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Geochemical Characteristics of Soils and Plants around Mining Sites in Parts of Ilorin Sheet 223

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Abstract: Mining is an important process that fosters economic growth by extracting valuable minerals from the earth's surface. However, this industry also poses significant environmental challenges, such as soil and water pollution and habitat destruction. This study aims to assess the impact of mining activities on heavy metal concentrations in soil and Neem plant leaves in two mining sites. The research utilized atomic absorption spectrometry (AAS) to analyze the heavy metal content in soil and plant samples. The obtained data were used to calculate various contamination indices, including the contamination factor index (CF), degree of contamination (Cd), modified degree of contamination (mCd), pollution load index (PLI), and accumulation index (Igeo) for soil samples. Additionally, the bioaccumulation coefficient (BAC) was calculated for Neem plant leaves. The X-ray diffraction (XRD) analysis was conducted to identify the mineral composition of the rock samples collected from the study area. The average values for Cu, Pb, Zn, Fe, Mn, Ni, and Co in test soil sites are higher than those in control sites, with significant differences (p-value <0.05) for Cu, Zn, Fe, and Co, indicating contamination due to mining. Similarly, for Neem plant leaves, the average concentrations of Cu, Pb, Zn, and Co are higher in test sites than in control sites, indicating bioaccumulation from the mining activities. However, the calculated contamination indices suggest that the level of contamination in the study area is relatively low. The XRD analysis revealed distinct peaks corresponding to various minerals, including Orthoclase, Albite, Muscovite, Quartz, Dolomite, Anorthite, and Illite. The mineral proportions were assessed, with quartz being dominant in the igneous rocks and dolomite in the marble samples.

Keywords: Atomic Absorption Spectrometry (AAS), Bioaccumulation Coefficient (BAC), contamination, neem plant, marble

I. INTRODUCTION

Mining is any activity that involves excavating the earth's surface for the purpose of exploiting its mineral wealth. This could be for local economic and industrial development or for export purposes (David, 2002). If properly coordinated, its positive socio-economic impact cannot be overemphasized as it provides natural resources for consumption, offers employment, as well as sources of revenue and foreign exchange. It can lead to the development of some socio-economic infrastructures like roads, schools, hospitals, among others (Hilson, 2002). The exploitation of mineral resources has assumed prime importance in several developing countries, including Nigeria, which is endowed with abundant mineral resources. This has contributed to the socio-economic status of the country (Adekoya, 2003). Aigbedion and Iyayi (2007) stated that the three stages of mineral development, i.e., exploration, mining, and processing, have caused different types of environmental damages, which include ecological disturbance, soil pollution, water pollution, destruction of natural flora and fauna, soil nutrient loss, among others.

Mining activities leave behind vast amounts of mine spoils and tailings, which become sources of metal contamination and environmental pollution. The direct effects of these processes lead to the degradation of cultivated, forested, or grazing lands, resulting in decreased production (Wong, 2003). Additionally, mining activities have indirect effects, such as air, soil, and water pollution, as well as siltation of rivers. Both direct and indirect effects can harm biodiversity and economic prosperity (Bradshaw, 1993).

These pollutants eventually get deposited on the leaves, flowers, and the soil supporting the plants. Consequently, the photosynthetic fruiting of plants is impaired when various chemical constituents, such as calcium and sulfur dioxide, enter the plants through pollution pathways. When these pollutants enter the stomata pores, they lead to the destruction of chlorophyll and disrupt photosynthesis in plants, subsequently leading to stunted growth or death (Ujoh & Alhassan, 2014). Moreover, heavy metals like lead, zinc, cobalt, iron, manganese, nickel, and copper can also cause diseases or even death in consumers who ingest plants affected by such pollutants.

According to Aigbedion and Iyayi (2007), a similar situation exists in all the limestone and marble quarries, albeit in different proportions, at Ewekoro, Nkalagu, Ashaka, Kalambaina, Okpilla, Jakura, among others. The discovery of limestone traces in Mbaylon, Gboko Local Government Area, Benue State of Nigeria in 1960 led to the establishment of a cement plant within the region, which commenced operations in 1980. Subsequently, in 2004, the plant came under the new management of Dangote Industries Plc, leading to its transformation into a state-of-the-art cement factory with 1.4 million tonnes lines (Vetiva Research, 2010). Due to intensive and extensive mining and quarrying activities, large volumes of dust are discharged into the air, contaminating the plant species within the area, and posing risks to the well-being of animals and humans. Plants growing in metal-enriched substrates take up metals to varying degrees in response to external factors (Marcshner, 1995; Greger, 1999).

