

Heavy Metals Contamination of Soils within Mining Sites in Ebonyi North Central Zone, Ebonyi State, Nigeria

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ABSTRACT

Mining activities adversely affect the qualities of the earth crust through accumulation of heavy metals in the soil. This study is planned to assess the heavy metal contamination within mining sites in Ebonyi north central zone, Ebonyi State, Nigeria. The study involves collection of three soil samples from different mining site within Ebonyi north central zone and a control. The soil samples were collected from a depth of 0-20 cm and taken to laboratory for analyses using Standard methods. The heavy metals (Mgkg⁻¹) concentrations range from 0.021-2.217; 14.55-297.21; 31.50-182.668; 0.01-417.667; 0.01-3.564; 1.126-1.774 and 2.925-5.615 for Copper (Cu), Iron (Fe), Zinc (Zn), Lead (Pb), Cadmium (Cd), Nickel (Ni) and Chromium (Cr) respectively. The pollution intensity was assessed using geoaccumulation index which revealed Cu, Ni and Cr unpolluted in all the mining sites, Cd moderately polluted to strongly polluted in all the mining sites, Zn unpolluted to moderately polluted in all the mining sites while Fe was unpolluted in all the sites except in Enyim-Agalagu. Other exception is Pb having unpolluted in Obichie-Ameka, unpolluted to moderately polluted in Enyim-Agalegu and strongly polluted in Enyigba. The consequences of the observed pollution include introduction of pollutants into the soil and its accumulation into microorganisms that live in the soil making the soil unproductive and unsafe for agricultural purposes. This study recommends appointment of community stakeholders from mining areas to relate with Ministry of Environment for continuous monitoring of mining sites. They should also request for management approach for regulation of mining activities within the locations.

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INTRODUCTION

Heavy metals are natural components of the earth crust. They are non biodegradable and as such persist in the environment (Obasi *et al.*, 2020) but found its way into soil and water resources through natural and anthropogenic sources. The natural sources of heavy metals in soil is associated with geochemical processes coupled with soil parental material while the anthropogenic sources is attributed to combustion of fossil fuels, agricultural and mining activities (Eyankware and Ephraim, 2021; Nagajyoti *et al.*, 2010). These activities release metals to the immediate environment which grossly lead to the pollution of the entire ecosystem (Aloh *et al.*, 2017; Obasi *et al.*, 2017).

Metals are considered as heavy when their (specific gravity) density is greater than a value of 5 or 6gcm⁻³ (Arantzazu *et al.*, 2000) and atomic number greater than 20 (Rahman *et al.*, 2013). They could be essential or nonessential to human health depending on their levels and physiological roles they play (Barceloux and Barceloux, 1999; Peralta- Videia *et al.*, 2009). VanBussel *et al.*, 2014 reported that low concentration of heavy metal such as Cu, Ni, Co and Zn, in soil are needed for certain biochemical and physiological processes in living organisms. When this heavy metal exceeds the stated threshold concentrations they may be considered toxic. Ahmad *et al.* (2005) reported that increased heavy metal content in the soil negatively affects soil microbial population, which may have direct negative effect on soil fertility. Cadmium is one of the major heavy metal that is considered to cause harmful effects on physiological processes of animals, humans, plants and aquatic organism (Faroon *et al.*, 2012). According to Obasi *et al.*, (2017) high

concentrations of heavy metal reduce plant growth, lower biomass production, reduces protein content and synthesis of chlorophyll pigments, which could lead to severe reduction in crop yields. Depending on the physicochemical properties of the soil-plant rooting environment, heavy metals accumulate in edible portions of food plants. Man ingests these heavy metals indirectly while consuming heavy metal-contaminated food plants (Obasi *et al.* 2017). Furthermore, heavy metals may be ingested directly from the soil through inhalation or dermal contact (Jaishankar *et al.*, 2014). The knowledge of heavy metals, their accumulation in the soil as well as their effects with the soil properties and qualities are essential in environmental monitoring. This study assesses the effects of different concentrations of some heavy metals within Ebonyi north central zone mining industries, Ebonyi State, Nigeria to ascertain the soil health and quality. This data will be invaluable in environmental policy for mining of heavy metals in the area and sustainability of public health.

Study Sites

The study sites lies within mining sites in Ebonyi north central zone, Ebonyi State. They are Enyim Agalegu (latitude 6° 10' 29" and longitude 8° 8' 8") in Ikwo L.G.A, Enyigba (latitude 6° 11' 30" N and longitude 8° 8' 45") in Abakaliki L.G.A, Ameka (latitude 6° 10' 19" N and longitude 8° 7' 59") in Ezza South L.G.A and Amachara (latitude 6° 10' 55" and longitude 8° 08' 28") in Izzi L.G.A. The mining sites are involved in the extraction of granite, lead, zinc and other quarrying products. It is geographically located on Nigeria's Benue Trough, which is a major mining province with large deposits in the lower and middle Benue regions.

