmed significant differences between the zones. The study also observed a decline in biodiversity and emphasized the importance of public sensitization and ecological restoration—insights that closely inform the current study.

Likewise, Okoth and Wanjiku (2022) explored how heavy metal concentrations varied spatially in soils surrounding gold mining locations in Western Kenya. Fifteen samples were collected from different mining points and analyzed after nitric-perchloric acid digestion. Their geospatial mapping revealed that lead and manganese were concentrated around processing sites and declined with distance. Their use of spatial analysis tools provides a model for interpreting the spread of contamination—a useful approach mirrored in the present research.

Finally, Lawal and Shuaib (2023) conducted a comparative study in Osun State, Nigeria, to analyze differences in metal levels between soils from mining and non-mining areas. Through cluster sampling and the application of ANOVA, they confirmed significant disparities in cadmium and lead levels. The researchers advocated for soil enhancement practices and stronger environmental oversight. This research aligns with current efforts to understand and mitigate the environmental impact of mining activities.

Moreover, these empirical works collectively demonstrate a consistent pattern of soil pollution in mining environments. Most utilized advanced analytical methods like AAS and ICP-MS, and uniformly highlighted cadmium, lead, chromium, nickel, and manganese as key pollutants.

# CHAPTER THREE

## 3.0 Research Methodology

### 3.1 Soil Analysis Approaches in Mining Impact Research

To accurately evaluate the environmental effects of mining, especially concerning heavy metal contamination, precise soil analysis is crucial. In environmental research related to mining, a combination of scientific techniques is employed to assess the chemical makeup of soils, determine contamination severity, and evaluate potential ecological risks. The standard procedure generally includes systematic sampling, chemical digestion of soil samples, and instrumental analysis using technologies such as Atomic Absorption Spectrophotometry (AAS) for heavy metal quantification (Aliyu *et al.,* 2020; Okafor and Bello, 2022).

### 3.2 Soil Sampling and Sample Preparation

Reliable soil data begins with careful and methodical sample collection. In mining environments, it is common to gather soil samples from multiple locations and at different depths to ensure a representative assessment of contamination levels across the study area.

After collection, the samples are allowed to air-dry at ambient temperature, preserving their chemical properties. Once dry, the samples are sieved—typically through a 2mm mesh—to remove coarse materials like stones and roots, ensuring homogeneity. This preparation step is vital to allow for consistent digestion and accurate spectrometric analysis (Eze and Akinola, 2019).

Throughout the process, it is essential to label samples correctly and store them in clean, contamination-free containers. These precautions help maintain sample quality and integrity ahead of laboratory testing (Adebayo *et al.,* 2021).

### 3.3 Digestion Using Aqua Regia Solution

Aqua Regia digestion is a standard procedure for liberating heavy metals from soil particles prior to instrumental analysis. Aqua Regia is a potent mixture of concentrated hydrochloric acid (HCl) and nitric acid ($HNO_3$), typically mixed in a 3:1 volume ratio. This combination is highly effective in breaking down soil matrices and dissolving most metal elements.

During digestion, approximately one gram of the sieved soil sample is placed in a digestion vessel. The Aqua Regia is added, and the mixture is gently heated until brown nitrogen oxide fumes subside—signaling the breakdown of organic material and the release of heavy metals into solution. Once the reaction is complete and cooled, the mixture is diluted with distilled water, filtered, and then prepared for further analysis (Ibrahim and Lawal, 2020).

Although Aqua Regia does not dissolve silicate-bound metals completely, it remains widely accepted in environmental soil studies for its efficiency, cost-effectiveness, and ease of use (Okafor and Bello, 2022).

### 3.4 Measurement with Atomic Absorption Spectrophotometry (AAS)

Atomic Absorption Spectrophotometry (AAS) is a widely used analytical technique for measuring trace concentrations of metals in digested soil solutions. Following digestion, the resulting liquid samples are analyzed using AAS, which operates on the principle that atoms absorb light at characteristic wavelengths.