Mining is the process of extracting useful minerals from the surface of the earth, and it can be divided into two groups: surface mining and underground mining. Some examples of substances that are mined include coal, gold, marble, limestone, diamonds, iron ore, etc. Mining is an important industry and one of the biggest contributors to the global economy. The development of mining industries impacts the resource acquisition potential and economic growth of a country, making it one of the most important sources of earnings for countries rich in mineral resources.

However, even though mining contributes significantly to the global economy, mining operations have negative impacts on plants, animals, and society in general. The negative effects of the mining industry on the environment include water pollution, biodiversity loss, air pollution, soil pollution, erosion, and the formation of sinkholes. The mining methods affect air quality, as materials that are unearthed to the surface are released when mineral deposits are exposed. Soil is removed during mining, and vegetation is also cleared, leading to airborne particles through road traffic and wind erosion (Lodhia, 2014).

A significant threat to the mining industry is biodiversity loss, resulting in habitat destruction for large masses, which affects vegetation, animals, and microorganisms. Endemic plant and animal species are particularly vulnerable as they are sensitive to specific environmental conditions; any disruption in their habitats can lead to extinction or put them at high risk of being wiped out.

Between March and June 2010, a series of lead poisonings in Zamfara State, Nigeria, led to the death of at least 163 people, including 111 children. Figures from the Nigeria Federal Ministry of Health state the discovery of 355 cases, with 46 percent proving fatal (Momoh, 2023).

Mining cannot be entirely avoided, although it poses hazards to society that could lead to high mortality rates and other adverse effects. Therefore, there is a need to minimize these impacts through solutions such as proper waste disposal, thorough site inspections, afforestation, among others.

Lead is a highly toxic metal that can accumulate in plants and cause severe damage. When plants absorb lead, it can reduce their growth and development, and in some cases, cause them to die. Lead can also inhibit photosynthesis in plants, leading to reduced production of carbohydrates and other essential nutrients. When animals consume plants contaminated with lead, it can cause damage to their organs, including the liver and kidneys. In severe cases, lead toxicity can lead to death.

Zinc is an essential micronutrient required by plants for growth and development. However, when present in high concentrations, it can become toxic to plants. Zinc toxicity in plants can cause chlorosis (yellowing of leaves), stunted growth, and reduced yield. When animals consume plants with high levels of zinc, it can lead to reduced feed intake, growth, and reproduction.

Cobalt is an essential micronutrient required by plants in small amounts. However, when present in high concentrations, it can be toxic to plants. Cobalt toxicity in plants can cause chlorosis, necrosis (death of plant tissues), and stunted growth. When animals consume plants with high levels of cobalt, it can cause damage to their liver, leading to reduced feed intake, growth, and reproduction.

Iron is an essential micronutrient required by plants for photosynthesis and other metabolic processes. However, when present in high concentrations, it can become toxic to plants. Iron toxicity in plants can cause chlorosis, necrosis, and reduced growth. When animals consume plants with high levels of iron, it can cause constipation, anemia, and reduced growth.

Manganese is an essential micronutrient required by plants for growth and development. However, when present in high concentrations, it can become toxic to plants. Manganese toxicity in plants can cause chlorosis, necrosis, and reduced growth. When animals consume plants with high levels of manganese, it can cause neurological disorders, including tremors and spasms.

Nickel is a heavy metal that can be toxic to plants at high concentrations. Nickel toxicity in plants can cause chlorosis, stunted growth, and reduced yield. When animals consume plants with high levels of nickel, it can cause damage to their kidneys, leading to reduced feed intake, growth, and reproduction.

Copper is an essential micronutrient required by plants for growth and development. However, when present in high concentrations, it can become toxic to plants. Copper toxicity in plants can cause chlorosis, necrosis, and reduced growth. When animals consume plants with high levels of copper, it can cause damage to their liver and kidneys, leading to reduced feed intake, growth, and reproduction.

