RESEARCH ARTICLE

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Environmental Impact Assessment of Mining Activities Around Rimin-Zayam, Toro LGA, Bauchi State

Adepeju Oluwabunmi Ogunleye, Umar Faruk Hassan, Doris Ezekiel Amin Boryo, Harami Malgwi Adamu, and Dahiru Adam Ajiya

ABSTRACT

Mining environment is known for a high level of heavy metals due to the activities which cause adverse alteration of the ecological system. This research study the partitioning of heavy metals in artisanal mining sites in RiminZayan, Toro Local Government Area Bauchi state, Nigeria. The concentration of heavy metals like lead, Cadmium, Iron, Zinc, Cobalt (Co), Copper , Chromium, Manganes and Nickel, were determined using the sequential extraction method recommended by Community Bureau of Reference (BCR) and physic-chemical properties such as the pH, cation exchange capacity, total organic carbon, total organic matter, electrical conductivity and soil particle size. The result show that the soil in the area has a clayey texture with the percentage of clay, slit and sand ranging from 9.29–27.10, 6.31–13.41 and 59.32–84.39 %, respectively. The pH levels of the soil ranged from 6.04 to 6.45 indicating that the soil in thee study is slightly acidic in nature. The observed electrical conductivity (EC) obtained in this study for the samples of soil sediments taken from around the mining site were 26.76, 31,30 and 42.66 µs/cm respectively. The percentages of organic matter of the soil in the same location are 0.423, 0.061 and 0.452 %. Cation exchange capacity (CEC) of the soil in the same vanity were respectively found to be 4.003, 7.385 and 3.994 cmol/kg. The metals were fractionated into six fractions and determined using Atomic Absorption Spectrophotometric techniques (AAS). The results of the soil analysed indicated that there was high abundance of heavy metals such as cadmium, chromium, copper, iron, lead, nickel, and zinc in the residual fraction, pointing to their lithogenic origins, and therefore primarily inherited from the parent material. Cobalt and manganese are bound to other fractions (exchangeable, carbonate, manganese oxide, iron-manganes oxide, organic matter-sulphide, and residual metals which shows their anthropogenic origin. The ratio of bioavailability factor (BF) ranged from 27.47 to 89.66, Contamination factor showed values ranging from 0.001 to 16.299 which suggests that some soils were not contaminated while some were moderately contaminated metals investigated. The degree of contamination (DC) showed that the highest recorded were from non - mining area (19.517) while active mining sites and abandoned mining sites values are: 5.985 and 3.843, respectively. This trend could be owing to the bioavailability and mobility of the metals from the mining sites to non-mining locations. The data generated were subjected to one-way ANOVA. The least significant difference test ($p \leq 0.05$).

Keywords: Contamination factor, degree of contamination, Enrichment factor, Geo-accumulation index.

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A. O. Ogunley*
Federal College of Education (T) Bichi, Nigeria.
(e-mail: lizzycrown478@gmail.com)
Dr. U. F. Hassan
Department of Chemistry, Abubaka Tafawa Balewa University, Nigeria.
Prof. D. E. A. Boryo
Department of Chemistry, Abubaka Tafawa Balewa University, Nigeria.
Prof. H. M. Adamu
Department of Chemistry, Abubaka Tafawa BalewaUniversity, Nigeria.
D. A. Ajiya
Department of Chemistry, Abubaka Tafawa BalewaUniversity, Nigeria.

**Corresponding Author*

I. INTRODUCTION

Pollution investigations in soil of the mining site revealed that human activities can adversely alter the ecological integrity of fragile soil systems in the region, resulting in bioaccumulation of chemical contaminants by heavy metals [1]. Sediment enrichment and impact on species abundance and biomass in soils of the environment as well as trace metals are naturally ubiquitous [2].

The fate, transport, and pollution characteristics of trace metals in the soils have become an important problem due to their toxic effects, accumulation and bioconcentration through the food chain [1]. Trace metals introduced into the environment are capable of having toxicological implications on terrestrial invertebrates, humans, and the natural environment [3]. Adverse health effects such as lung and skin cancer, prostatic proliferative lesions, peripheral neuropathy, kidney dysfunction, dermal lesions, and peripheral vascular disease, have been attributed to trace metals pollution. Metal toxicity mainly depends on the metal speciation and bioavailability, as well as on the means of uptake, accumulation, and excretion rates of the organisms [3]. Mining refers to the process of extraction of mineral deposits from the surface of the earth or from beneath the surface [4]. Mining may well have been the second of humankind's earliest endeavours, while agriculture was the first. The two industries ranked together as the primary or basic industries of early civilization. Little has changed in the importance of these industries since the beginning of civilization.

