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Research article

Assessment of the environmental impact of gemstone mining on vegetation and soil in the Egbeda mine site, Saki, Nigeria

Udofia, E.V[*1]., Onuoha C. C[2]., Ojo, O. H[3]., Asibe, G. A[2]., Kehinde, E. F[4]., Ahmad, B. M[5]., Adekplorvi, G[6]., Umar, M. M[5]., Sani, A. H[5]., Boakye, T. K[7] and Surajo, A. A[5].

[1]Department of Biology, Faculty of Sciences, Federal University of Technology Akure, Akure, Ondo State, 340110, Nigeria
[2]Department of Microbiology, Faculty of Life Sciences, Modibbo Adama University, Yola, 640261, Nigeria
[3]Department of Biochemistry, Faculty of Sciences, Adekunle Ajasin University, Akungba Akoko, 342111, Nigeria
[4]Department of Microbiology, Faculty of Natural Sciences, Redeemer's University, Ede, Osun, 232101, Nigeria
[5]Department of Microbiology, Faculty of Life Sciences, Bayero University Kano, Kano, 700241, Nigeria
[6]Department of Biomedical Sciences, School of Allied Health Sciences, University of Cape Coast, Cape Coast, 2076, Ghana
[7]Department of Forestry, National School of Forestry Engineering, Ecole Nationale Forestiere d' Ingenieurs, Salé, 11000, Morocco

*Corresponding author, Email address: ekeminivudofia@gmail.com

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Abstract

Gemstone mining, though economically valuable, poses environmental risks by altering soil properties and introducing heavy metals into ecosystems. In Egbeda, Saki, Nigeria, pollutants like zinc, copper, lead, and arsenic accumulate in soil and plants, negatively affecting plant health and soil fertility. This study investigates the extent of heavy metal contamination at the Egbeda mining site to inform ecological remediation and ensure sustainability. Random samples of soil and plants (*Scleria depressa*) were collected from the mining and control sites for analysis. The study evaluated physical and chemical soil properties (pH, conductivity, porosity, bulk density, organic carbon, nitrogen, cation exchange capacity) as well as heavy metal concentrations, including zinc, copper, arsenic, lead, chromium, cadmium, and nickel. Atomic Absorption Spectroscopy (AAS) Buck Technique, involving incineration and wet digestion was used to determine metal concentrations. Results, assessed via an independent Student's T test, revealed that Zinc showed the highest concentration in the soil (1.3870 mg/kg at the mining site and 1.2090 mg/kg at the control), while cadmium had the lowest (0.5000 mg/kg at the mining site and 0.0010 mg/kg at the control). Although heavy metal concentrations were elevated at the mining site, they remained within World Health Organization (WHO) permissible limits for both plants and soils. The findings suggest that heavy metal levels are safe for agricultural use, but continued monitoring is necessary to prevent potential ecological risks.

Keywords: Risk assessment, heavy metals, gemstone mining, *Scleria depressa*, plants, and soil.

Introduction

Mining typically involves the retrieval of valuable minerals or other geological substances from the Earth, typically sourced from ore bodies, lodes, veins, seams, reefs, or placer deposits (Zambales, 2021). The accumulation of heavy metals in biological organisms poses a significant threat to both humans and other life forms. This danger arises from the gradual buildup of certain chemical elements in the body, surpassing the usual physiological need for these substances (Chibuike and Obiora, 2014). Mining can have a negative impact on the environment through a variety of methods, such as the erosion of mine dumps, the creation of sinkholes, the release of chemicals during mining operations that pollute soil, groundwater, and surface water, and the general extinction of organisms (Agboola *et al*., 2020). Mining activities lead to a multitude of issues, including but not limited to land degradation, the disposal of excess material, deforestation, the discharge of mine water, subsidence, water pollution resulting from runoff, coal washing processes, the release of gases and dust causing air pollution, noise pollution, mine fires, harm to forest ecosystems, destruction of wildlife habitats, and occupational health risks (Githira and Onifade, 2020; Punia and Singh, 2021).The persistent contamination of land by heavy metals and organic pollutants poses a serious threat to the ecosystem, animal health, and human well-being. In agriculture and food processing, there is increasing worry about the safety of fruits and beverages that may be tainted by these absorbed metals.

