Journal of Radiation and Nuclear Applications
An International Journal

http://dx.doi.org/10.18576/jrna/070310

Pollution Load Index of Heavy Metals Resulting from Mining Activities in Plateau State, Nigeria

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Received: 9 Jun. 2022, Revised: 19 Jul. 2022, Accepted: 25 Aug. 2022.
Published online: 1 Sep 2022.

Abstract: Accumulation of heavy metals in agricultural soils, plant and water are aggressed by industrial and other human activities such as mining. Plants received heavy metals from soils through ionic exchange, redox reactions, precipitation-dissolution, and so on. The work intends to evaluate the extent to which the water, soil and plants in parts of Plateau State are polluted through a factor known as pollution load index. The results revealed that, the Contamination Factor for heavy metals in Bassa, Jos South, Barkin Ladi, Mangu and Jos East have their values in trend with Cr (0.04) > As (0.013) > Pb (0.006) > Ni (0.005) > Cd (0.003) for water, Cr (75.2) > Pb (74.8) > Ni (43.6) > As (24.4) > Cd (3.58) for soil and Ni (5.4) > Pb (1.72) > Cr (0.71) > Cd (0.03) > As (0.028) for plant. It can therefore be concluded that the soil, water and plants in the study area are seriously polluted and call for serious concern and regulatory control.

Keywords: Heavy Metals; Soil; Edible Plant; Water; Pollution Load Index.

1 Introduction

Accumulation of heavy metals in agricultural soils is instigated by industrial and other human activities such as mining, smelting, cement-pollution, energy and fuel production, power transmission, traffic activities, intensive agriculture, sludge dumping and melting operations [1-5]. Plants received heavy metals from soils through ionic exchange, redox reactions, precipitation-dissolution, and so on. Which implies that the solubility of trace elements based on factors like minerals in the soil (carbonates, oxide, hydroxide etc.), soil organic matter (humic acids, fulvic acids, polysaccharides and organic acids), soil pH, redox potential, content, nutrient balance, other trace elements concentration in soil, physical and mechanical characteristics of soil, soil temperature and humidity, etc. [6-9]. The bioavailability of metals in soil is a variable process which is based on specific combinations of chemical, biological, and environmental parameters [10, 11]. Metals distribution in plants is very heterogeneous and is governed by genetic, environmental and toxic factors. The variation of heavy metals in plant-soil association is based mainly on the levels of soil contamination and plant species [12, 13]. Plants traps heavy metals from the soil through the root and from the atmosphere through over ground vegetative organs [14]. Some plants species have lower tolerance to toxic metals absorption in polluted mine soil as they accumulate high concentrations of Ni, Cr, As, Cd, and Pb [15]. More so, different plant species grown in the same soil may have different concentration of the same element [16]. Some authors have reported the existence of differences in accumulation of heavy metals in plant cultivars, age of plants, plant organs and tissues [17-20]. The same heavy metals can contaminate water through erosion, where heavy metals are flushed to our rivers and streams and we consume them. Pollution Load Index of metals in water, soil and edible plant tissues is studied using an index called Pollution Load Index [21, 22]. In this work, we intend to evaluate the extent to which the water, soil and plants in parts of Plateau State are polluted through a factor known as pollution load index.

2 Materials and Methods

2.1 Materials

The materials that will be used in carrying out this research are;

i. Hand trowel
ii. Plastic containers

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iii. Hand gloves
iv. polyethylene sampling bottles
v. Geo-positioning System meter (GPS meter)
vi. Masking tape
vii. Permanent marker and Joter
viii. X-Ray Fluorescence Spectrometry System (XRF)

2.2 Method

2.2.1 The Study Area

Plateau is the twelfth-largest state in Nigeria. Approximately in the centre of the country, it is geographically unique in Nigeria due to its boundaries of elevated hills surrounding the Jos Plateau which is its capital, and the entire plateau itself [23].

Plateau State is celebrated as "The Home of Peace and Tourism". With natural formations of rocks, hills and waterfalls, it derives its name from the Jos Plateau and has a population of around 3.5 million people. Plateau State is located at North Central Zone out of the six geopolitical zones of Nigeria. With an area of 26,899 square kilometers, the State has an estimated population of about three million people. It is located between latitude 08°24'N and longitude 008°32' and 010°38' east. The state is named after the picturesque Jos Plateau, a mountainous area in the north of the state with captivating rock formations. Bare rocks are scattered across the grasslands, which cover the plateau. The altitude ranges from around 1,200 metres (3,900 ft) to a peak of 1,829 metres (6,001 ft) above sea level in the Shere Hills range near Jos. Years of tin and columbite mining have also left the area strewn with deep gorges and lakes [23].