A. Study Area

The study area is located within Ifelodun Ilorin South Local Government area of Kwara State. Kwara State lies at latitudes 8°20'N to 8°30'N and longitudes 4°35'E to 4°35'E, covering an area of 35,705 km2. The areas are known for their lush vegetation and fertile land, providing ideal conditions for farming. The climate of the study area is classified as tropical, experiencing hot and humid conditions throughout the year, with temperatures ranging from the mid-20s to mid-30s degrees Celsius. The region experience two main seasons: the rainy season, which typically lasts from April to October with heavy rainfall and high humidity, and the dry season, lasting from November to March, characterized by low rainfall and lower humidity. The areas are characterized by savanna vegetation with tall grasses and scattered trees. The soil in the areas are predominantly tropical ferruginous, which is typical of the savanna biome. The landscape in Isale-Osin and Elerinjare is relatively flat, with low hills and valleys. The general relief of the study area is low with the granitic rocks outcropped as domes and relatively low hills while the marble and diorite outcropped as oval or semi-circular hills. The areas are characterized with dendritic drainage systems with different tributaries.

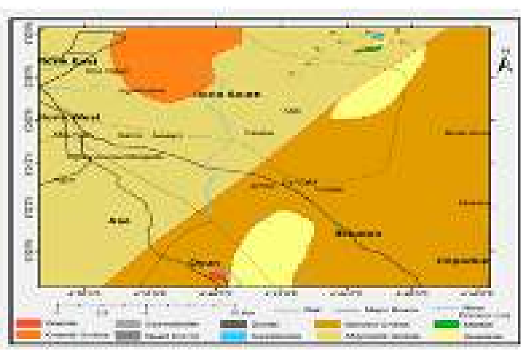

Figure 1: Geological Map of the study area

The major occupation of people in the areas is farming and hunting. Most farmers make ridges along steep slope for growing of crops like to cassava, yam and guinea corn etc. Because of the vegetation of the study area, cattle rearing is prominent in the area, making the area transient settlement for nomadic herdsmen.

Geology of the Study Area

The study area which falls within the Basement Complex of Nigeria. The Basement Complex is a region in Nigeria that consists of a variety of rock types, which were formed over billions of years through various geological processes such as sedimentation, metamorphism, and volcanic activity. In the northeastern part and central part, several types of rocks can be found, including pegmatite, granitic gneiss, banded gneiss, marble, diorite, amphibolite, and syenodiorite.

Pegmatite

Pegmatite is an igneous rock that is formed from the crystallization of magma. It is often composed of large crystals of various minerals, including feldspar, mica, and quartz. Pegmatite is usually found in veins or pockets within other rocks, such as gneiss or granite. In Isale Osin and Elerinjare, pegmatite is found as veins within the granitic gneiss.

Pegmatite is a metamorphic rock that is formed from the recrystallization of pre-existing rocks, such as granite, under high pressure and temperature. It is composed of minerals such as quartz, feldspar, and mica, and often has a banded appearance due to the alternating layers of different minerals. In Isale Osin and Elerinjare, granitic gneiss is likely to be found as the predominant rock type.

Figure 2: A pegmatite outcrop and pegmatite intrusion

Banded Gneiss

Banded gneiss is a type of gneiss that is characterized by its alternating bands of different colors or mineral compositions. It is formed through the process of regional metamorphism, which occurs when rocks are subjected to high pressure and temperature over a wide area. In Isale Osin and Elerinjare, bounded gneiss may be found as layers within the granitic gneiss.

Figure 3: Banded gneiss

Marble

Marble is a metamorphic rock that is formed from the recrystallization of limestone or dolomite under high pressure and temperature. It is composed primarily of the mineral calcite and has a smooth, polished appearance. Marble is found in very high quantities forming an extended ridge in the area.

Diorite

Diorite is an intrusive igneous rock that is composed of plagioclase feldspar, biotite, hornblende, and other minerals. It is formed from the crystallization of magma beneath the Earth's surface. In Elerinjare, diorite is found in massive quantities.

Figure 4: Large exposure of a Diorite

Syenodiorite

Syenodiorite is an intrusive igneous rock that is composed of plagioclase feldspar, hornblende, and other minerals. It is similar to diorite, but with a higher content of sodium-rich plagioclase feldspar. In Elerinjare, syenodiorite may be found as small intrusions within the predominant rock type is granitic gneiss, which is likely to be the result of the recrystallization of pre-existing granite under high pressure and temperature. The presence of bounded gneiss and amphibolite layers within the granitic gneiss suggests that the area was subject to regional metamorphism, which caused the formation of these layered rocks.