Scleria depressa, known as flattened nut sedge, is a perennial herbaceous plant from the Cyperaceae family that thrives in wetland and marshy environments. Its unique characteristics make it a prime candidate for studying metal accumulation in contaminated areas. Found in regions that are often hotspots for metal pollution due to runoff and sediment buildup, *Scleria depressa* is well-suited for examining how plants can bioaccumulate metals. Its fibrous root system is particularly effective in absorbing heavy metals from the soil, which is a significant advantage in understanding the mechanisms behind metal accumulation (Bora and Sarma, 2020; Page & Feller, 2015). Furthermore, this species demonstrates a remarkable tolerance to heavy metals, enabling it to flourish even in polluted soils. This resilience positions *Scleria depressa* as a valuable species for exploring phytoremediation strategies, where plants are utilized to extract or stabilize metals in contaminated environments (Saxena *et al.,* 2020).

By selecting *Scleria depressa* for research, scientists can compare its metal uptake capabilities with other plant species, shedding light on the ecological implications of metal pollution and enhancing our understanding of effective bioremediation methods (Yan *et al.,* 2020). Ultimately, the study of *Scleria depressa* not only advances our knowledge of plant interactions with pollutants but also offers potential solutions for environmental restoration. According to a comprehensive study on the environmental burden of disease by the World Health Organization (WHO, 2007), environmental risk factors account for a quarter of the total burden of disease and 2.97 million human deaths every year in Africa. Since toxic metals constitute serious health hazards, the extent of toxic metal contamination of the African environment has been the subject of considerable interest. Heavy metals, a class of elements inherently dense and toxic, have become ubiquitous contaminants of grave concern within the global environmental landscape (Omonona *et al.,* 2020). These elements, despite being naturally occurring, are often mobilized and concentrated by human activities such as industrial manufacturing, mining operations, and agricultural practices (Yap and Al-Mutairi, 2021).

Consequently, heavy metal pollution poses a significant threat to ecological integrity and public health, with metals such as arsenic, cadmium, chromium, lead, and mercury being particularly notorious for their toxicity and propensity for bioaccumulation (Gnanasekaran and Raj, 2023). The global burden of heavy metal contamination is a reflection of the complex interplay between economic development and environmental stewardship. The country's substantial oil reserves and mineral wealth have fueled economic growth but have also led to significant environmental challenges (Anyanwu *et al.*, 2018). The oil industry, in particular, has been a source of environmental concern, with oil spills and gas flaring contributing to the heavy metal load in the Niger Delta region (Idowu, 2022). Additionally, artisanal gold mining in the northern part of the country has resulted in devastating lead poisoning incidents, underscoring the urgent need for effective management and remediation strategies (Johnbull *et al.,* 2018). The objective of this research is aimed to investigate the impact of gemstone mining on various soil properties and heavy metals accumulation in plants and soil within the Egbeda mining site.

Methodology

Study Area

The experiment was conducted at a gemstone mining site in Saki (Latitude 8°44'10"N, Longitude 3°21'43"E), where mining activities likely cause heavy metal contamination in the soil. This area is ideal for studying metal accumulation due to the disturbance from mining operations.

The control site (Latitude 8°43'23"N, Longitude 3°23'24"E) is free from mining activities and represents the natural, undisturbed environment. It serves as a baseline for comparison, helping to assess metal levels in plants and soil without the influence of human-induced contamination. Both sites share similar environmental features, with the control area being untouched by mining.

Sample Collection

Soil and plant samples were gathered at random from two locations in Egbeda community, Saki, Oyo State. The first location is a gemstone mining site while the latter is a control site.