Though situated in the tropical zone, a higher altitude means that Plateau State has a near temperate climate with an average temperature of between 13 and 22 °C. Harmattan winds cause the coldest weather between December and February. The warmest temperatures usually occur in the dry season months of March and April. The mean annual rainfall varies between 131.75 cm (52 in) in the southern part to 146 cm (57 in) on the Plateau. The highest rainfall is recorded during the wet season months of July and August. The average lower temperatures in Plateau State have led to a reduced incidence of some tropical diseases such as malaria. The Jos Plateau makes it the source of many rivers in northern Nigeria including the Kaduna, Gongola, Hadeja and Damaturu rivers. The Jos Plateau is thought to be an area of younger granite which was intruded through an area of older granite rock, making up the surrounding states. These "younger" granites are thought to be about 160 million years old. This creates the unusual scenery of the Jos Plateau. There are numerous hillocks with gentle slopes emerging from the ground like mushrooms scattered with huge boulders. Also, volcanic activity 50 million years ago created numerous volcanoes and vast basaltic plateaus formed from lava flows. This also produces regions of mainly narrow and deep valleys and pediments (surfaces made smooth by erosion) from the middle of rounded hills with sheer rock faces. The phases of volcanic activities involved in the formation of Plateau State have made it one of the mineral rich states in the country. Tin is still mined and processed on the plateau [23].

Plateau State is known as The Home of Peace and Tourism in Nigeria. Although the tourism sector isn't thriving as much as it should due to meagre allocations to it by the State Government, its natural endowments are still attractions to tourists mostly within Nigeria [23].

The geographical coordinates of the data points are tabulated in Table 1 and the map of Nigeria showing Plateau state, the map of Plateau state showing the mining Local Governments and map of mining Local Government showing the sample points are shown respectively in Figure. 1, 2 and 3.

Table 1: Geographical Coordinates of the Data Points.

Village	Sample Points	Geographical Coordinates	
		East	East
Bassa	PT01	8°44'34.8"	10°09'39.6"
	PT02	8°40'58.8"	10°06'50.4"
	PT03	8°41'49.5"	10°06'00.00"
	PT04	8° 46' 4.8"	10° 4' 30"
	PT05	8° 51' 7.2"	10° 6' 57.6"
	PT06	8° 54' 3.6"	10° 7' 55.2"
	PT07	8° 50' 56.4"	10° 3' 57.6"
	PT08	8° 48' 3.6"	10° 0' 32.4"
	PT09	8° 41' 52.8"	9° 57' 21.6"
	PT10	8° 46' 37.2"	9° 56' 2.4"
	PT11	8° 43' 4.8"	9° 51' 46.8"
	PT12	8° 39' 3.6"	9° 44' 42"
Jos South	PT01	8° 49' 48"	9° 50' 42"
	PT02	8° 52' 33.6"	9° 49' 37.2"
	PT03	8° 49' 4.8"	9° 47' 34.8"
	PT04	8° 55' 55.2"	9° 46' 51.6"
	PT05	8° 48' 21.6"	9° 45' 10.8"
	PT06	8° 52' 48"	9° 44' 24"
	PT07	8° 53' 34.8"	9° 43' 22.8"
	PT08	8° 51'	9° 43' 1.2"
	PT09	8° 44' 2.4"	9° 42' 54"
	PT10	8° 43' 8.4"	9° 40' 19.2"
	PT11	8° 45' 46.8"	9° 40' 1.2"
	PT12	8° 49' 51.6"	9° 39' 32.4"
Barkin Ladi	PT01	9° 4' 55.2"	9° 40' 33.6"
	PT02	9° 1' 30"	9° 37' 55.2"

