

Heavy Metal Contamination Assessment in Agricultural Soils of Pb-Zn Mining Areas: A Case Study of Ebonyi State, Nigeria

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Abstract - This study examined the level of heavy metal contamination in the agricultural soils of the Pb-Zn mineralization zone of Ameri, Ameka, Enyigba, and Ishiagu in Ebonyi State, Nigeria. Thirty-three soil samples were collected for analysis for the concentrations of Pb, Zn, Cu, Cr and Cd, using the Atomic Absorption Spectrophotometry (AAS) method. Physicochemical parameters such as pH, EC, and TOC were also determined. The study found that the soil pH ranges from 2.0 to 6.93, averaging 4.17. The results of the heavy metals analyzed ranked as follows: Pb > Zn > Cu > Cd > Cr. The study found that the mean concentrations of lead (Pb) in the excavated soils and quarry soils were 65.76 ppm and 57.03 ppm, respectively, which is higher than the control values. The Contamination Factor (CF) results showed moderate to high contamination levels for Pb and Cd. The study also found that the Enrichment Factor (EF) values indicated the level of anthropogenic activities on the environment. The Pollution Load Index (PLI) confirmed that there is a level of deterioration of the soil environment. The research concludes without doubting the level of heavy metal contamination which is very high, and remediation measures should be put in place to save the environment.

Keywords - heavy metals, soil contamination, Pb-Zn mining, contamination factor, enrichment factor, pollution load index, Nigeria.

I. INTRODUCTION

Mining operations have been identified as one of the prominent human-induced origin of heavy metal pollution in our surroundings. The process of ore formation from mineral deposits releases huge amounts of trace metals into the environment, with soils acting as the major repository of pollutants as reported by (Alloway, 1995; Kabata-Pendias & Pendias, 2001). In Nigeria, the Pb-Zn mineralization belt of the Lower part of the Benue Trough is identified as a region of major concern due to the high levels of pollution caused by past mining activities in the region.

The study area, which covers the Enyigba, Ameri, Ameka, and Ishiagu communities in Ebonyi State, falls within 6°09'N and 6°13'N latitudes and 8°04'E and 8°09'E longitudes. The area has experienced lead and zinc mining operations over the years, leading to the deposition of mine tailings and waste matter

in the soils of the region as reported by (Orajaka, 1965; Nwachukwu, 1972). The geological formation of the area is composed of sediments of the Cretaceous age of the Asu River Group, mainly dark carbonaceous shales with intercalated limestone and volcanic rocks as reported by (Nwajide, 1990).

Soil-borne heavy metals have always been recognized as major pollutants of the environment and human health due to their non-biodegradability and bioaccumulative potential in the food chain as reported by (Brady & Weil, 2005). Lead, cadmium, and other toxic metals in the environment can be transferred from the soil to crops and eventually into the human system through the consumption of the crops as reported by (Cui et al., 2004). The level of pollution is controlled by various factors, including the soil pH, organic matter constituent and varieties of metal pollutants in our environment (Alloway, 1990).

In assessing soil contamination, it is important to use relevant indices that quantify the level of pollution in

comparison to background values. The Contamination Factor (CF) and Enrichment Factor (EF) are common indices that offer information on the level of soil pollution and the relative presence of natural and anthropogenic sources of pollution (Lacatusu, 2000; Birth, 2003). The Pollution Load Index (PLI) is also important in assessing the general level of soil quality deterioration (Tomlinson et al., 1980).

This research aim is to: (i) determine the concentration of heavy metals (Pb, Zn, Cu, Cr Cd,) in the soils around the Pb-Zn mining areas, (ii) evaluating the effect of various physical and chemical parameters, (iii) evaluating the degree of contamination, and (iv) determining the potential sources of contamination through statistical analysis.

II. MATERIALS AND METHODS

Study Area

This research was carried out in five Local Government Areas in Ebonyi State, Southeastern Nigeria, which include Abakaliki, Ikwo, Ezza South, Izzi, and Ezza North Local Government Areas. The area has a tropical to equatorial climate with distinct wet (March to October) and dry (November to February) seasons. Annual rainfall varies within 1200mm to 2300mm, with an average temperature ranging from 25°C to 35°C in the corresponding months. The area is naturally forest with tropical forest vegetation, dominated by palm trees and economic trees, although much has been cleared for farming.



Figure1 Ebonyi State map showing Agricultural zone.

Sampling

Thirty-three samples was collected, made up of 26 samples of soils, 4 samples of borehole water, and 3

samples of plant materials from the study area. The samples were obtained from the abandoned mine areas and quarry sites in the study area. Soil samples were obtained by auguring the soils at depths of 0-15cm and 15-30cm, respectively. Global Positioning System (GPS) readings were obtained for the samples for the purpose of geo-referencing the samples. The random sampling method was used in the research area, and the samples collected was air-dried, sieved with 2mm mesh, and then ground into powder for further analysis.