Soil and Plant

Soil samples were obtained at a depth of 0-0.15m (surface) and 0.15-0.30m (sub- surface) from both locations. A hand trowel was used to randomly collect a total of three surface and sub-surface soil samples from each location. Clean and properly labelled containers were used to store all samples collected.

Scleria depressa plant was carefully uprooted ensuring that the roots were still intact. The plant samples were first placed in a clean bag and then appropriately labeled according to the location where they were collected. The samples were then thoroughly cleaned with distilled water to remove any remaining dust or other particles as part of the preparation process. Following that, the samples were left to air dry in a dust-free wire mesh cage. They were dried, and then, using a stainless steel blender, they were ground into a fine powder for further examination. Soil samples were also collected and their bulk density, pH, and conductivity were measured a few days after they had air dried. The analysis of both the plant and soil samples took place at two different locations: the Sustainable Environmental and Laboratory Consultants near NNPC Mega Station, along the Benin/Owo Expressway in Akure, and the Crop Soil and Pest Laboratory at the Federal University of Technology Akure (FUTA), Akure.

Physical and Chemical Properties of Soil

pH and Soil Conductivity

A pH meter was used to measure the pH of soil samples. Soil samples (10g) were placed in a sample cup, mixed with 20ml of water, and allowed to sit for 30 minutes. The pH levels of the soil samples were then determined using the pH meter (Hanna Portable pH/EC/TDS/Temperature Meter (HI9811-5). At room temperature (22°C), soil conductivity was measured with an auto-conductivity equipment (TLS-100 Portable Thermal Conductivity Meter), and the results were noted.

Organic carbon and organic matter

The determination of organic carbon and organic matter was conducted using the Walkley-Black Wet Oxidation Method (Bahadori and Tofighi, 2017). A small amount of soil sample was finely processed to a powder. Following that, 1g of the pulverized material was precisely weighed and transferred to a 250ml conical flask. In this flask, 10ml of $K_2Cr_2O_7$ and 20ml of H_2SO_4 were added. The flask's contents were violently swirled for one minute before being left to stand for thirty minutes. Following the incubation period, 100ml of distilled water was added to the flask, followed by 3-4 drops of ferroin indicator. The mixture was then titrated with 0.5M $Fe_2NH_4SO_2$. Initially, the solution exhibited a greenish tint, which gradually transformed into a dark green hue. At this point, drops of ferrous sulfate were carefully added until the color sharply changed from green to a reddish-brown shade. Blank titration was done without soil to standardize the iron (II) solution. In the reaction $K_2Cr_2O_7$ oxidizes carbon and the excess $K_2Cr_2O_7$ is titrated with Iron (II) solution.

Cation Exchange Capacity (CEC)

CEC was determined using the ammonium saturation method described by Choo and Bai (2016). Ten grams of soil that had been air-dried and run through a 2mm sieve were put in a 250ml beaker. One hundred milliliters of 1N NH_4OAc (pH 7.0) were added, mixed, and left overnight. The following day, the mixture was filtered, discarding the leachate. The remaining soil residue was rinsed with 100ml of 95% ethanol, 20ml at a time, and the leachate was discarded again. The resulting residue was then leached with 100ml of 1M NaCl to displace ammonia, and the extract was collected in a 100ml volumetric flask. Distillation was performed using a Macro Kjeldahl Red-Bromocresol Green mixed indicator. The distillation apparatus had the condenser positioned about 2cm above the boric acid surface. From the resulting extract, 10ml was transferred to the distillation flask along with 10ml of 40% Sodium hydroxide, and distillation began. The liberated NH_3 was collected in the boric acid until 50ml of distillate was obtained. The endpoint was reached when the color of this distillate transitioned from deep blue to pink during titration with 0.01M HCl. A blank sample underwent the same distillation and titration process.