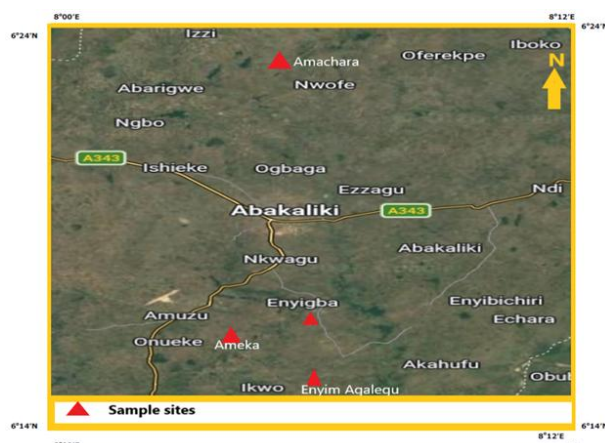


Figure 1: Ebonyi North Central Zone, Showing the Study Sites

Sample Collection and Preparations

Soil sample collection and analysis was done in line with the method outlined by Obasi *et al.* (2020). The soil samples was collected from four different communities (Enyim Agalegu in ikwo LGA, Enyigba izii, Obichie Amaeka Ezza and Amachara) near each facility. Random sampling method was carried out in each location and soil samples were collected at a depth of 0-20 cm using soil auger. A control site (Amachara) was also selected at a distance of 5 km away from the facilities and a composite sample was formed in each locations. All the samples collected was taken to the laboratory, air dried for 2 - 3 days at ambient temperature of 21°C to 27°C. Then, crushed with mortar and sieved through a 10 mesh (2mm) screen sieve before laboratory analyses.

Determination of Heavy Metals

One gram of pulverized and oven dried 50°C soil sample was weighed into a 100ml conical flask. 10ml aqua regia HNO₃: HCl (3:1) was added then boiled with steady heat to almost dryness. It was allowed to cool and leached with 5ml of 6M H₂SO₄. 5ml of distilled water was added and allowed to boil for 10mins. It was then allowed to cool and diluted to 100 ml. The filtrate was filtered using Whatman filter paper no 42. Thereafter, the filtrate was subjected for metal analysis (Cd, Cu, Cr, Pb, Fe, Ni and Zn) using Atomic Absorption Spectrophotometer (AAS) (Varian spectra AA 55B Model)

Pollution Assessment Method

Geoaccumulation index (Igeo) model was used to assess pollution level/intensity of mining sites (Ogunbanjo *et al.*, 2016) using the equation below for the computation as described by Müller, (1969).

$$\text{Geoaccumulation Index (Igeo)} = \text{Log}_2 (C_n/NB_i)$$

Where: N = is the fluctuation coefficient, typically set at 1.5 to account for differences caused by regional geology.

B_i = Average shale values of metals for calculations in crust (World geochemical background concentration) (Carrion-Paladines *et al.*, 2025; Chen *et al.*, 2018)

The average shale values of metals for calculations in crust (World geochemical background concentration) were taken from Turekian and Wedepohl (1961), and they are 0.3, 45, 90, 20, 47200, 68, and 95 for Cd, Cu, Cr, Pb, Fe, Ni, and Zn, respectively. The Igeo for each metal was calculated and classified as follows: unpolluted (Igeo ≤ 0), unpolluted to moderately polluted (0 < Igeo ≤ 1), moderately polluted (1 < Igeo ≤ 2), moderately polluted to strongly polluted (2 < Igeo ≤ 3), strongly polluted (3 < Igeo ≤ 4), strongly to extremely polluted (4 < Igeo ≤ 5), and extremely polluted (Igeo ≥ 5) (Guan *et al.*, 2014; Okedeyi *et al.*, 2014; Ogunbanjo *et al.*, 2016; Adimalla and Wang, 2018).

