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ARTICLE

Transfer Factor of Heavy Metals due to Mining Activities in Some Parts of Plateau State, Nigeria (Health Implications on the Inhabitants)

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ABSTRACT

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. 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, and so on. In this study, the soil-edible plant and soil-water Transfer Factor (TF) for various metals showed that the TF values differed slightly between the locations. On soil-edible plant transfer, the mean TF for different heavy metals in soil-edible plants decreased in the following order: As (0.6) mg/kg > Cd (0.1) mg/kg > Cr (0.06) mg/kg > Pb (0.003) mg/kg > Ni (0.001) mg/kg. The total TF for different locations decreases in the following order: Barkin Ladi (1.0) mg/kg > Jos South and Jos East (0.7) mg/kg > Bassa and Mangu (0.6) mg/kg. On soil-water transfer, the mean TF for different heavy metals in soil-edible plants decreased in the following order: Cd (0.001) mg/L > As (0.0007) mg/L > Cr (0.0005) mg/L > Pb (0.0001) mg/L and Ni (0.0001) mg/L. The total TF for different locations decreases in the following order: Jos South (0.003) mg/kg > Barkin Ladi, Bassa, Jos East and Mangu (0.002) mg/kg. Based on the findings of this study, it can be concluded that the water and edible plants in the study area are good for public consumption, even though, regular checking of heavy metals in the study area is recommended.

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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 [1-7]. 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, and so on [8]. The bio-availability of metals in soil is a variable process which is based on specific combinations of chemical, biological, and environmental parameters [9]. 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 [10]. Plants traps heavy metals from the soil through the root and from the atmosphere through over ground vegetative organs [11]. 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 [12]. More so, different plant species grown in the same soil may have different concentrations of the same element [13]. Some authors have reported the existence of differences in accumulation of heavy metals in plant cultivars, age of plants, plant organs and tissues [14-17]. The same heavy metals can be transferred to water through erosion, where heavy metals are flushed to our rivers and streams and we consume them. Transmission of metals from soil to plant tissues and from soil to water is studied using an index called Transfer Factor (TF). Soil to plant transfer factor is calculated as a ratio of concentration of a specific metal in plant tissue to the concentration of same metal in soil, also soil to water transfer factor is calculated as a ratio of concentration of a specific metal in water to the concentration of same metal in soil, both represented in same units [18]. Higher TF values (≥1) indicate higher absorption of metal from soil by the plant and also indicate higher transfer of metal from soil to the water. On the contrary, lower values indicate poor response of plants towards metal absorption and the plant can be used for human consumption and also lower values indicate poor response of water towards metal transfer and the water can be used for human consumption [19].

The present study will unveil the extent of transfer factor of heavy metals due to mining activities in some selected part Plateau State, Nigeria and the health implications on the inhabitants.

2. Materials and Method

2.1 Materials

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

i. Hand trowel
ii. Plastic containers
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 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 (Hodder, 2000).

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 [20].

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 [20].

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 [20].

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 Figures 1, 2 and 3.

Table 1. Geographical Coordinates of the Data Points

Village	Sample Points	Geographical Coordinates	
		East	North
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"

Table 1 continued

Village	Sample Points	Geographical Coordinates	
		East	North
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"