The presence of pegmatite and small intrusions of diorite and synodiorite within the granitic gneiss suggests that the area experienced some igneous activity, likely in the form of magma intrusion into the pre-existing rock. Marble may also be found in small quantities, indicating that there may have been some localized high-pressure and high-temperature conditions that caused the recrystallization of limestone or dolomite.

Generally, the geology of Isale Osin and Elerinjare in Ifelodun Local Government Area of Kwara State, Nigeria, reflects the complex geological history of the Basement Complex of Nigeria. The rock types present in the area were formed over billions of years through various geological processes, and their composition and characteristics can provide valuable information about the geological history and evolution of the region.

II. Materials and methods

A. Sample collection

This involves collecting samples of plants from around the mining sites and taking soil samples around the mining sites, as well as plants and soil samples away from the mining site as 'control samples.' This requires a systematic approach to sample collection and data recording to ensure that the data is accurate and representative of the study area. The materials collected for this study include rock, soil, and plant samples (Azadirachta indica). Soil and plant samples were taken from different locations around marble mining sites (test samples) and away from the marble mining site (control samples). The soil samples were collected from a depth of 0-15 cm and air-dried in the laboratory, while the plant samples were oven-dried at 350°C for four hours. Subsequently, they were digested using nitric and hydrochloric acid and labeled appropriately for analytical methods, such as atomic absorption spectrometry (AAS), to determine the concentrations of copper (Cu), lead (Pb), zinc (Zn), iron (Fe), manganese (Mn), nickel (Ni), and cobalt (Co). The collected rock samples from the study area underwent X-ray diffraction (XRD) analysis to identify the minerals present and quantify their abundance in each rock sample.

The Neem tree was used in this study because it is a folklore plant commonly employed in medicinal preparations. Previous studies by Pataranwat et al. (2007) on mercury emissions and potential risks at a small-scale gold mining site in Thailand found elevated concentrations of mercury in Neem flowers, confirming its relevance for our investigation. The preliminary geochemical and mineralogical analysis of neem soils was made to explore the potential links between Neem tree derivatives snd soils (Mahaney et al., 2016). The investigation of heavy metals contents in neem trees parts in UAE showed that the heavy metals were within the permissible limit suggested by World Health Organisation (WHO) (Abu-Abdoun & Al-Balawna, 2019)

A total of 5 plant samples (4 test samples: CSS, DMA, H2 3, and PLS1 3, and 1 control sample: CS 1) and 5 soil samples (4 test samples: DW, H2, PLS1, DN, and 1 control sample: CS 3) were collected. The rock samples collected were banded gneiss, granite gneiss, and marble.

Heavy metals such as lead, zinc, cobalt, iron, manganese, nickel, and copper are commonly found in soils around mining sites due to mining activities. When these metals enter the food chain through plants, they can have adverse effects on both the plants and the animals that consume them. In this discussion, we will consider the effects of each of these heavy metals on plants around mining sites and the animals that consume them.

B. Laboratory Analysis

This involves air-drying and oven-drying the samples, followed by digestion with the aid of nitric and hydrochloric acid (aqua regia method). Atomic absorption spectrometry (AAS) is essential for ensuring the accuracy and precision of the study. The AAS analysis was carried out Cental Research Laboratory, University of Ilorin, Nigeria. The geochemical analysis for the concentration of heavy metals such as lead, zinc, copper, iron, cobalt and manganese were determined in soil and plant samples. The result were thereafter subjected to statistical analysis and environmental pollution indices evaluation.