II. Materials and Methods

The surface soil layer at a depth of 0–20 cm (ploughing layer) was sampled with a stainless steel trowel. Each sample was a composite of 20 sub-samples from already mined locations, presently mining locations and the control (where there were no mining activities) in the area was geographically located. The sample was kept in labelled polythene bags for laboratory analyses. The samples were air-dried in the laboratory for two weeks before being crushed in a ceramic pestle and mortar, sieved through a 2 mm screen plastic sieve, and dried to constant mass in an oven at 75 C. Aliquote of soil sample was digested using a tri-acid mixture of $HClO_4$, HNO_3 and H_2SO_4, filtered using Whatman filter paper number 1into a 100 cm volumetric flask and water was added to mark. The levels of the heavy metals of interest were determined at their wavelengths using Atomic Absorption Spectroscopy model number OMP – AES 4200. The levels of heavy metal concentrations in the soil samples were evaluated for parameters such as enrichment factor, Geo accumulation, Contamination factor and Degree of Contamination.

A. Enrichment Factor

The enrichment factor (EF) was calculated based on the standardization of the tested heavy metal against the concentration of the reference metal [5], [6].

$$\text{Ef} = \frac{Cn(sample)/Cref(sample)}{Bn(background)/Bref(background)}$$

where, EF is the enrichment factor, Cn (sample) = concentration of the examined metals in the soil sample, C_{ref} (sample) = concentration of the reference metal in the soil sample, Bn (background) = concentration of the examined metal in the background sample and B ref(background) = reference metal's concentration in the background sample.

B. Geo-Accumulation Index

Geo accumulation index was calculated using the method by Muller [7] expressed as follows:

$$I\ geo = \log_2 [Cn / 1.5Bn]$$

where, Cn is the measured concentration of heavy metals in soil sample, Bn is the concentration of metal in the background. The correction factors 1.5, is introduced to minimize the effect of the possible variation in the background or control values which may be attributed to lithogenic variation in the sample [7] and [6].

C. Contamination Factor (CF)

The level of contamination of soil by metals is expressed in terms of contamination factors (CF) calculated [8]:

$$\text{CF} = \frac{Cm\ sample}{CmBackground}$$

where Cm sample is the concentration of a given metal in soil sample. Cm Background is the concentration of an element in the background soil sample. Four contamination categories are recognized on the basis of the contamination factor (CF), and its interpretation is as follows: Cf<1 means low contamination factor, 1<Cf<3 means moderate contamination factor, 3<Cf<6 means considerable contamination factor and Cf>6 means very high contamination factor.

D. Degree of Contamination (C_{deg})

The contamination factor described above is a single element index. The sum of contamination factor for all the elements examined represents the contamination degree (C_{deg}) of the environment and four classes are recognized as follows: $C_{deg}<8$ means low degree of contamination, $8<C_{deg}<16$ means moderate degree of contamination, $16<C_{deg}<32$ means considerable degree of contamination and $C_{deg}>32$ means very high degree of contamination.

III. Results and Discussion

The RAC was applied in this study based on the values of the exchangeable bound fraction of the metal as a percentage of the availability of the metals in the soil sediment. Generalizing, the RAC of cadmium, chromium, copper, iron, manganese, and nickel exhibited low to medium risks, being that their percentages in the exchangeable fractions are less than 40%, indicating that the release of metals into solution is undetectable and safe to the environment. The other metals of lead and zinc exhibited medium to high risk, which was at elevated percentages >50%, hence were considered highly dangerous and can easily enter the food chain [9]. This risk of Lead in the studied environment is probably a result of gold mining.

TABLE I: Risk assessment Code of HEAVY metals in the Soil Segments Sampled from the Mining Areas around Rimin-Zayam, Toro LGA, Bauchi State

Location	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Active	15.5	5.2	7.1	0.4	379	--	37.2	99.7
Abandoned	16.3	5.6	9.9	0.5	0.8	0.7	40.1	100
Non-mining	17.9	16.0	17.0	0.6	0.62	0.6	100	100

At the abandoned mining site, the RAC values for the soil sediments revealed that cadmium, chromium, copper, iron, manganese, and nickel exhibited low, exhibiting percentages of the exchangeable fractions to be less than 10%, hence were classified as low risk and indicating that their release into the environment was within the safe limit. The RAC value for the lead was 27.2% which was within the 10–30% classification used to designate medium environmental risks, while, Zinc had the RAC value of 89.7%.