RESULTS AND DISCUSSIONS

Table 1: Heavy Metals from Mining and Unmining Sites

SN	Parameter (mgk ⁻¹)	Enyim-Agalegu	Enyigba	Obich-Ameka	Control (Amachara)
1	Cu	0.231 ± 0.2	2.217 ± 0.1	0.242 ± 1.2	0.021 ± 0.2
2	Fe	297.210 ± 0.3	35.892 ± 0.03	20.622 ± 0.2	14.550 ± 0.1
3	Zn	182.668 ± 0.3	162.868 ± 0.3	159.54 ±	31.500 ± 0.1
4	Pb	38.377 ± 0.1	417.667 ± 0.3	18.151 ± 0.3	0.01 ± 0.01
5	Cd	3.484 ± 0.3	3.564 ± 0.03	2.145 ± 0.3	0.01 ± 0.01
6	Ni	1.475 ± 0.02	1.774 ± 0.01	1.126 ± 0.01	Nil
7	Cr	5.615 ± 0.3	4.473 ± 0.01	2.925 ± 0.02	Nil

Heavy Metal Concentration in the Mined and Unmined Soil

The results of different study sites from mined and un-mined sites are in decreasing order as follows: Enyim-Agalegu (Fe>Zn>Pb>Cr>Cd>Ni>Cu); Enyigba (Pb>Zn>Fe>Cr>Cd>Cu>Ni); Obichie Ameka (Zn>Fe>Pb>Cr>Cd>Ni>Cu) and Control (Fe>Zn>Cu>Pb>Cd) respectively. The Ni and Cr concentration in the control was below detectable limits. From the results, it could be observed that heavy metals

concentration was high in all the samples within the mined perimeter than that of the control samples as shown in Table 1.0. This observation is in line with the findings of Olanrewaju *et al.*, 2022, who observed that heavy metals concentration was high in all the samples within the mined perimeter than that of the control samples and concluded that mining activities contributes to the accumulation of heavy metals in the soil.

From the study, Pb, in particular, recorded an exceptionally high concentration at Enyigba (417.667 mg/kg), which may

be linked to direct proximity to mine tailings or ore processing areas. This finding is consistent with the report of Nwakanma (2021), who also recorded elevated Pb concentrations in soils close to Enyigba mining pits in Ikwo, attributing it to improper disposal of tailings and leachates that is continuously going on in this location. Anka *et al.*, (2020) affirmed the deductions that the act of manual grinding into fine particles and processing of gold found in lead-rich ore resulted in extensive dispersal into space of lead dust, causing massive environmental contamination from the lead deposits in Abare villages where the gold ore are being processed. The comparison of Pb and Cd concentration with international guideline shows that the concentrations of Pb and Cd in the study areas exceed recommended limits for agricultural soils (FAO/WHO, 2007). This indicates potential ecological and human health risks. Humans and animals get exposed to lead either by direct contact with contaminated soil mass, fine soil particles, air-borne dust, contaminated clothing, shoes or even pets in the house (PennState Extension, 2010) or from drinking water, eating garden produced food contaminated with lead taken up from soil into the plant tissues or lead dust on edible leaves and fruits. The presence of lead particles in the air lead to lead poisoning in children and adults. Lead poisoning in children causes neurological damage leading to reduction in intelligence, loss of memory, learning disabilities and problems of coordination (UNEP, 2003). Lead poisoning

manifestations in adult human populations may include tooth decay, loss of appetite, headache, confusion, apathy, irritability and insomnia (Alka, 2002).

The Fe concentrations in the soil samples investigated were lower than the maximum permissible limit of Fe (2100 mg/kg) reported by World Health Organization, WHO (1996) while the concentration of Zn in the mined perimeter was within the permissible limits in the soil that is between 100 – 300 mgkg⁻¹ (Gilmur and Kittrick, 1979; EU, 2002). According to Yap *et al.* (2009), the significant sources of heavy metals include anthropogenic environmental activities like mining, smelting processes, steel and iron industries, chemical industries, agriculture, and domestic activities. In this content, the sources did not outweigh natural sources like weathering of the parent material and volcanic eruptions. Cadmium concentrations, although lower than Pb and Zn, are still noteworthy given its high toxicity even at trace levels. The observed Cd range (2.1446–3.5643 mg/kg) was above permissible limits of 0.8mg/kg in the soil (WHO, 1996). The concentration of Ni and Cr was below the permissible limits of 10mg/kg (USEPA, 2006) in the mined and non-mined perimeter.

Generally, this report is in line with the results of Nwakanma (2021) who consistently confirmed the presence of heavy metals in concentrations higher in mined areas than un-mined areas.