	PT03	8° 58' 1.2"	9° 36' 39.6"
	PT04	8° 55' 26.4"	9° 34' 19.2"
	PT05	9° 0' 25.2"	9° 30' 36"
	PT06	8° 59' 31.2"	9° 27' 25.2"
	PT07	8° 55' 8.4"	9° 28' 33.6"
	PT08	8° 48' 25.2"	9° 29' 20.4"
	PT09	8° 53' 13.2"	9° 23' 13.2"
	PT10	8° 43' 55.2"	9° 22' 55.2"
	PT11	8° 42' 57.6"	9° 21' 10.8"
	PT12	8° 44' 13.2"	9° 20' 34.8"
Mangu	PT01	9° 9' 57.6"	9° 42' 21.6"
	PT02	9° 6' 21.6"	9° 34' 19.2"
	PT03	9° 13' 8.4"	9° 33'
	PT04	9° 11' 52.8"	9° 31' 30"
	PT05	9° 12' 36"	9° 29' 34.8"
	PT06	9° 17' 20.4"	9° 28' 22.8"
	PT07	9° 15' 21.6"	9° 25' 40.8"
	PT08	9° 11' 20.4"	9° 25' 58.8"
	PT09	9° 4' 1.2"	9° 25' 12"
	PT10	9° 8' 6"	9° 7' 55.2"
	PT11	9° 16' 30"	9° 6' 57.6"
	PT12	9° 12' 18"	9° 4' 1.2"
Jos East	PT01	9° 13' 22.8"	10° 0' 57.6"
	PT02	9° 7' 37.2"	10° 0' 7.2"
	PT03	9° 4' 8.4"	9° 59' 24"
	PT04	9° 0' 46.8"	9° 57' 50.4"
	PT05	9° 3'00.00"	9° 57' 3.6"
	PT06	9° 0' 46.8"	9° 55' 51.6"
	PT07	9° 0' 28.8"	9° 53' 45.6"
	PT08	9° 8' 2.4"	9° 55' 8.4"
	PT09	9° 13' 8.4"	9° 53' 20.4"
	PT10	9° 8' 24"	9° 51' 57.6"
	PT11	9° 13' 1.2"	9° 49' 4.8"
	PT12	9° 6' 21.6"	9° 46' 12"

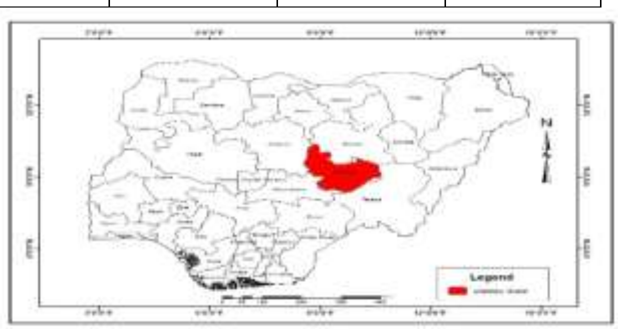

Fig. 1: Map of Nigeria Showing Plateau State.

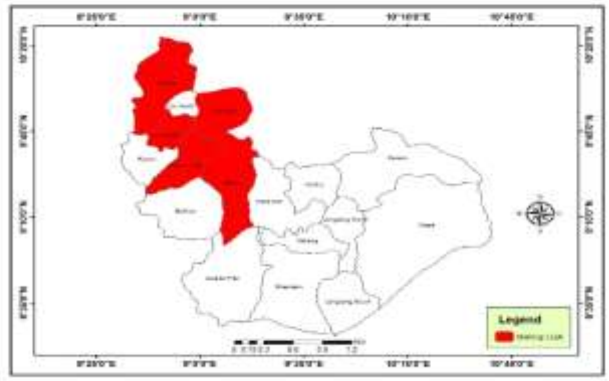

Fig. 2: Map of Plateau State Showing Mining Local Government Areas.

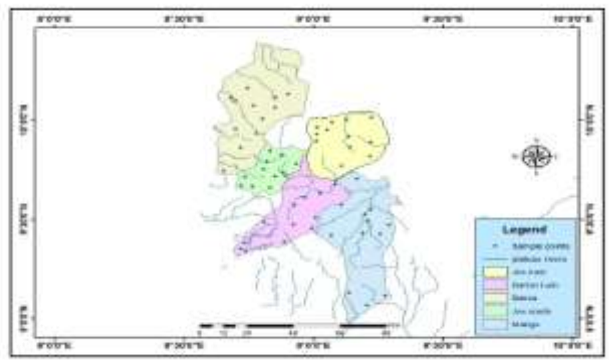

Fig. 3: Map of Mining Local Government Areas Showing Sample Points.

2.2.2. Population Sample

The population of the study include all the notable towns where mining activities takes place within Plateau State which include 5local governments (Mangu, Barkin Ladi, Jos South, Jos East and Bassa) with 95 villages.