At the active mining site, the RAC values for the soil sediments revealed that iron, manganese, and nickel exhibited low, exhibiting percentages of the exchangeable fractions to be less than 10%, hence were classified as low risk and indicating that their release into the environment was within the safe limit. The RAC value for chromium and copper was 27.2% which was within the 10–30% classification used to designate medium environmental risks. The RAC value for cadmium was 36% which was within the 30–50% classification used to designate high environmental risks. While lead and zinc had the RAC value>50%.

In this study, the geochemical background reference used in the Igeo calculations were soils taken at a depth of 50cm at the respective locations. The index of geo–accumulation was assessed based on the seven descriptive classes proposed by Müller (1979) and it showed that the mean values of the geo–accumulation index for all the metals ranged from 0.007 to 183.733, suggesting that some soils were not contaminated whilst, others were moderately contaminated.

TABLE II: Geo-accumulation Index of Heavy Metals in the Soil Sediments Sampled from the Mining Areas around Rimin-Zayam, Toro LGA, Bauchi State

Location	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Active	--	0.2955	--	0.0205	0.1556	0.0228	--	0.00032
Abandoned	--	0.5675	--	0.0432	0.5968	0.0070	--	0.0006
Non-mining	--	0.3697	--	0.0179	0.2479	0.0.0131	3.2653	0.00013

TABLE III: Enrichment Factor of the Heavy Metals Present in the Soil Sediment Sampled from the Active Mining Site at Rimin-Zayam

Location	Cd	Cr	Cu	Mn	Ni	Pb	Zn
Active	0	9.796	0	8.835	1.049	0	0.16
Abandoned	0	13.136	0	13.82	0.162	0	0.008
Non-mining	0	20.631	0	13.77	0.722	183.733	0.007

The calculated values of the geo–accumulation in soils as presented in Table II and are discussed in conjunction with the enrichment factor of the metals which are presented in Fig. 1. According to the classes established for I_{geo}, the analyzed sediments can be considered unpolluted to moderately polluted by the elements cadmium, copper, nickel, and zinc, moderately polluted by the elements by the elements of chromium and manganese and polluted by zinc, in accordance with the results obtained in the EF analysis. This may be attributed to differences in the soil matrix such as its contents of organic matter, variation in pH and redox potential.

At the active mining site, the values of geo-accumulation index ranged from 0.0006 to 0.5968, indicating that they were all within the limits of $0<I_{geo}\leq1$, implying that the soil samples were unpolluted to moderately polluted by their presence. Cadmium (0), chromium (0.2955), copper (0), iron (0.0205), manganese (0.1556), nickel (0.0228), lead (0) and zinc (0.00032). The negative values in the indexes of geo–accumulation for chromium, iron, manganese, nickel, and zinc as shown in Fig. 1 were as a result of deficient to minimal enrichment and in general is comparable to results reported for enrichment factor. It was observed that the soil was negligibly enriched with the metals of cadmium (0), chromium (9.796),

copper (0), manganese (8.835), nickel (1.049), lead (0) and zinc (0.16) hence no indication of significant soil enrichment by these metals.