III. Result and Discussion

Samples of plant and soils in the study area were analyzed for heavy metal concentration using Atomic Abortion Spectroscopy AAS. The average values for Cu, Pb, Zn, Fe, Mn, Ni, and Co in the test sites for soil are 0.8972 ± 0.0542 mg/kg, 0.7096 ± 0.4980 mg/kg, 1.4138 ± 0.2923 mg/kg, 14.9305 ± 0.8847 mg/kg , 6.5358 ± 2.8067 mg/kg , 0.7181 ± 0.2837 mg/kg , and 0.5775 ± 0.2919 mg/kg, respectively. In contrast, in the control sites, the average values for Cu, Pb, Zn, Fe, Mn, Ni, and Co are 0.6310 ± 0.0014 mg/kg , 0.1260 ± 0.0057 mg/kg, 0.9070 ± 0.0014 mg/kg, 13.3910 ± 0.0014 mg/kg, 2.5360 ± 0.0014 mg/kg , 0.3895 ± 0.0148 mg/kg

, and 0.0320 ± 0.0028 mg/kg, respectively. There is a significant difference (p-value <0.05) between the average heavy metal concentrations in soil from marble mining sites (test) and non-mining sites (control) for Cu, Zn, Fe, and Co. The average concentration of all metals in the mining sites soils is higher than the average concentration in the non-mining sites soils.

The average values for Cu, Pb, Zn, Fe, Mn, Ni, and Co in the test sites of Neem plant leaves are 0.3135 ± 0.1178, 0.1663 ± 0.0391, 1.1583 ± 0.3745, 13.0828 ± 0.6472, 3.4044 ± 2.7002, 0.2764 ± 0.1323, and 0.1075 ± 0.0617, respectively. In contrast, in the control sites, the average values for Cu, Pb, Zn, Fe, Mn, Ni, and Co are 0.1800 ± 0.0014, 0.2625 ± 0.0460, 0.3950 ± 0.0014, 15.3080 ± 0.0014, 7.3960 ± 0.0014, 0.2955 ± 0.0078, and 0.2990 ± 0.0028, respectively. There is a significant difference (p-value <0.05) between the average heavy metal concentrations in Neem plant leaves from marble mining sites (test) and non-mining sites (control) for Pb, Zn, Fe, and Co. The average concentration of Cu, Pb, Zn, and Ni in the Neem plant leaves from marble mining sites is higher than the average concentration in the non-mining sites, indicating bioaccumulation resulting from mining activities. On the other hand, the average concentrations of Fe, Mn, and Co are higher in the Neem plant leaves from non-mining sites than those in the mining sites.

Table 1: Heavy Metal Concentration in Plant and Soil Samples

Sam	Test Type	Sample Media	Replicate Test	Cu (mg/Kg)	Pb (mg/Kg)	Zn (mg/Kg)	Fe (mg/Kg)	Mn (mg/Kg)	Ni (mg/Kg)	Co (mg/Kg)
CS 1	Control	Plant	1	0.181	0.23	0.396	15.307	7.397	0.29	0.297
			2	0.179	0.295	0.394	15.309	7.395	0.301	0.301
CSS	Test	Plant	1	0.448	0.153	0.934	13.216	7.456	0.125	0.041
			2	0.446	0.15	0.932	13.218	7.454	0.129	0.044
DW	Test	Soil	1	0.92	0.502	1.046	15.498	6.639	0.63	0.492
			2	0.922	0.6	1.044	15.496	6.367	0.635	0.475
H2	Test	Soil	1	0.917	1.355	1.8	15.327	8.708	1.113	0.693
			2	0.915	1.36	1.802	15.325	8.706	1.117	0.696
PSL1	Test	Soil	1	0.942	0.851	1.486	15.399	8.661	0.745	0.933
			2	0.94	0.855	1.484	15.397	8.683	0.75	0.941
CS 3	Control	Soil	1	0.632	0.122	0.908	13.392	2.537	0.379	0.034
			2	0.63	0.13	0.906	13.39	2.535	0.4	0.03
DMA	Test	Plant	1	0.397	0.223	1.428	13.881	3.593	0.44	0.194
			2	0.395	0.23	1.426	13.879	3.59	0.443	0.197
DN	Test	Soil	1	0.81	0.074	1.325	13.5	2.26	0.376	0.197
			2	0.812	0.08	1.323	13.502	2.262	0.379	0.193
H2 3	Test	Plant	1	0.189	0.127	1.374	13.051	1.506	0.343	0.12
			2	0.187	0.13	1.72	13.053	1.504	0.346	0.118
PLS1 3	Test	Plant	1	0.222	0.157	0.727	12.181	1.065	0.191	0.076
			2	0.224	0.16	0.725	12.183	1.067	0.194	0.07