In this method, the sample is first atomized in a flame or furnace, and a beam of light is passed through the atomized vapor. Each metal absorbs light at a specific wavelength, and the degree of absorption indicates the amount of that metal present in the sample (Aliyu *et al.,* 2020).

AAS is especially suitable for analyzing elements such as cadmium (Cd), lead (Pb), chromium (Cr), nickel (Ni), and manganese (Mn), due to its high sensitivity and precision. It is the preferred tool in studies assessing heavy metal contamination in soils near mining operations (Adebayo *et al.,* 2021).

**Table 1: Soil Sample Locations**

| **Location** | **Longitude** | **Latitude** | **Remarks** |
|---|---|---|---|
| L1 | 4°41′02.1″ E | 7°28′31.2″ N | Well water |

| | | | |
|---|---|---|---|
| L2 | 4°29′42.3″ E | 8°52′31.0″ N | Borehole water |
| L3 | 4°29′41.7″ E | 8°52′26.1″ N | Stream water |
| L4 | 4°29′32.5″ E | 8°52′24.5″ N | Stream water |
| L5 | 4°28′27.2″ E | 8°52′22.0″ N | Stream water |
| L6 | 4°28′21.4″ E | 8°51′20.2″ N | Stream water |
| L7 | 4°28′17.8″ E | 8°52′19.1″ N | Stream water |
| L8 | 4°28′10.2″ E | 8°52′15.8″ N | Stream water |
| L9 | 4°28′09.1″ E | 8°53′14.1″ N | Stream water |
| L10 | 4°28′07.5″ E | 8°53′15.0″ N | Stream water |

### 3.5 Field Operations

The fieldwork was primarily centered on the collection of soil samples. A total of ten samples were obtained from both suspected contaminated sites and uncontaminated (control) areas. These samples were gathered at depths ranging from 3 to 6 cm to evaluate how contaminants are distributed vertically within the soil profile. During the field investigation, several on-site physico-chemical parameters were measured, including soil temperature and electrical conductivity. Additionally, certain properties such as pH, temperature, conductivity, and total dissolved solids (TDS) were evaluated prior to sample collection to better understand the baseline conditions of the sampling areas.

### 3.6 Laboratory Analysis

The ten collected soil samples were transferred to the laboratory in properly sealed and labeled containers, numbered from 1 to 10 for easy identification. These samples were analyzed for heavy metals and key elemental components using Atomic Absorption Spectrophotometry (AAS), a reliable technique for determining trace metal concentrations in environmental samples.

#### 3.6.1 Procedure for Atomic Absorption Spectrophotometry in Analyzing Heavy Metal Content (e.g., Pb, Cd, Hg, Zn, Mn)

**Sample Collection and Preparation**

Soil samples were carefully collected from selected locations suspected of heavy metal contamination due to mining or industrial activities. Stainless-steel augers were used to obtain surface samples (0–15 cm depth) and minimize contamination. Each sample was stored in a clean, labeled polyethylene bag and transported to the laboratory under controlled conditions to preserve integrity.

In the laboratory, the soil samples were air-dried at ambient temperature to remove excess moisture that could interfere with digestion. After drying, the samples were manually ground using a mortar and pestle to break down aggregates and improve homogeneity. The powdered soil was then sieved using a 2 mm mesh to eliminate stones, roots, and debris. Proper homogenization ensured that the subsample taken for analysis represented the bulk sample accurately.

**Digestion of Soil Samples**

To release heavy metals from the soil matrix into solution form for analysis, a digestion process was conducted. Approximately 1–2 grams of each dried and sieved soil sample was weighed and placed into a clean digestion flask. A mixture of concentrated nitric acid ($HNO_3$) and perchloric acid ($HClO_4$) in appropriate volumes, or alternatively Aqua Regia ($HCl:HNO_3$ in a 3:1 ratio), was added to each flask. This strong acid combination was selected to effectively break down the organic and inorganic components binding the metals in the soil.

The digestion flasks were heated gently on a hot plate within a fume hood to avoid exposure to toxic fumes. The heating continued until the mixture turned clear or pale yellow, indicating complete digestion. After cooling, each solution was filtered using Whatman No. 42 filter paper into a clean 50 mL volumetric flask and made up to the mark with deionized water. This filtered solution contained the heavy metals in ionic form, ready for quantitative analysis using the spectrophotometer.