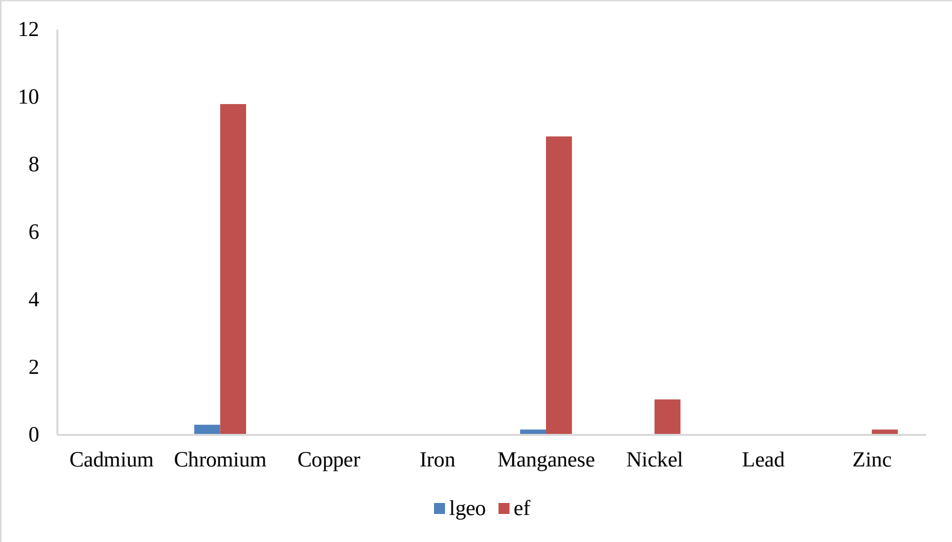

Fig. 1. Comparison of the geo-accumulation index and Enrichment factors of heavy metals in the soil sediments sampled from the active mining areas around Rimin–Zayam, Toro LGA, Bauchi state.

At the abandoned mining site, the values of the geo-accumulation index ranged from 0.00032 to 0.2955, thus revealing that the soil sediments were unpolluted to moderately polluted by the metals present. A breakdown indicates that the levels of seven metals of cadmium (0), chromium (0.5675), copper (0), iron (0.0432), manganese (0.5968), nickel (0.0070), lead (0) and zinc (0.006) in the soil poses no concern for been flagged for pollution risk, while those of chromium (0.5675) and manganese (0.5968) can be identified as causing minimal pollution to the soil. This value in the indexes of geo-accumulation of iron, manganese, nickel, and zinc as shown in Fig. 2wasas a result of deficient to minimal enrichment and in general is comparable to results reported for enrichment factor. The values of enrichment factor for the studied metals obtained in this study are also shown in Figure 2 and were observed in the ranges of 0.008 to 13.82. In general, it was found that the surface sediments were negligibly enriched with cadmium (0), copper (0), lead (0), nickel (0.162) and zinc (0.008). However, chromium (13.136) and manganese (13.82) indicated significant enrichment with an enrichment factor signifying significant soil enrichment by the metals.

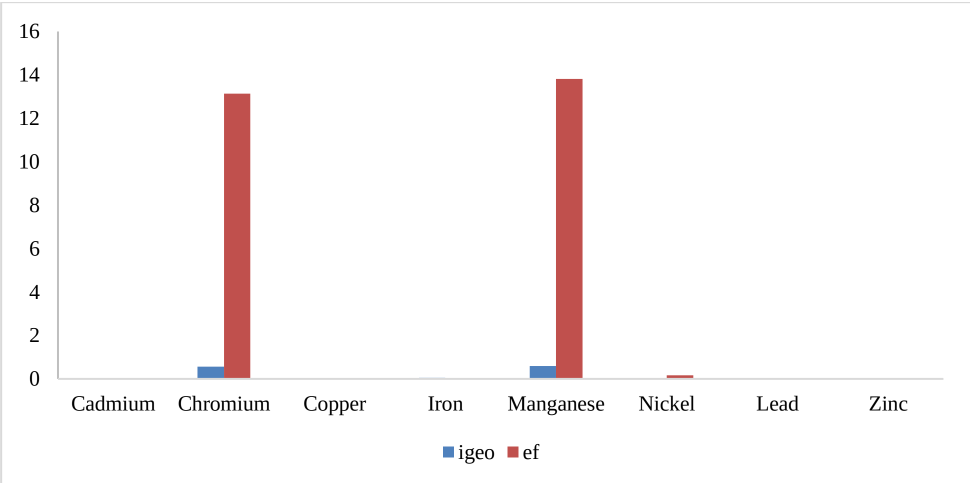

Fig. 2. Comparison of the geo-accumulation index and Enrichment factors of heavy metals in the soil sediments sampled from the abandoned mining areas around Rimin-i–Zayam, Toro LGA, Bauchi State.

In the non–mining area, the values of the geo-accumulation index ranged from 0.00013 to 3.2653 thus revealing that the soil sediments were unpolluted to moderately polluted by the metals present. A breakdown of this, revealed that the levels of seven metals of cadmium (0), chromium (0.3697), copper (0), iron (0.0179), manganese (0.2479), nickel (0.0131) and zinc (0.00013) in the soil fell under the classification designated as $0 < Igeo \leq 1$, implying that the soil samples were unpolluted to moderately polluted by their presence. Lead however had an index of 3.2653 which is within the classification$1 < I_{geo} < 5$ thus indicating it poses moderate pollution to the habitat. These negative values of the indexes of geo-accumulation of iron, manganese, nickel, and zinc as shown in Figure iii were as a result of deficient to minimal enrichment and in general, is comparable to results reported for enrichment factor. The values of enrichment factors for the studied metals obtained in this study as shown also in Fig. 3. While it was found that the surface sediments were negligibly enriched by the other metals, with lead having a value at 183.733 indicated significant soil enrichment which might pose toxic and harmful health risk to both plants and animals.