Table 2: Average Concentrations of Heavy Metals in Plant and Soil Samples

Sample ID	Test Type	Sample Type	Cu	Pb	Zn	Fe	Mn	Ni	Co
CS 1	Control	Plant	0.18	0.2625	0.395	15.308	7.396	0.2955	0.299
CSS	Test	Plant	0.447	0.1515	0.933	13.217	7.455	0.127	0.0425
DW	Test	Soil	0.921	0.551	1.045	15.497	6.503	0.6325	0.4835
H2	Test	Soil	0.916	1.3575	1.801	15.326	8.707	1.115	0.6945
PSL1	Test	Soil	0.941	0.853	1.485	15.398	8.672	0.7475	0.937
CS 3	Control	Soil	0.631	0.126	0.907	13.391	2.536	0.3895	0.032
DMA	Test	Plant	0.396	0.2265	1.427	13.88	3.5915	0.4415	0.1955
DN	Test	Soil	0.811	0.077	1.324	13.501	2.261	0.3775	0.195
H2 3	Test	Plant	0.188	0.1285	1.547	13.052	1.505	0.3445	0.119
PLS1 3	Test	Plant	0.223	0.1585	0.726	12.182	1.066	0.1925	0.073

Table 3 Heavy metal concentration (mean+SD, mg/kg) for the test and control sites

	Plant		**Soil**	
Metal	**Average± Std Dev**	**P-Value**	**Average± Std Dev**	**P-Value**
Cu	Test: 0.3135 ± 0.1178	0.164	Test: 0.8972 ± 0.0542	0.0002*
	Control: 0.1800 ± 0.0014		Control: 0.6310 ± 0.0014	
Pb	Test: 0.1663 ± 0.0391	0.016*	Test: 0.7096 ± 0.4980	0.1517
	Control: 0.2625 ± 0.0460		Control: 0.1260 ± 0.0057	
Zn	Test: 1.1583 ± 0.3745	0.0248*	Test: 1.4138 ± 0.2923	0.0471*
	Control: 0.3950 ± 0.0014		Control: 0.9070 ± 0.0014	

Fe	Test: 13.0828 ± 0.6472	0.0016 *	Test: 14.9305 ± 0.8847	0.0465 *
	Control: 15.3080 ± 0.0014		Control: 13.3910 ± 0.0014	
Mn	Test: 3.4044 ± 2.7002	0.0806	Test: 6.5358 ± 2.8067	0.0901
	Control: 7.3960 ± 0.0014		Control: 2.5360 ± 0.0014	
Ni	Test: 0.2764 ± 0.1323	0.8499	Test: 0.7181 ± 0.2837	0.156
	Control: 0.2955 ± 0.0078		Control: 0.3895 ± 0.0148	
Co	Test: 0.1075 ± 0.0617	0.003*	Test: 0.5775 ± 0.2919	0.0354 *
	Control: 0.2990 ± 0.0028		Control: 0.0320 ± 0.0028	

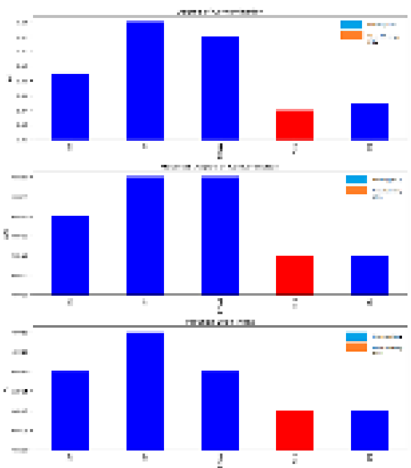

Figure 2: Distribution of Degree of contamination (top), modified degree of contamination (middle), and pollution load index (bottom) of the soil samples

A. Contamination Factor Index (CF)

Table 4 shows the results of the contamination factor index computed for the soil samples collected from the study area. The range of values for the computed CF is 0.0140-0.0209, 0.0039-0.0679, 0.0095-0.0190, 0.0056-0.0164, and 0.0017-0.0493 for Cu, Pb, Zn, Ni, and Co, respectively. All the metals in the water samples have CF values less than 1.0, which represents a low degree of contamination.