Exchangeable bases (Calcium and Magnesium)

From the sample, 20ml was pipetted into 250ml conical flask (V_2). Further added 100ml of deionised water and I5ml of concentrated Ammonium solution (used as buffer) was added. Ten (10) drops of 2% KCN (2g of KCN in 100ml deionized water) and ten drops of Hydroxyl Ammonium chloride were utilized as a masking agent. Five (5) drops of Eriochrome black (0.4g EBT + 4g OH NH_2HCl in 100ml alcohol) was used as indicator. Titrate from wine red to deep blue end point using 0.01M EDTA. After a repeat titration, the mean was estimated (Dimkpa *et al.,* 2017).

For Calcium

The procedure began with transferring 20ml of the sample into a 250ml conical flask labeled as V_2. Subsequently, 100ml of deionized water and 100ml of a 20% potassium hydroxide (KOH) solution were introduced. Additionally, 10 drops of 5% Hydroxylamine hydrochloride and 10 drops of 2% KCN were incorporated into the mixture. To ensure uniformity, a small amount of calcein indicator was included. The titration process commenced, shifting the solution's color from wine red to deep blue, employing a 0.01M EDTA solution. The mean value was calculated by repeating the titration procedure (Zhai and Bakker, 2016).

Bulk Density of Soil

The sampler was pressed into the soil's surface, either vertically or horizontally, to fill it but not to the point where the soil was compressed. The sampler and its contents were taken out. Separation was made between the two cylinders holding the inner cylinder's undisturbed soil. The soil extending from both ends were cut and empty cans were weighed (W_1). The soil was put into an already weighted can (W_2). The soil was dried in an oven for about 24 hours at 105^0C and the core sampler's volume was calculated (V). The contents of the can were removed to desiccator and allowed to cool for about an hour, and then weighed (W_3) (Walter *et al.,* 2016).

$$\text{Bulk density} = \frac{W3 - W1}{V}$$

Particle-Size Analysis (Hydrometer method)

Fifty grams (50g) of 2mm sieved, oven-dry soil were placed in a 250ml beaker. Then, 100ml of Calgon (Sodium polyphosphate) was added and left to soak for 30 minutes. Afterward, the mixture was transferred to a dispersing cup, stirred for 3 minutes using a mechanical stirrer, and then quantitatively transferred to a sedimentation cylinder. Distilled water was added to fill the cylinder to the 1000ml mark while a hydrometer was present in the suspension. The contents were thoroughly mixed with the plunger, and after 40 seconds, the hydrometer reading was recorded. The suspension's temperature was measured with a thermometer. This process was repeated to ensure accuracy. Two hours later, another hydrometer reading and temperature measurement were taken (Elfaki *et al.,* 2016).

Nitrogen Determination in Soil

A 500ml Macro Kjeldahl flask holding 2g of soil sample was weighed; 1g of catalyst and 20ml of concentrated sulphuric acid were added; the flask was then cooked on the digesting stand until the solution became clear and the soil residue turned white. The flask was heated continuously for few more minutes to ensure complete digestion. The duration of heating depends on the material and type of heater employed. The system was then allowed to cool. More deionized water of 50ml was added, thoroughly mixed, and then decanted and filtered. The solution was transferred to 100ml volumetric flask up to its 100ml mark with the aid of deionised water after which blank digestion was carried out. The process of digestion was followed by distillation (Wang *et al.,* 2016).

Extraction of Phosphorus

This is determined using the $HClO_4$ digestion and colorimetric analysis. Finely milled soil of 10g was weighed into a 250ml conical flask, and 30ml of Hypochlorate solution was then added. Further digestion was carried out in a fume cupboard at 130^0C until the solution appeared clear. The temperature was increased if and when necessary. After digestion was complete, hypochlorate vapour appeared as a white fume, turning the soil residue white. The flask was then taken out and allowed to cool at ambient temperature. Also, 50ml of distilled water was added and further filtered into a 100ml standard flask and the volume was brought to 100ml mark before the reading was recorded (Zeng *et al.*, 2024).