Analytical Methods

The digestion of soil was carried out using Aqua Regia (25% HNO₃ + 75% HCl). The analysis of total Pb, Zn, Cu, Cd, and Cr was done using Atomic Absorption Spectrophotometer (Unicam model) following the procedure given by Radojevic (1999). The efficiency of extraction was checked by using standard reference materials. The other parameters, i.e.,Electrical Conductivity (EC),Total Organic Carbon (TOC) and pH, went through analyses with the aid of titrimetric methods.

Pollution Indices Calculations

The Contamination Factor (CF) is calculated by dividing the concentration of metals present in the sample by the background concentration, i.e., $CF = C_n/B_n$, where C_n is the concentration of metals present in the sample, and B_n is the background concentration obtained from the control sample (Lacatusu, 2000). The values of CF are used to determine the extent of contamination, which can be categorized as low, moderate, considerable, and very high if CF values are below 1, range from 1 to 3, range from 3 to 6, and above 6, respectively.

The Enrichment Factor (EF) is calculated using the following formula: $EF = (C_m/C_{Fe})_{sample} / (C_m/C_{Fe})_{control}$, where C_m is the concentration of heavy metals, and C_{Fe} is the concentration of iron used as an indicator element (Birth, 2003). EF interpretation: <1 = no enrichment; 1-3 = minor; 3-5 = moderate; 5-10 = moderately severe; 10-25 = severe; 25-50 = very severe; >50 = extremely severe. The Pollution Load Index (PLI) is calculated as: $PLI = (CF_1 * CF_2 * CF_3 * ... * CF_n)^{(1/n)}$, where n is the number of metals.

PLI > 1 represents deterioration in the quality of the soil, while PLI < 1 represents perfection (Tomlinson et al., 1980).

in soils of the study area follows this order: Pb > Zn > Cu > Cd > Cr.

III. RESULTS AND DISCUSSION

Physical and chemical Parameters

Physicochemical parameters showed the presence of acidic conditions in the soils of the study area. pH levels in the abandoned mine areas ranged from 2.0 to 4.00, with an average of 3.64, while the pH levels in the quarry sites ranged from 3.0 to 6.93, with an average of 4.70.

Acidic conditions in the study area are caused by the oxidizing sulphide minerals, such as pyrite and chalcopyrite, in the mine environment.

Electrical conductivity levels ranged from 150-650 $\mu\text{S}/\text{cm}$ in the mine areas and 120-600 $\mu\text{S}/\text{cm}$ in the quarry areas, showing high ionic content caused by brine springs, which are related to the Pb-Zn mineralization zone.

Low levels of total organic carbon were present in the research area, with levels ranging from 0.02% to 2.04% (average 0.46%) in mine soils and 0.029% to 1.02% (average 0.31%) in quarry soils.

The concentration of lead in soils of the study area showed the highest value compared to other metals.

The average concentration of lead in soils of mine areas recorded as 65.76 ppm (range: 22-127 ppm), whereas in soils of quarry areas, it was 57.03 ppm (range: 16.63-121.43 ppm) compared to 2.01 ppm in soils of the control area in mine sites and 0.52 ppm in soils of the control area in quarry sites. The values of lead in soils of the research area far exceeds its permissible limit which is 85 ppm set by WHO (2006) in agricultural soils.

The concentration of zinc in soils of mine areas ranged between 23-120 ppm with an average of 77.49 ppm, whereas in soils of quarry areas, it ranged between 21.14-117.56 ppm with an average of 76.4 ppm.

The high zinc concentration in soils of the studied area is due to the Pb-Zn mineralization in the region. The average copper concentration in soils within the mine areas (22.20 ppm) is relatively low compared to an average value of 30.0 ppm in soils reported by Lindsay (1979).

The cadmium concentration in soils of the study area showed relatively high values indicating significant contamination of soils in the area due to processing of sulphide ore.

Table 1: Physicochemical Parameters of Soil Samples from Study Areas

Parameter	Mine Area	Quarry Area	Control
pH Range	2.0 - 4.0	3.0 - 6.93	6.5 - 7.2
pH Mean	3.64	4.70	6.8
EC ($\mu\text{S}/\text{cm}$)	150-650	120-600	80-150
TOC (%)	0.02-2.04	0.029-1.02	1.5-2.5

Note: TOC = Total Organic Carbon, EC = Electrical Conductivity

Heavy Metal Concentrations

The analysis of heavy metals indicated that their concentration in soils of all study sites is relatively high. The pattern of concentration of heavy metals

Table 2: Heavy Metal Concentrations (ppm) in Soil Sample

Metal	CF (Mine)	CF (Quarry)	CF Class	EF Range	EF Class

higher; (2) restriction of agricultural activities on the highly contaminated soil; (3) monitoring the soil and crop qualities in the mining areas; (4) formulation of environmental management plans for the abandoned mining areas; and (5) health education for the inhabitants of the mining areas.

Acknowledgement

The author gratefully acknowledges the moral support provided by my supervisors Prof E.G Imeokparia and Late Prof I.O Imasuen for their criticism and guidance.

Funding: This research received no external funding.

Conflicts of Interest: The author declares no conflict of interest.

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