Table 2: Heavy Metals Pollution Intensity on the Studied Sites

Parameters	(Mg/kg)	Bi	Pollution Level	Pollution intensity
Enyim- Agalegu				
Copper	0.231	45	-8.200	Unpolluted
Iron	297.210	47,200	2.070	Moderately polluted to strongly polluted
Zinc	182.668	95	0.358	Unpolluted to moderately polluted
Lead	38.377	20	0.355	Unpolluted to moderately polluted
Cadmium	3.4836	0.3	2.953	Moderately polluted to strongly polluted
Nickel	1.475	68	-6.118	Unpolluted
Chromium	5.615	90	-4.587	Unpolluted
Enyigba				
Copper	2.217	45	-4.921	Unpolluted
Iron	35.892	47,200	-10.938	Unpolluted
Zinc	162.868	95	0.193	Unpolluted to moderately polluted
Lead	417.667	20	3.800	Strongly polluted
Cadmium	3.564	0.3	2.986	Moderately polluted to strongly polluted
Nickel	1.774	68	-5.878	Unpolluted
Chromium	4.473	90	-4.921	Unpolluted
Obichie- Ameka				
Copper	0.242	45	-7.966	Unpolluted
Iron	20.622	47,200	-1.780	unpolluted
Zinc	159.538	95	0.163	Unpolluted to moderately polluted
Lead	18.151	20	-0.725	Unpolluted
Cadmium	2.145	0.3	2.253	Moderately polluted to strongly polluted
Nickel	1.126	68	-6.506	Unpolluted
Chromium	2.925	90	-5.506	Unpolluted
Amachara (Control)				
Copper	0.021	45	-11.703	Unpolluted
Iron	14.550	47,200	-2.2829	unpolluted
Zinc	31.500	95	-2.177	Unpolluted
Lead	0.01	20	-11.703	Unpolluted
Cadmium	0.01	0.3	-5.4933	Unpolluted
Nickel	ND	68	-	Unpolluted

Parameters	(Mg/kg)	Bi	Pollution Level	Pollution intensity
Chromium	ND	90	-	Unpolluted

ND= Not Detected, Bi=World Geochemical Background Concentration

Table 2.0 shows the heavy metals concentrations on soils from mined and unmined sites, world geochemical background concentration, pollution level and intensity. The pollution intensity was assessed using geoaccumulation index which revealed Cu, Ni and Cr unpolluted in all mining sites, Cd moderately polluted to strongly polluted in all the mining sites and Zn Unpolluted to moderately polluted. The other result shows that Fe, Cd and Pb were generally higher at the mine sites than at the control site.

The concentration of Iron on soil cannot be entirely linked to wastes (Eddy *et al.*, 2004) as its presence could be due to lithological or crustal origin (Levy *et al.*, 1992). The higher concentration of Zn than the control could be attributed to deposit of splashes and Zn high mobility in mining areas (Keller *et al.*, 2002; Krzyztof *et al.*, 2004). Also, Pb was considerably unpolluted to moderately polluted in Enyi-Agalegu, moderately polluted to strongly polluted in Enyigba and unpolluted in Obichie-Ameke (Table 2). The high values of Pb in Enyigba and Cd in all mining sites (Table 2) indicate anthropogenic input resulting from mining activities (Ogunbanjo *et al.* 2016; Guo *et al.*, 2025) thus high ecological and health risk (Obasi *et al.* 2017). Higher level of lead contaminations recorded in the soil was also made by Anka *et al.* (2020) on a cultivated crop having 385 to 688 mg/kg in a farmlands at Abare village. He said, this is not unconnected with the processing of gold contaminated with lead ore in the village. Lead contamination is a phenomenon in which lead content in the environment outweighs natural concentration and causes deterioration of the environmental quality (Rahman *et al.*, 2013). Lead typically occurs in soils at concentrations ranging from 10 to 50 mg/kg but due to contamination from various industrial sources, urban soils often have much greater lead concentrations frequently ranging from 150 mg/kg to as high as 10,000 mg/kg at the base of a home painted with lead-based paints (UNICEF, 2011). Amadi and Chigbu, (2020) conclude that continue unregulated exploitation of ore minerals would escalate heavy metal concentrations causing a shift in soil pH, crop productivity and yield patterns. Guo *et al.*, 2025 illustrated that metal mines have higher Igeo for Cd and Cu, reflecting potentially more severe pollution risks. Cd is readily released as mobile Cd²⁺ ions following sulfide oxidation. The arid climate further amplifies Cd risk by inhibiting leaching and promoting its enrichment in surface soils through evaporation. Cd's high mobility combined with climatic conditions renders it the primary risk driver, necessitating prioritized managements.

CONCLUSION

This study has shown that the concentration of heavy metals within mining sites in Ebonyi north central zone, Ebonyi State has increased when compared to un-mined areas. The pollution intensity revealed that Enyim-Agalegu and Enyigba sites was moderately polluted to strongly polluted with Cadmium in all mining sites while lead had concentration above recommended safe limits at Enyigba. This elevated heavy metal concentration present risks to soil degradation, reduced agricultural productivity, and potential health hazards through food chain accumulation and human exposure. From the study, regular monitoring of heavy metal concentrations in soils especially in Ebonyi north central zone were mining is continually going on is recommended. Also, the Ministry

of Environment and health agencies should be involved for safety of lives and the environment.

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