Determination of Sodium and Potassium

Flame photometry was used to determine potassium. The soil sample as calculated masses were dissolved in separate flasks and made up to one litre to give 1000mg/L stock of Na and K. The solutions were further diluted to 100mg/L by pipetting into 10ml stock solution and made up to 100ml with distilled water. Working standard of 0, 2, 4, 6, 8 and 10mg/L was used. The procedure was repeated and readings were recorded (Garcia *et al.*, 2018).

Metal Analysis

The 2g sample was carefully weighed and put into a 250ml conical flask after being dried for an hour in an oven. Approximately 20ml of Trioxonitrate acid (HNO_3) was added, followed by a controlled heating process. Initially, low heat was applied for about 15 to 20 minutes, followed by a medium heat setting for an additional 30 minutes. Finally, the heat was raised to a high level until complete digestion was achieved. During this process, the flask was periodically rotated to ensure clarity in the solution, which was confirmed by the presence of white vapors. The sample residue was filtered after cooling and added to the digest to make it up to 50ml or 100ml, depending on the needs. Subsequently, the sample was then put into a sample bottle, and an Atomic Absorption Spectrophotometer (AAS) (Varian AA 240FS) was used to determine the concentration of elements like Zn, Cu, As, Pb, Cr, Cd, and Ni. It is important to remember that the AAS machine works best when it is powered on for 30 to 45 minutes prior to the introduction of any sample (Uddin *et al.*, 2016).

Translocation Factor

According to Radulescu *et al.* (2013), translocation factor is calculated as the ratio of the metal content (in mg/kg) in the root to that in the outer leaf or other plant parts (shoot) (mg/kg).

$$TF = \frac{Concentration\ of\ metals\ \left(\frac{mg}{kg}\right)\ in\ the\ receiving\ level\ (shoot)}{Concentration\ of\ metals\ \left(\frac{mg}{kg}\right)\ in\ the\ source\ level\ (root)}$$

Bioaccumulation Factor

Bioaccumulation factor is calculated on the basis of dry weight (Radulescu *et al.*, 2013).

$$BF = \frac{Mp}{Ms} = \frac{Metal\ content\ in\ plant (shoot)\ \left(\frac{mg}{kg}\right)}{Metal\ content\ in\ soil\ \left(\frac{mg}{kg}\right)}$$

Data Analysis

The data obtained from this research underwent a Student's Independent T-test to identify significant differences. Levene's variance test (Levene, 1960) was utilized for this purpose using the SPSS 17.0 software on Windows 8.1.