2.2.3. Sample Collection

Soil, water and vegetable samples were pair collected. A simple systematic random sampling technique was used to select twenty (12) soil sample, twenty (12) edible plant sample, and twenty (12) water samples from each of the five (5) Mining local government of Plateau State. One hundred and Eighty (180) samples in all (36 per local government) were analyzed in this study. Vegetables' rooted soil samples were taken at 0-20 cm depth. A composite sample composed of three (3) subsamples at each sampling site for water, vegetables and soils.

2.2.4. Soil Sample Collection

Twelve sample of soil from the Mining local government of Plateau State was collected. The sample was collected by coring tool to a depth of 5 cm or to the depth of the plough line. The collected samples each of approximately 4 kg in wet weight was immediately transferred into a high-density polyethylene zip lock plastic bag to prevent cross contamination. Each sample was marked with a unique identification number (sample ID) for traceability and its position coordinates were recorded for reference purposes using GPS meter.

2.2.5. Edible Plant Sample Collection

Twelve edible plant samples were collected from the Mining local government of Plateau State. The collected samples were immediately transferred into a high-density polyethylene zip lock plastic bag to prevent cross contamination. Each sample was marked with a unique identification number (sample ID) for traceability.

2.2.6. Water Sample Collection

Twelve water samples were collected from streams from the Mining local government of Plateau State. The collected samples were immediately transferred into plastic containers and was well covered to avoid cross contamination. Each sample was marked with a unique identification number (sample ID) for traceability.

2.2.7. Edible Plant Sample Preparation

Only the edible part of each plant sample was used for analysis. The plant samples were washed with ultrapure water three times. After the water had evaporated, the plant samples were weighed, oven-dried at 65 °C for 48 h, weighed again and then crushed into powder. The heavy metal concentrations in edible portions of plant were determined on a wet weight basis. The edible plant sample was taken for XRF analysis.

2.2.8. Soil Sample Preparation

All soil samples were naturally air-dried until constant weight is reached. The dried soil samples were homogenized with pestle in a mortar, and then passed through standard sieves 0.9 mm, 0.3 mm, and 0.15 mm for analysis of pH, organic matter (OM) and heavy metal contents, respectively. Soil pH were measured using a pH electrode and the ratio of solid: water was 1:2.5. OM contents of soil samples were determined using the loss on ignition method. The soil sample was taken for XRF analysis.

2.2.9. Water Sample Preparation

Water samples for heavy metals determination was acidified with two (2) drops of concentrated HNO_3; Samples for Dissolved oxygen determination was fixed with 2ml each of Manganese (II) sulphate solution (winkler A) and Alkali-iodide Azide reagent (Winkler B) per sample. These operations were carried out on the field. All samples were then placed in an ice-chest and taken to the laboratory on the same day. The digested water sample was taken XRF analysis.

2.2.10. Method of Data Analysis

Concentrations of elements was analyzed by the X-Ray Florescence Spectrometric Analysis available at Centre for Dryland Agriculture Bayero University, Kano. The results obtained was used to evaluate the pollution load index.

2.2.11. Pollution Load Index (PLI)

Each sample collection spot was evaluated for the extent of metal pollution by employing the method based on the Pollution Load Index (PLI) developed by [24].

as follows:

$$PLI = (CF_1 x CF_2 x CF_3 x \dots x CF_n) \qquad 1$$

where: n is the number of metals studied and CF is the Contamination factor as calculated in Equation (2) according to [24].

$$CF = \frac{C_m Sample}{C_m Background} \qquad 2$$

Where C_m = Concentration of sample from the flooded farm, C_m Background = Concentration of sample from the control area.

If PLI < 1: indicates perfection

PLI = 1: indicates pollutants are present but only at baseline levels.

PLI > 1: indicates deterioration of site quality.

3 Results and Discussion

3.1 Results

The results for the concentration levels of five heavy metals (Ni, Cr, As, Cd and Pb) was determined using XRF Cu-Zn method. A total of twenty samples each of water, soil and edible were randomly collected from some mining sites of Plateau State, Nigeria. The coordinates (Latitudes and Longitudes) of the sample points were also measured and recorded with the aid of a Global Positioning System (GPS). The results which include heavy metals concentration in water, heavy metals in soil and heavy metals in edible plants are presented in Table 2 respectively.

Table 2: Concentration of Water, Soil and Edible Plant Samples for Bassa, Jos South, Barkin Ladi, Mangu and Jos East.