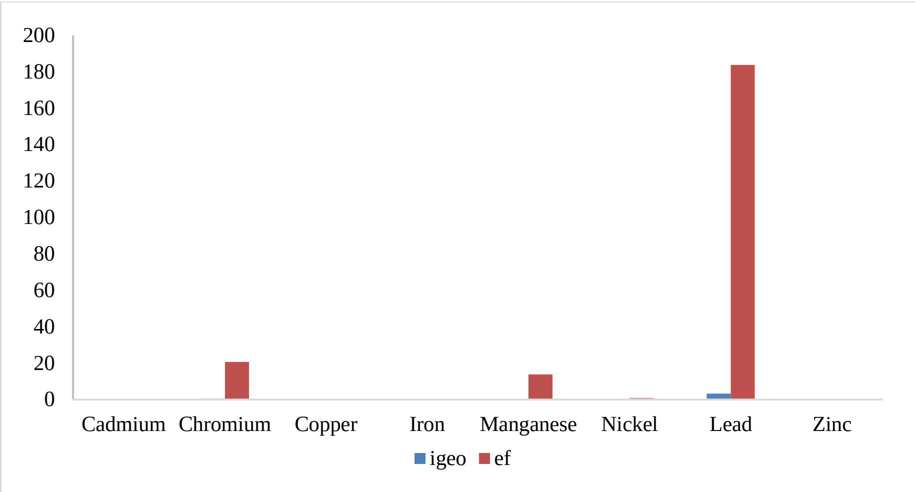

Fig. 3. Comparison of the Geo–accumulation index and Enrichment factors of heavy metals in the soil sediments sampled from the non- mining areas around Rimin-Zayam, Toro LGA, Bauchi state.

The contamination factor showed values ranging from 0.001 to 16.299, which suggest that some soils were not contaminated whilst, others were moderately contaminated by the metals present.

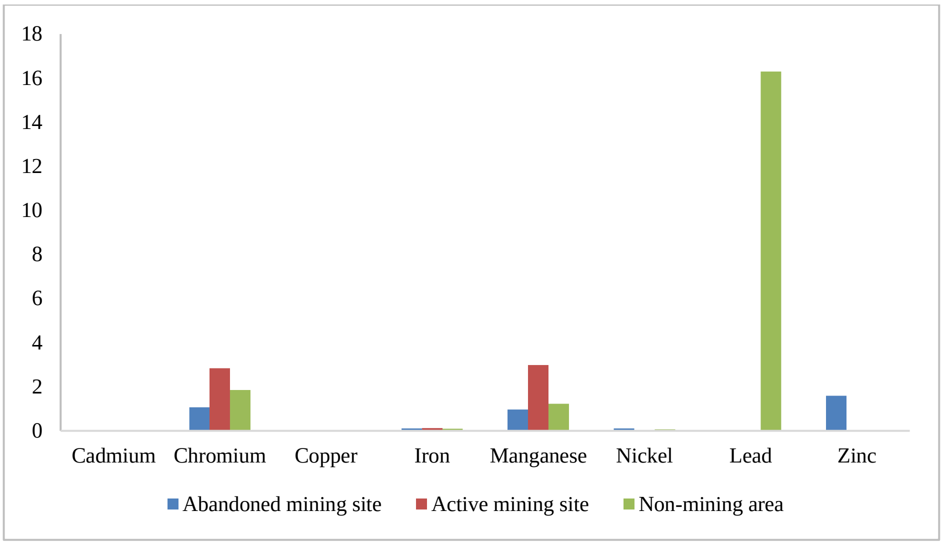

Fig. 4. Contamination factors of heavy metals in the soil sediments sampled from the mining areas around Rimin-Zayam, Toro LGA, Bauchi state.

At the active mining site, overall contamination of soils at the site assessed based on the contamination factor indicated considerable contamination by manganese and chromium, but showed no contamination by cadmium, copper, iron, nickel, and lead being that their calculated CF<1.5. On the basis of the mean values of CF, sediments were mostly enriched with the metals of chromium and manganese in the following order: Cr>Mn>Ni>Zn. This clearly indicated that the soils at this site have been largely polluted by chromium and manganese which are projected to have been contributed directly and indirectly from the mine dumps within the vicinity.