Table 4: Contamination Factor Index for the soils samples

ID	Test type	Sample Type	Cu	Pb	Zn	**Ni**	**Co**
DW	Test	Soil	0.0205	0.0276	0.0110	0.0093	0.0254
H2	Test	Soil	0.0204	0.0679	0.0190	0.0164	0.0366
PSL1	Test	Soil	0.0209	0.0427	0.0156	0.0110	0.0493
CS 3	Control	Soil	0.0140	0.0063	0.0095	0.0057	0.0017
DN	Test	Soil	0.0180	0.0039	0.0139	0.0056	0.0103

B. Degree of Contamination (Cd)

The minimum and maximum values for the degree of contamination (Cd) range from 0.037 in sample CS 3 to 0.160 in H2 (Table 5). None of the samples have Cd values above 5, which is the number of metals used for its computation (Zahran et al., 2015). This indicates a low degree of contamination for the soil samples. The distribution of Cd is shown in Figure 2, and it can be observed that Cd values are lower in the non-mining sites (control), indicating lesser contamination.

Table 5: Degree of contamination (top), modified degree of contamination (middle), and pollution load index (bottom) of the soil samples

ID	Test type	Sample Type	C_d	mC_d	PLI
DW	Test	Soil	0.094	0.019	0.017
H2	Test	Soil	0.160	0.032	0.027
PSL1	Test	Soil	0.140	0.028	0.024
CS 3	Control	Soil	0.037	0.007	0.006
DN	Test	Soil	0.052	0.010	0.009

C. Modified Degree of Contamination (mCd)

The minimum and maximum values for the modified degree of contamination (mCd) range from 0.007 in sample CS 3 to 0.032 in H2 (Table 4-5). None of the samples have mCd above 1.5, indicating a nil to very low degree of contamination for the soil samples. The distribution of mCd is shown in Figure 2, and it can be observed that mCd values are lower in the non-mining sites (control), representing lesser contamination.

D. Pollution Load Index (PLI)

The minimum and maximum values for the Pollution Load Index (PLI) range from 0.006 in sample CS 3 to 0.027 in H2 (Table 4-5). None of the samples have PLI above 1.0 which implies unpolluted soils (Tomlinson et al, 1980). The distribution of PLI is shown in Figure 2, and it can be observed that PLI values are lower in the non-mining sites (control), representing lesser contamination.

E. Geoaccumulation Index (Igeo)

Table 6 shows the results of the geoaccumulation index (Igeo) computed for the soil samples collected from the study area. The range of values for the computed Igeo is -0.6741 to -6.165 for Cu, -8.806 to -4.466 for Pb, -7.296 to -6.306 for Zn, -8.078 to -7.092

for Ni, and -9.799 to -4.927 for Co, respectively. All the metals in the water samples have Igeo values less than 0, which represents practically uncontaminated soils.

Table 6: Geoaccumulation Index for the soils samples

ID	Test type	Sample Type	Cu	Pb	Zn	Ni	Co
DW	Test	Soil	-6.196	-5.767	-7.091	-7.333	-5.881
H2	Test	Soil	-6.203	-4.466	-6.306	-6.515	-5.359
PSL 1	Test	Soil	-6.165	-5.136	-6.584	-7.092	-4.927
CS 3	Control	Soil	-6.741	-7.895	-7.296	-8.033	-9.799
DN	Test	Soil	-6.379	-8.606	-6.750	-8.078	-7.191

F. Bioaccumulation coefficient (BAC)

Table 7 shows the computed bioaccumulation coefficients (BAC) for the leaf samples from the Neem plant across the study area. The BAC for Cu and Ni is less than 1.0, which implies that the Neem plants are excluders for these metals. The majority (>60%) of the samples also have BAC values less than 1 for Pb, Co, and Zn. However, 40%, 20%, and 20% of the Neem leaves show accumulation of Pb, Zn, and Co, respectively, with BAC>1.