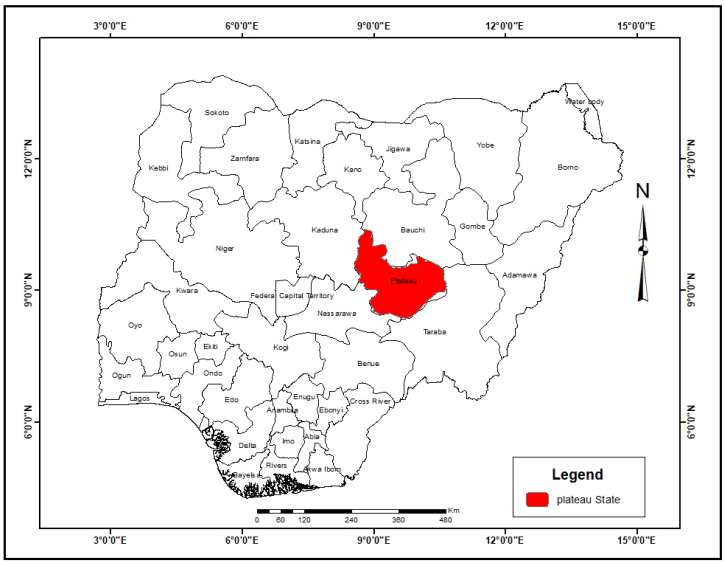

Figure 1. Map of Nigeria Showing Plateau State

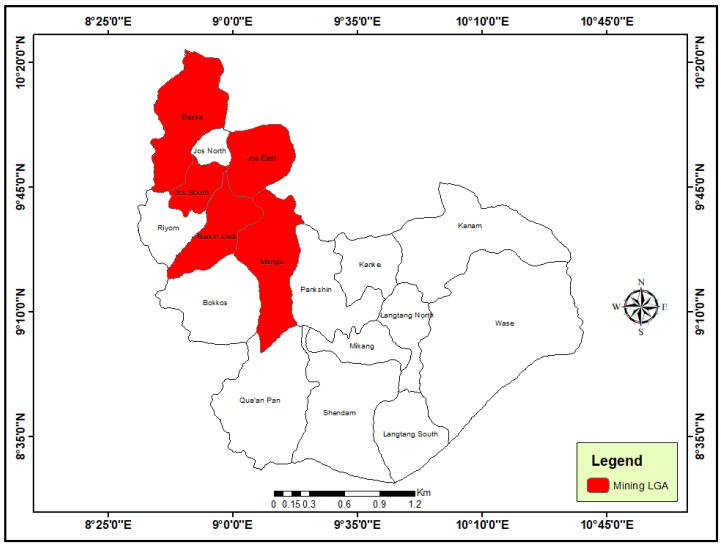

Figure 2. Map of Plateau State Showing Mining Local Government Areas

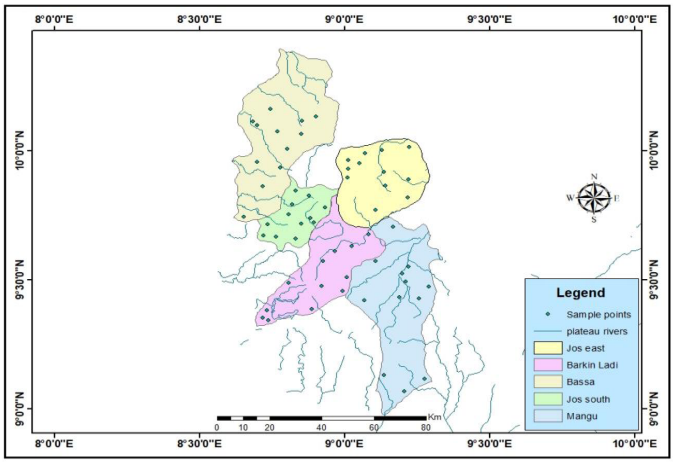

Figure 3. Map of Mining Local Government Areas Showing Sample Points

2.2.2 Population Sample

The population of the study includes all the notable towns where mining activities take 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 (20) soil sample, twenty (20) edible plant sample, and twenty (20) water samples from the mining local government of Plateau State. Sixty (60) samples in all were analyzed in this study. Vegetables' rooted soil samples were taken at 0-20 cm depth. A composite sample is composed of three (3) subsamples at each sampling site for water, vegetables and soils.

2.2.4 Soil Sample Collection

Twenty samples 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

Twenty 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

Twenty water samples were collected from streams from the mining local government of Plateau State. The collected samples were immediately transferred into plastic containers and were 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 concentration in edible portions of plant was 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 were 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 soil-plant and soil-water transfer factor.

Transfers factor

Transfers factor (TF) was calculated to understand the extent of risk and associated hazard due to waste water irrigation and consequent heavy metals accumulation in edible portion of test plant and water. According to Rilwan et al. [21], the Transfers factor from soil to plant and from soil to water is given by the relation;

$$TF_{soil\text{-}plant} = \frac{C_{plant}}{C_{soil}} \text{ and } TF_{soil\text{-}water} = \frac{C_{water}}{C_{soil}} \quad (1)$$

The ratio "> 1" means higher accumulation of metals in plant or water parts than soil (Sajjad et al., 2009). If the transfer coefficient of a metal is greater than 0.50, the plant will have a greater chance of the metal contamination by anthropogenic activities [22].