Villages	Ni	Cr	As	Cd	Pb	Total
Water (mg/l)						
Bassa	0.004	0.04	0.007	0.003	0.005	**0.0590**
Jos South	0.004	0.04	0.017	0.003	0.006	**0.0670**
Barkin Ladi	0.006	0.03	0.021	0.003	0.007	**0.0680**
Mangu	0.006	0.05	0.013	0.002	0.009	**0.0800**
Jos East	0.006	0.03	0.009	0.002	0.005	**0.0500**
Mean	**0.005**	**0.04**	**0.013**	**0.003**	**0.006**	**0.0670**
Soil (mg/kg)						
Bassa	43.4	84.1	18.5	2.58	81.6	**230.22**
Jos South	43.1	81.7	19.8	3.13	72.8	**220.59**
Barkin Ladi	45.6	70.7	29.5	4.21	72.8	**222.86**
Mangu	44.3	71.7	29.9	4.29	73.5	**223.70**

Jos East	41.5	67.9	24.5	3.70	73.5	**211.03**
Mean	**43.6**	**75.2**	**24.4**	**3.58**	**74.8**	**221.68**
Edible Plants (mg/kg)						
Bassa	6.00	0.85	0.022	0.02	1.79	**8.6730**
Jos South	5.43	0.76	0.03	0.03	1.72	**7.9600**
Barkin Ladi	5.8	0.8	0.03	0.03	1.88	**8.5400**
Mangu	5.0	0.6	0.03	0.03	1.63	**7.3300**
Jos East	4.78	0.56	0.027	0.03	1.57	**6.9700**
Mean	**5.40**	**0.71**	**0.028**	**0.03**	**1.72**	**7.8946**

3.1.1. Results Analysis

The results for the concentration of heavy metals in water, soil and edible plants which are presented in Table 2 are further used to calculate the pollution load index as presented in Table 3.

Table 3: Pollution Load Index of Water, Soil and Edible Plant Samples.

H/M	Ni	Cr	As	Cd	Pb	Total
Water						
Bassa	1.20	9.60	9.60	9.60	4.80	**34.8**
Jos South	1.32	8.40	20.4	13.2	7.20	**50.4**
Barkin Ladi	1.92	7.20	25.2	10.8	8.40	**54.0**
Mangu	1.68	12.0	15.6	8.40	10.8	**49.2**
Jos East	1.68	7.20	10.8	8.40	6.00	**32.9**
Mean	**1.56**	**8.88**	**16.32**	**10.1**	**7.44**	**44.3**
Soil						
Bassa	10.8	9.60	10.8	10.8	9.60	**51.6**
Jos South	10.8	9.60	12.0	12.0	8.40	**52.8**
Barkin Ladi	13.2	9.60	18.0	14.4	8.40	**63.6**
Mangu	7.20	7.20	14.4	10.8	8.40	**48.0**
Jos East	9.60	8.40	14.4	14.4	8.40	**56.4**
Mean	**10.3**	**8.88**	**13.9**	**12.5**	**8.64**	**54.5**
Edible Plant						
Bassa	7.20	8.40	2.40	12.0	10.8	**40.8**
Jos South	6.00	7.20	3.60	18.0	10.8	**45.6**
Barkin Ladi	7.20	7.20	3.60	15.6	10.8	**44.4**
Mangu	6.00	6.00	3.60	16.8	9.60	**42.0**
Jos East	6.00	4.80	3.60	18.0	9.60	**42.0**
Mean	**6.48**	**6.72**	**3.36**	**16.1**	**10.3**	**43.0**

It was observed from Table 3 that the total pollution load index of heavy metal from water samples is in decreasing order trend with Barkin Ladi (54.0) > Jos South (50.4) > Mangu (49.2) > Bassa (34.8) > Jos East (32.9).
It was also observed from Table 3 that the total pollution load index of heavy metal from soil samples is in decreasing order trend with Barkin Ladi (62.7) > Jos East (56.4) > Jos South (52.8) > Bassa (51.6) > Mangu (48.0).
It was similarly observed from Table 3 that the total pollution load index of heavy metal from edible plant samples is in decreasing order trend with Jos South (45.6) > Barkin Ladi (44.4) > Mangu and Jos East (42.0) > Bassa (40.8).

3.1.2. Comparison of Results with World Health Organization (WHO)

The results presented on Table 1 were used to plot charts in order to compare the results of the present study with World Health Organization (WHO) as seen in Figure 1, 2 and 3.