Results

In the analysis of soil metal concentrations (mg/kg), zinc (Zn) exhibited the highest levels, both at the mine site (1.3870 ± 0.0044 mg/kg) and at the control site (1.2090 ± 0.0029 mg/kg). Conversely, cadmium (Cd) showed the lowest concentrations, with 0.5000 ± 0.0577 mg/kg at the mining site and 0.0010 ± 0.0000 mg/kg at the control site. Similarly, arsenic (As) and chromium (Cr) concentrations were higher at the mining site compared to the control location. Arsenic levels were 0.5010 ± 0.0091 mg/kg at the mine site and 0.0020 ± 0.0000 mg/kg at the control site, while chromium levels were 0.6150 ± 0.0147 mg/kg at the mine site and 0.1073 ± 0.0015 mg/kg at the control site (Table 1). In *Scleria depressa*, the heavy metal concentrations in the roots ranged from 0.0020 ± 0.0001 mg/kg (arsenic, the lowest) to 1.0640 ± 0.1193 mg/kg (zinc, the highest) at the mining site. At the control site, concentrations ranged from 0.0010 ± 0.0010 mg/kg (cadmium, the lowest) to 0.8370 ± 0.0197 mg/kg (zinc, the highest). No significant differences were observed between the two sites. In the shoot, cadmium concentration was significantly higher at the mining site (0.0020 ± 0.0010 mg/kg) compared to the control site (0.0010 ± 0.0000 mg/kg), although the difference was not statistically significant (p = 0.382) (Tables 2 and 3). The physical and chemical parameters of soil at both the mining and control sites were compared (Table 4). The translocation factor (TF) of the selected elements in *Scleria depressa* followed this increasing order of magnitude: TFCd > TFAs > TFCu > TFPb > TFCr > TFNi > TFZn. At the control site, copper (Cu) had the highest TF of 0.94, while lead (Pb) had the lowest TF of 0.33. The mean translocation factor of heavy metals at the control site was in the following order: Pb > As > Ni > Cd > Cu > Cr. This TF pattern indicates the biomobility and transport of heavy metals across different levels (Table 5). In the analysis of the bioaccumulation factor (BF) of heavy metals in *Scleria depressa*, if BF > 1, the plant is considered an accumulator; if BF = 1, there is no influence; and if BF < 1, the plant is classified as an excluder. At the mining site, nickel (BFNi = 3.07), lead (BFPb = 1.27), and copper (BFCu = 1.08) had BF values greater than 1, indicating that these metals were actively accumulated in the plant. In contrast, arsenic (BFAs), zinc (BFZn), and cadmium (BFCd) had BF values less than 1, indicating they were excluders (Radulescu *et al.*, 2013). At the control site, cadmium (BFCd = 4.00) was the most assimilated element, while nickel (BFNi = 0.30) was the least accumulated element (Table 6). The values represent the mean of the element concentration in the top surface soil of two different locations.

Table 1: Concentration of Heavy Metals in the Surface Soil

	Mining Site (mg/kg)	Control Site (mg/kg)	tcal	P-value	Sig.	Remarks
Zinc	1.3870±0.0044	1.2090±0.0029	34.047	0.000	0.482	NS
Copper	0.7650±0.075	0.2090±0.0044	-64.059	0.000	0.234	NS
Arsenic	0.5010±0.0091	0.0020±0.0000	-54.994	0.000	0.020	S
Lead	0.5290±0.0070	0.1010±0.0006	-60.936	0.000	0.078	NS
Chromium	0.6150±0.0147	0.1073±0.0015	-34.296	0.001	0.034	S
Cadmium	0.5000±0.0577	0.0010±0.0000	-8.643	0.013	0.116	NS
Nickel	0.5420± 0.0061	0.0110±0.0006	-86.905	0.000	0.105	NS

Key: S.E: Standard Error; t_{cal}=Calculated t value; NS=No significant difference ($p > 0.05$); S= Significant difference ($p < 0.05$). Each value is the mean of 3 replicates.

Table 2: Concentration (Mean±S.E) of Heavy Metals in the roots of *Scleria depressa*

Element	Mining Site (mg/kg)	Control Site (mg/kg)	tcal	P value	Sig.	Remarks
Zinc	1.0120±0.0023	0.6090±0.0045	-79.546	0.000	0.176	NS
Copper	0.7290±0.0201	0.6970±0.0096	1.436	0.032	0.207	NS
Arsenic	0.0060±0.0010	0.0030±0.0006	-2.598	0.060	0.23	NS
Lead	0.1930±0.0051	0.0850±0.0067	12.847	0.000	0.577	NS
Chromium	0.1290± 0.0026	0.1260±0.0031	12.847	0.000	0.71	NS
Cadmium	0.0040±0.0006	0.0030±0.0000	-1.732	0.158	0.116	NS
Nickel	0.0850±0.0040	0.0510±0.0029	-6.846	0.002	0.417	NS

Key: S.E: Standard Error; t_{cal}=Calculated t value; NS=No significant difference ($p > 0.05$); S= Significant difference ($p < 0.05$). Each value is the mean of 3 replicates.