**Instrument Calibration**

Before analyzing the digested samples, the Atomic Absorption Spectrophotometer (AAS) was calibrated to ensure accuracy and reliability of measurements. Calibration was carried out using a series of standard solutions with known concentrations for each heavy metal of interest (Pb, Cd, Hg, Zn, and Mn). These standards were prepared by diluting certified stock solutions and used to generate calibration curves.

For each metal, the specific analytical wavelength was selected on the AAS—for instance, 283.3 nm for lead (Pb), 228.8 nm for cadmium (Cd), 253.7 nm for mercury (Hg), 213.9 nm for zinc (Zn), and 279.5 nm for manganese (Mn). The absorbance readings of the standards were recorded, and a linear relationship between absorbance and concentration was established. A blank solution (acid and water only) was also run to correct for background absorbance. Only after the calibration curve showed strong linearity (with a correlation coefficient, $R^2$, near 1.0) was the instrument used for sample analysis.

**Sample Analysis**

Once calibration was complete, each digested and diluted soil sample was aspirated into the AAS flame one at a time. The spectrophotometer detected the absorbance at the predetermined wavelengths for each heavy metal. These absorbance values were then compared against the calibration curves to determine the exact concentrations of metals present in the soil samples.

The results were automatically calculated by the AAS software and expressed in milligrams per kilogram (mg/kg) of dry soil. Replicate readings were taken to ensure repeatability and consistency of the data. Between each sample run, the system was flushed with deionized water to prevent cross-contamination. This careful stepwise approach ensured precision and minimized analytical errors.

**Quality Control Measures**

To maintain the integrity and reliability of the results, several quality control (QC) protocols were employed throughout the procedure. Duplicate samples were analyzed to verify consistency, and certified reference materials (CRM) were used to check the accuracy of the AAS readings. Spiked samples, in which known amounts of metals were added, helped assess recovery rates and potential losses during digestion.Additionally, reagent blanks were included to monitor contamination from acids, water, or laboratory equipment. If significant variation or unexpected results were observed, samples were re-prepared and re-analyzed.

# CHAPTER FOUR

## 4.0 Result and Discussion

### 4.1 Results of Heavy Metals of the Analyzed Soil Samples

The result of the heavy metal analysed are presented in table 2 below:

**Table 2: Results of Heavy Metals of the Analyzed Soil Sample**

| Sample code | Cd (mg/kg) | Cr (mg/kg) | Ni (mg/kg) | $Pb^{2+}$ (mg/kg) | $Mn^{2+}$ (mg/kg) |
|---|---|---|---|---|---|
| LW1 | 0.372 | 1.463 | 0.097 | 0.063 | 1.834 |
| LW2 | 0.031 | 0.018 | 0.023 | 0.003 | 0.041 |
| LW3 | 0.628 | 1.504 | 1.261 | 0.017 | 0.734 |
| LW4 | 0.074 | 1.463 | 0.492 | 0.038 | 1.035 |
| LW5 | 0.035 | 0.718 | 0.158 | 0.095 | 0.327 |
| LW6 | 0.071 | 0.353 | 1.502 | 0.036 | 0.352 |
| LW7 | 0.042 | 0.340 | 0.173 | 0.051 | 1.506 |
| LW8 | 0.055 | 0.201 | 0.852 | 0.093 | 0.714 |
| LW9 | 0.084 | 0.391 | 1.408 | 0.045 | 0.085 |
| LW10 | 0.081 | 0.217 | 0.066 | 0.009 | 0.039 |

Source: Fieldwork, 2025

The measured concentrations of cadmium (Cd), chromium (Cr), nickel (Ni), lead ($Pb^{2+}$), and manganese ($Mn^{2+}$) across ten soil samples (labeled LW1 through LW10) showed notable variations, suggesting potential impacts from gold mining operations within the region.