The degree of contamination (CD) as calculated is presented in Fig. 5 which shows that the non-mining area has the highest level of contamination with a value of 19.517 when compared to the active mining site with a value of 5.985 and the abandon mining sites with its at 3.843. This trend could be attributed to the bioavailability and mobility of the metals from the mining locations to the non-mining locations.

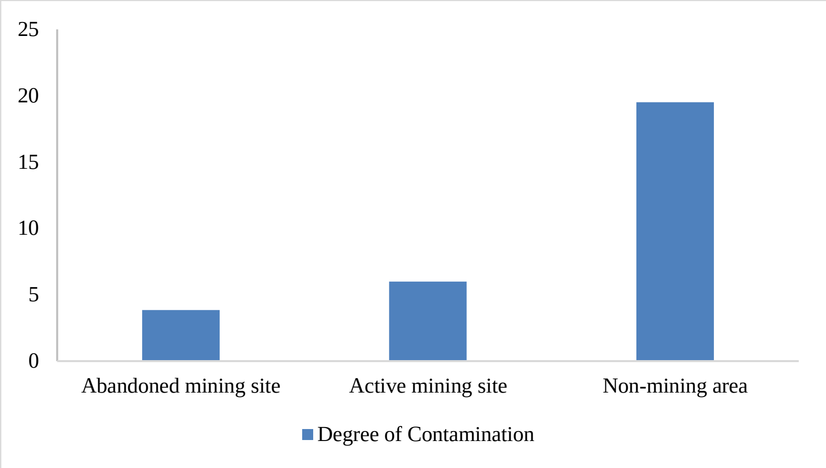

Fig. 5. Degree of Contamination by heavy metals in the soil sediments sampled from the mining areas around Rimin-Zayam, Toro LGA, Bauchi state.

The pollution load index provides an integrated contamination assessment based on the Cf of each trace metal. The PLI values for all three locations are presented in Figure vi and were estimated at 3.843, 5.985 and 19.17, respectively, for the active, abandoned, and non-mining areas. This indicated that the soils were uncontaminated, moderately to heavily contaminated by investigated metals, since some of the studied metals exceeded the background metal concentration. However, it must be noted that the PLI values obtained for soil samples were dominated by individual contributions of lead and chromium.

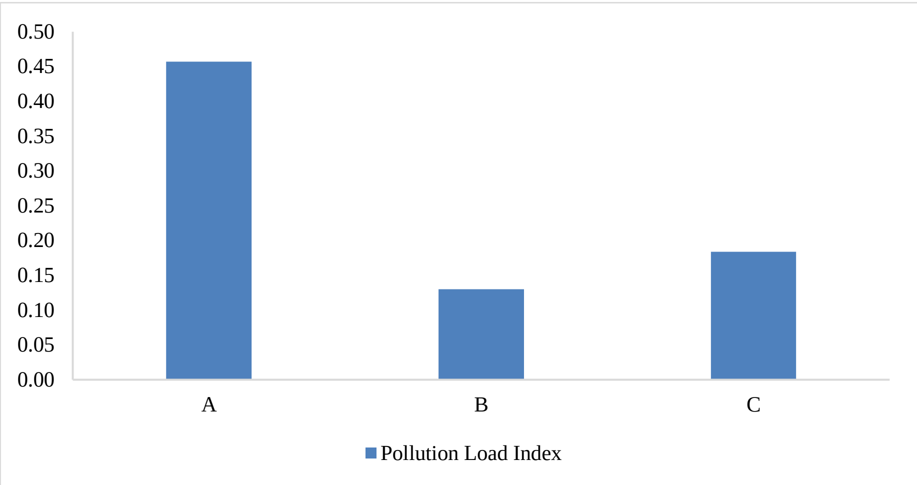

Fig. 6. Pollution load Index of heavy metals in the soil sediments sampled from the mining areas around Rimin–Zayam, Toro LGA, Bauchi state.

IV. Conclusion

From the deductions made from the Geo-accumulation index, Pollution Index and Contamination factors, in which it was observed that there was a significantly introduction of highly labile Cobalt as well as high abundance of lithogenic chromium and lead in the soil. Thus, it is necessary to recommend that a Soil-Plant correlation in terms of Bio-concentration factor and transfer factors should be made as to whether there will be transfer of such in the food chain is significant and could as such pose any health risk on both humans and animals.

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