Table 3: Concentration (Mean±S.E) of Heavy Metals in the shoots of *Scleria depressa*

Element	Mining Site Mean±S.E (mg/kg)	Control Site Mean±S.E (mg/kg)	Ttcal	P-value	Sig.	Remarks
Zinc	1.0640±0.1193	0.8370±0.0197	9.857	0.001	0.356	NS
Copper	0.5020±0.0029	0.4540±0.0281	1.698	0.165	0.105	NS
Arsenic	0.0020±0.0001	0.0020±0.0001	0.000	1.000	1.116	NS
Lead	0.1400±0.0015	0.0390±0.0015	46.754	0.000	1.000	NS
Chromium	0.1190±0.0053	0.1120±0.0012	-1.292	0.266	0.099	NS
Cadmium	0.0020±0.0001	0.0010±0.0010	-1.109	0.382	0.039	S
Nickel	0.0460±0.0021	0.0280±0.0017	6.647	0.003	0.643	NS

Key: S.E=Standard Error; t_{cal}=Calculated t value; NS=No significant difference ($p > 0.05$), S= Significant difference ($p < 0.05$). Each value is the mean of 3 replicates.

Table 4: Comparison of the Physical and Chemical Properties of Soil at Mining and Control Sites

Soil Parameters	Pair	Mean±S.E	N	S.D	Tcal	P-value	Sig.	Remarks
pH	MS	6.97±0.03	3	0.06	-0.085	0.939	0.167	NS
	CS	6.96±0.15	3	0.27				
Conductivity (µs/cm)	MS	1232.00±2.03	3	32.62	-45.748	0.000	0.067	NS
	CS	365.00±18.84	3	3.51				
Porosity (g/cm3)	MS	49.6±0.03	3	0.06	1.302	0.263	0.025	S
	CS	51.6±1.54	3	2.66				
Bulk Density (g/cm3)	MS	1.26±0.75	3	0.13	-0.523	0.629	0.906	NS
	CS	1.21±0.78	3	0.14				
Sodium (cmol/kg)	MS	110.11±2.99	3	5.18	-15.305	0.001	0.185	NS
	CS	58.22±1.60	3	2.77				
Phosphorus (mg/kg)	MS	0.64±0.06	3	0.10	-4.194	0.014	0.872	NS
	CS	0.32±0.05	3	0.09				
Potassium (cmol/kg)	MS	138.00±4.93	3	8.54	-5.141	0.016	0.307	NS
	CS	110.00±2.31	3	4.00				
Calcium (cmol/kg)	MS	2.14±0.20	3	0.35	-0.072	0.946	0.912	NS
	CS	2.12±0.19	3	0.33				
Magnesium (cmol/kg)	MS	1.32±0.20	3	0.35	-1.086	0.38	0.071	NS
	CS	1.10±0.05	3	0.09				
CEC (cmol/kg)	MS	4.21±0.11	3	0.18	0.782	0.497	0.133	NS
	CS	4.42±0.24	3	0.42				
Organic Carbon (%)	MS	1.19±0.04	3	0.07	9.640	0.001	0.048	S
	CS	3.08±0.19	3	0.33				
Nitrogen (%)	MS	0.25±0.04	3	0.07	-1.241	0.293	0.368	NS
	CS	0.15±0.06	3	0.11				

Key: S.E=Standard Error; N=Number of Samples; SD=Standard deviation; t_{cal}=Calculated t value; MS=Mining site; CS=Control site; CEC=Cation Exchange Capacity.