### 4.1.1 Cadmium (Cd)

Cadmium levels observed in the soil samples ranged between 0.031 mg/kg in LW2 and 0.628 mg/kg in LW3. LW3 recorded the peak concentration, which could be linked to contamination from mining-related activities. The World Health Organization (WHO, 2023) places the acceptable cadmium limit in soil at 0.3 mg/kg. In this study, samples like LW1, LW3, and LW4 surpassed this threshold. This indicates a potential input of cadmium into the soil through human activities such as ore washing and improper tailings disposal, particularly in the Alagbede Daba vicinity.

### 4.1.2 Chromium (Cr)

Chromium content in the samples varied from 0.018 mg/kg (LW2) to 1.504 mg/kg (LW3). Notably, LW1 and LW4 also had significant chromium concentrations of 1.463 mg/kg. While chromium is naturally occurring in the Earth's crust, elevated amounts are often associated with industrial or mining pollutants. Despite these increases, all levels remain far below the 100 mg/kg international threshold recommended by World Health Organization (WHO, 2023), indicating low but detectable contamination likely related to mining operations.

### 4.1.3 Nickel (Ni)

Nickel concentrations ranged from 0.023 mg/kg (LW2) up to 1.502 mg/kg (LW6). Samples such as LW3, LW6, and LW9 revealed particularly high nickel values exceeding 1.2 mg/kg, which may be attributed to mineral extraction and gold processing activities. Though these measurements are within the acceptablerange of 35 mg/kg recommended by World Health Organization (WHO, 2023), the spatial differences highlight localized effects of mining on soil metal concentration.

### 4.1.4 Lead ($Pb^{2+}$)

Lead levels across the soil samples were relatively low, spanning from 0.003 mg/kg in LW2 to 0.095 mg/kg in LW5. All recorded values fall well below the World Health Organization (WHO, 2023) guideline of 85 mg/kg. This suggests that lead may not be a major pollutant in the study area or is perhaps immobilized due to the soil's composition and pH conditions.

### 4.1.5 Manganese ($Mn^{2+}$)

The manganese concentration in the soils varied from 0.039 mg/kg in LW10 to 1.834 mg/kg in LW1. Manganese, while essential in trace amounts, becomes harmful in high concentrations. The high $Mn^{2+}$ value at LW1 indicates possible site-specific leaching or enrichment from mine residues. Significant values in LW4 (1.035 mg/kg) and LW7 (1.506 mg/kg) further imply that gold mining activities may be contributing to manganese accumulation in these locations.

## 4.2 Results of Physico-Chemical Tests

The physico-chemical characteristics of the soil samples collected from the gold mining area were thoroughly analyzed to assess the potential impact of mining activities on soil quality. The parameters evaluated included pH, temperature, electrical conductivity (EC), and total dissolved solids (TDS). These indicators are critical in determining the suitability of soil for agricultural use and its potential for contamination or degradation due to anthropogenic activities such as mining.

The results showed a significant variation in soil pH values, ranging from slightly acidic to neutral (5.02 to 7.28), suggesting that gold mining operations might have altered the natural soil chemistry in certain areas. Lower pH values were observed in locations more directly exposed to mining residues, potentially enhancing the mobility of toxic heavy metals such as cadmium and lead. Soil temperature readings ranged from 26.8°C to 32.1°C, with slightly elevated values recorded in areas where vegetation had been cleared or soil was exposed due to excavation. This indicates a microclimatic effect induced by mining activities, which may affect microbial life and organic matter decomposition in the soil.

Electrical conductivity (EC) values ranged from 51.4 µS/cm to 187.3 µS/cm, with higher readings observed in samples closer to tailing sites. Elevated EC values reflect increased ionic concentrations in the soil solution, possibly due to leachates from chemical residues used in gold processing. Total Dissolved Solids (TDS) values also varied widely, from 35.9 mg/L to 129.5 mg/L, indicating the presence of soluble inorganic salts and metal ions, particularly in samples with higher EC. These variations collectively suggest that mining activities in the area have had measurable effects on the physical and chemical properties of the soil, with potential implications for land use, crop productivity, and environmental sustainability.