Table 7: Bio accumulation coefficients (BAC) for Neem Plant leaves in the study area

ID	Cu	Pb	Zn	Ni	Co
CS 1	0.29	2.08	0.44	0.76	9.34
CSS	0.55	1.97	0.70	0.34	0.22
DMA	0.43	0.41	1.37	0.70	0.40
H2 3	0.21	0.09	0.86	0.31	0.17
PLS1 3	0.24	0.19	0.49	0.26	0.08

G. Spearman Rank Correlation Coefficient of Heavy Metals

Tables 8 and 9 show the computed Spearman Rank correlation coefficient matrices for the heavy metals analyzed in this study, both for the Neem plant leaves and soil samples, respectively. A correlation coefficient value ≥0.7 is considered high. For the Neem leaves, both negative and positive correlations exist among the heavy metals. Notably, high positive correlations are observed between Fe and Pb, Mn and Fe, Co and Pb, Co and Fe, and Ni and Co.

In the soil samples, all correlation coefficients are positive. Strong correlations are observed among Cu with Fe and Co; Pb with Zn, Mn, Ni, and Co; Zn with Mn, Ni, and Co; Fe with Co; Mn with Ni and Co; and Ni with Co, respectively.

IV. Conclusion

This research sheds light on the complex relationship between mining activities and environmental contamination, with a focus on heavy metal concentrations in soil and Neem plant leaves. The results underscore the significance of sustainable environmental management practices to preserve natural ecosystems and safeguard human health. By examining both soil and plant samples, the research provides a comprehensive assessment of the environmental impacts of mining, making it a valuable contribution to the field of environmental science and resource management. The findings serve as an essential reference for policy makers, researchers, and industries to implement effective measures to mitigate the negative consequences of mining activities and promote a more sustainable and environmentally responsible approach to mineral extraction.

REFERENCES

Abu-Abdoun, I. I., & Al-Balawna, Z. A. (2019). Heavy metals contents in neem tree (Azadirachta indica) parts and surroundings. Acta Scientific Medical Sciences, 38, 126-130.

Adekoya, J. (2003). Environmental effect of solid minerals mining. In J. Phys. Sci. Kenya (pp. 625–640).

Aigbedion, I., & E, I. S. (2007). Environmental effect of mineral exploitation in Nigeria. International Journal of Physical Sciences, 2, 2.

Hilson, G. (2002). Small-scale mining and its socio-economic impact in developing countries. Natural Resources Forum, 26, 3–13. https://doi.org/10.1111/1477-8947.00002

Mahaney, W. C., Voros, J., Krishnamani, R., Hancock, R. G., Aufreiter, S., Milner, M. W., & Allen, C. C. (2016). Physico-geochemical and mineral composition of neem tree soils and relation to organic properties. Geografiska Annaler: Series A, Physical Geography, 98(2), 143-154.

Marchner, H. (1995). Mineral nutrition of higher plants (2nd ed.). Academic Press.

Momoh, S. (2023). Sad Story of Nigeria's Neglected Treasure. Independent.ng. https://independent.ng/sad-story-of-nigerias-neglected-treasure/

Ujoh, F., & Alhassan, M. M. (2014). Assessment of pollutants in streams around a cement plant in Central Nigeria. International Journal of Science and Technology, 4, 3.

Wang, L., Xie, X., Li, Q., Yu, Z., Hu, G., Wang, X., & Liu, J. (2022). Accumulation of potentially toxic trace elements (PTEs) by native plant species growing in a typical gold mining area located in the northeast of Qinghai-Tibet Plateau. Environmental Science and Pollution Research, 29, 5.

Wang, Y., Huang, J., & Gao, Y. (2012). Arbuscular mycorrhizal colonization alters subcellular distribution and chemical forms of cadmium in Medicago sativa L. and resists cadmium toxicity. PLoS ONE, 7, e48669. https://doi.org/10.1371/journal.pone.0048669

Wang, Z., Liu, X., & Qin, H. (2019a). Bioconcentration and translocation of heavy metals in the soil-plants system in Machangqing copper mine, Yunnan Province, China. Journal of Geochemical Exploration, 200, 159–166.

Wang, Z., Liu, X., & Qin, H. (2019b). Bioconcentration and translocation of heavy metals in the soil-plants system in Machangqing copper mine, Yunnan Province, China. Journal of Geochemical Exploration, 200, 159–166.

Yu, Y.-Q., & Yang, J.-Y. (2019). Oral bioaccessibility and health risk assessment of Vanadium(IV) and Vanadium(V) in a vanadium titanomagnetite mining region by a whole digestive system in-vitro method (WDSM). Chemosphere, 215, 294–304. https://doi.org/10.1016/j.chemosphere.2018.09.163