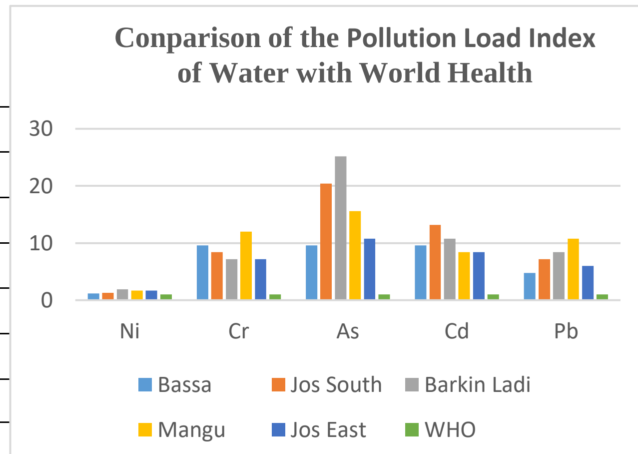

Fig. 4: Comparison of Pollution Load Index of Water with World Health Organization.

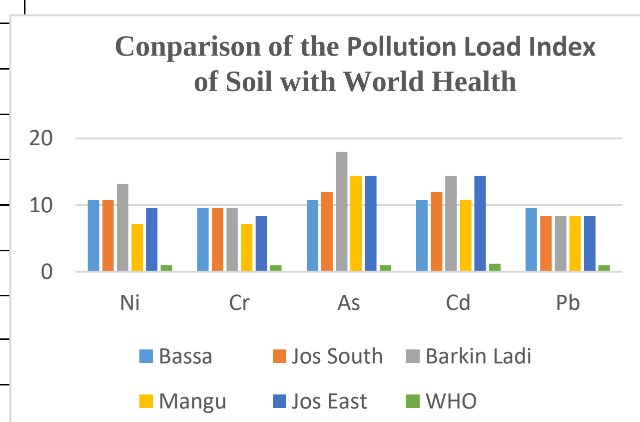

Fig.5: Comparison of Pollution Load Index of Soil with World Health Organization.

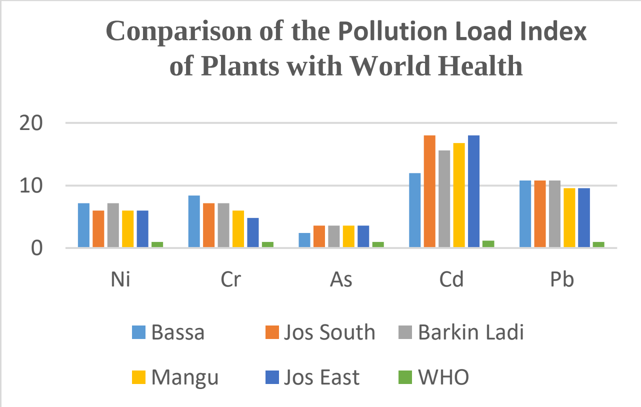

Fig.6: Comparison of Pollution Load Index of Edible Plants with World Health Organization

Based on the chart presented in Figure 4, the water in all the villages for all the heavy metals are found above the recommended limit of World Health organization of PLI≤ 1.

Based on the chart presented in Figure 5, the soil in all the villages for all the heavy metals are found above the recommended limit of World Health organization of PLI≤ 1.

Based on the chart presented in Figure 6, the plants in all the villages for all the heavy metals are found above the recommended limit of World Health organization of PLI≤ 1.

3.2. Discussion

Pollution of different elements in plants depends on the relative level of exposure of plants to the contaminated soil as well as the deposition of toxic elements in the polluted air by sedimentation. In this study, the Pollution Load Index (PLI) for various metals showed that the PLI values differed slightly between the locations.

The total pollution load index of heavy metal from water samples is in decreasing order trend with Barkin Ladi (54.0) > Jos South (50.4) > Mangu (49.2) > Bassa (34.8) > Jos East (32.9).

It was also observed that the total pollution load index of heavy metal from soil samples is in decreasing order trend with Barkin Ladi (62.7) > Jos East (56.4) > Jos South (52.8) > Bassa (51.6) > Mangu (48.0).

It was similarly observed that the total pollution load index of heavy metal from edible plant samples is in decreasing order trend with Jos South (45.6) > Barkin Ladi (44.4) > Mangu and Jos East (42.0) > Bassa (40.8).

4 Conclusions

Based on the results presented, the findings indicate deterioration of site quality and can therefore be concluded that the soil, water and plants in the study area are highly polluted and call for serious concern and regulatory control.

Acknowledgement

Praise is to our creator, Lord of the worlds, the Eternal Guardian of the heavens and earths, Disposer of all created beings. Whom through His blessings upon us, we were able to successfully complete this work.

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