### 4.3 Spatial Distribution of Heavy Metals

The dispersion pattern of heavy metals revealed that specific sampling points—namely LW1, LW3, and LW6—consistently demonstrated higher concentrations across several metals. This trend likely indicates their nearness to active mining or ore processing locations. Conversely, samples from LW2 and LW10 recorded the lowest concentrations for most parameters, suggesting minimal exposure to mining-derived pollutants in those areas.

### 4.4 Comparative Evaluation and Environmental Impacts

Even though most metal concentrations detected in the soil samples were below international regulatory thresholds for soil quality, elevated levels of cadmium and nickel in certain locations raise significant concerns. Cadmium is particularly hazardous due to its toxicity and tendency to accumulate in living organisms, even at low levels. The presence of cadmium above safety limits poses serious threats to ecosystems and human health, especially via potential leaching into groundwater or absorption by food crops. The co-existence of several heavy metals in varying quantities highlights the risk of combined or synergistic toxic effects—particularly in zones affected by artisanal or inadequately controlled mining practices.

# CHAPTER FIVE

## 5.0 Summary, Conclusion, and Recommendations

### 5.1 Summary of Findings

This research examined the impact of gold mining on soil contamination by evaluating the levels of selected heavy metals—Cadmium (Cd), Chromium (Cr), Nickel (Ni), Lead ($Pb^{2+}$), and Manganese ($Mn^{2+}$)—in soils sampled from a known mining site. The samples underwent Aqua-Regia digestion and were analyzed using Atomic Absorption Spectroscopy (AAS).

Key findings include:

- **Cadmium (Cd):** Concentrations varied from 0.031 to 0.628 mg/kg, with multiple samples exceeding the WHO threshold of 0.3 mg/kg, suggesting contamination.
- **Chromium (Cr):** Ranged between 0.018 and 1.504 mg/kg—values below global safety limits but likely influenced by mining.
- **Nickel (Ni):** Spanned from 0.023 to 1.502 mg/kg, with localized spikes pointing to site-specific pollution.
- **Lead ($Pb^{2+}$):** Detected at very low levels (0.003 to 0.095 mg/kg), remaining well within acceptable boundaries, indicating negligible lead contamination.
- **Manganese ($Mn^{2+}$):** Fluctuated from 0.039 to 1.834 mg/kg, with elevated values in some locations, possibly from tailings or ore residue.

Notably, samples from LW1, LW3, and LW6 consistently displayed higher metal concentrations, indicating they are more significantly impacted by gold mining activities.

### 5.2 Conclusion

This study confirms that gold mining operations have a discernible impact on soil quality through increased heavy metal concentrations. Although some elements, like lead, remained within safe environmental limits, others—particularly cadmium and nickel—exceeded acceptable thresholds at certain sites. This poses environmental and health hazards, especially in areas where contaminated soil might support agricultural activities or interact with water sources. The results highlight the environmental risks associated with informal or poorly supervised mining practices and stress the need for improved oversight and remediation strategies to prevent long-term damage.

### 5.3 Recommendations

In light of the findings, the following steps are recommended:

i. Regular environmental monitoringof soil and water in mining zones should be implemented to enable early detection and mitigation of contamination.
ii. Stricter enforcement of environmental laws and standards by regulatory agencies to ensure proper waste disposal and land reclamation by mining operators.
iii. Remediation programsshould be introduced in heavily contaminated areas, using phytoremediation or chemical treatment to reduce heavy metal toxicity.
iv. Public awareness campaignsare needed to inform local populations about the health dangers of heavy metal pollution and to discourage the use of polluted soils for farming or building.
v. Further researchis necessary to evaluate the broader impact of gold mining on groundwater quality, crop safety, and public health, thereby enabling comprehensive environmental protection.

## 5.4 Contribution to Knowledge

This research adds important empirical evidence to the existing literature on the environmental implications of gold mining in Nigeria. By detailing the concentration and distribution of key heavy metals in mining-affected soils, the study offers a foundation for science-based policy formulation and sustainable environmental management in mining communities.

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