Table 5: Translocation Factor or Mobility Index of Heavy Metals in Soil from Mining and Control Sites

	Translocation Factor (TF)						
SITE	TFZn	TFCu	TFAs	TFPb	TFCr	TFCd	TFNi
Mining site	1.75	0.69	0.67	0.73	0.87	0.33	0.90
Control site	0.83	0.65	0.33	0.05	0.94	0.50	0.33

Table 6 Bioaccumulation Factor of Heavy Metals in Soil from Mining and Control Sites

	Bioaccumulation Factor (BF)						
SITE	BFZn	BFCu	BFAs	BFPb	BFCr	BFCd	BFNi
Mining site	0.74	1.08	0.67	1.27	1.07	0.50	3.07
Control site	0.49	0.59	0.50	1.34	0.53	4.00	0.30

Discussion

The results of heavy metal concentration in soils and plants were found to all be below the WHO permissible limit. The highest permissible level in plants is 0.60mg/kg for Zn, Cu (10mg/kg), As (5mg/kg), Pb (2mg/kg), Cr (1.30mg/kg), Cd (0.02mg/kg), Ni (10mg/kg), and the permissible amount in soil is Zn (50mg/kg), Cu (36mg/kg), As (6mg/kg), Pb (85mg/kg), Cr (100mg/kg), Cd (0.8mg/kg), Ni (35mg/kg) (WHO, 1996). All of the metals examined showed higher levels at the mine site than at the control site. Arsenic, chromium, and cadmium levels were significantly higher, but the remainder were not, which is consistent with the findings of Chizoruo *et al.*, (2017) and *Khan et al.*, (2022).

The results of physical and chemical properties of soils showed that the pH at the mine site was lower than at the control site. This is consistent with the findings of Nwaugo *et al.*, 2007 and Adekiya *et al.,* 2024, who found lower pH at mine sites compared to controls. This is as result of increase used of the land for mining and acid mine drainage. Soils at the mine site show a significantly higher bulk density than those of the control. The increased bulk density at the mine site can be attributed to the presence or use of soil compactors like tractors etc. Organic carbon of soils at the mine site was significantly higher than those of the control. It is the reservoir of necessary and non-essential components for plant growth, and hence plays a vital role in soil productivity (Daulta *et al.*, 2023; Gloria and Katan, 2016), as well as metal solubility in soil (Oladipo *et al.*, 2016; Hamid *et al.*, 2020). Sodium levels were also substantially greater in the mine site than in the control.

Analysis of plants for heavy metals that were below WHO (1996) permissible limits revealed that the concentration of heavy metals in plants at the mine was higher than that of the control, but the difference was not significant except for cadmium in the shoots and arsenic and chromium in the roots, which could be attributed to the metals' inability to be absorbed by the root. It can therefore be induced that the soil at the mine site is suitable for agricultural purposes and plants are also safe for consumption by grazing animals. The translocation factor of some metals tested (Zn) were found to be higher than 1 which showed the biomobility and transport of heavy metals through different levels in the soil.

Bioaccumulation factor of some metals tested in the mine site (copper, lead, chromium, and nickel) and in the control site (cadmium) were found to be higher than 1. According to Radulescu *et al.*, 2013, a bioaccumulation factor greater than 1 one indicates those metals are easily assimilated in plant tissues. This makes them not suitable for consumption by man and animals.

Conclusion

In summary, the analysis of plant and soil samples from the Egbeda mining site in the Saki area revealed the presence of various metals, although the concentrations were relatively low. Notably, zinc had the highest mean concentration in both plants and soils. It's worth noting that the levels of selected elements (including Zn, Cu, As, Pb, Cr, Cd, and Ni) in both plants and soils fell within the permissible limits set by the World Health Organization (WHO) for heavy metals in soils and plants. As a result, there may be less cause for concern in this regard. However, the physicochemical properties of most soil samples from the mining site indicate that they are unsuitable for agricultural purposes.

Recommendations

People’s habitation should be far away from mining sites and miners should be given thorough medical care. Furthermore, gemstone mining should be paid much attention to and miners involved in gemstone mining should always wear appropriate protective. Government should enforce laws against illegal mining, mining activities be well regulated to avoid the destruction of agricultural soils. Also, efforts should be geared towards reducing the negative impact of mining on the environment.

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