3. Results and Discussion

3.1 Results

The results for the concentration levels of five heavy metals (Ni, Cr, As, Cd and Pb) were 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 in water, heavy metals in soil and heavy metals in edible plants are presented in Tables 2-4 respectively.

Table 2. Concentration of Water Samples in mg/L.

H/M / S/P	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
			Bassa						**Jos South**			
P01	0.003	0.050	0.005	0.003	0.001	**0.062**	0.001	0.05	0.003	0.001	0.005	**0.060**
P02	0.001	0.050	0.006	0.001	0.005	**0.063**	0.002	0.03	0.002	0.003	0.002	**0.039**
P03	0.005	0.050	0.020	0.002	0.006	**0.082**	0.005	0.04	0.060	0.005	0.004	**0.114**
P04	0.002	0.020	0.010	0.005	0.005	**0.042**	0.003	0.07	0.020	0.002	0.001	**0.096**
P05	0.005	0.060	0.005	0.001	0.010	**0.081**	0.004	0.01	0.004	0.004	0.030	**0.052**
P06	0.003	0.020	0.002	0.002	0.002	**0.029**	0.004	0.02	0.007	0.005	0.004	**0.040**
P07	0.012	0.040	0.001	0.003	0.003	**0.060**	0.014	0.04	0.002	0.001	0.006	**0.063**
P08	0.006	0.010	0.010	0.005	0.006	**0.037**	0.005	0.04	0.040	0.003	0.002	**0.090**
P09	0.003	0.050	0.005	0.003	0.001	**0.062**	0.001	0.05	0.001	0.006	0.004	**0.062**
P10	0.005	0.050	0.020	0.002	0.006	**0.082**	0.006	0.02	0.060	0.003	0.006	**0.095**
P11	0.003	0.020	0.002	0.002	0.002	**0.029**	0.001	0.01	0.003	0.001	0.001	**0.016**
P12	0.001	0.050	0.006	0.001	0.005	**0.063**	0.005	0.06	0.004	0.005	0.004	**0.078**
	0.004	**0.040**	**0.007**	**0.003**	**0.005**	0.059	**0.004**	**0.04**	**0.017**	**0.003**	**0.006**	0.067
			Barlin Ladi						**Mangu**			
P01	0.004	0.040	0.004	0.002	0.006	**0.056**	0.005	0.06	0.002	0.001	0.007	**0.075**
P02	0.004	0.020	0.003	0.002	0.003	**0.032**	0.005	0.04	0.001	0.003	0.004	**0.053**
P03	0.007	0.030	0.070	0.004	0.005	**0.116**	0.006	0.05	0.050	0.003	0.006	**0.115**
P04	0.005	0.060	0.030	0.001	0.002	**0.098**	0.004	0.08	0.010	0.002	0.003	**0.099**
P05	0.006	0.020	0.005	0.003	0.040	**0.074**	0.007	0.04	0.003	0.002	0.050	**0.102**
P06	0.006	0.010	0.008	0.004	0.003	**0.031**	0.004	0.03	0.006	0.003	0.004	**0.047**
P07	0.016	0.030	0.003	0.002	0.007	**0.058**	0.015	0.05	0.001	0.001	0.006	**0.073**
P08	0.007	0.030	0.050	0.002	0.003	**0.092**	0.002	0.05	0.030	0.001	0.004	**0.087**
P09	0.003	0.040	0.002	0.005	0.005	**0.055**	0.004	0.06	0.001	0.004	0.006	**0.075**
P10	0.008	0.010	0.070	0.002	0.007	**0.097**	0.003	0.03	0.050	0.001	0.008	**0.092**
P11	0.003	0.020	0.004	0.002	0.002	**0.031**	0.005	0.04	0.002	0.001	0.003	**0.051**
P12	0.007	0.050	0.005	0.004	0.005	**0.071**	0.008	0.07	0.003	0.003	0.006	**0.090**
	0.006	**0.030**	**0.021**	**0.003**	**0.007**	0.068	**0.006**	**0.05**	**0.013**	**0.002**	**0.009**	0.080
			Jos East									
P01	0.008	0.03	0.001	0.002	0.005	**0.046**						
P02	0.002	0.01	0.002	0.002	0.003	**0.019**						
P03	0.009	0.02	0.01	0.004	0.004	**0.047**						
P04	0.001	0.03	0.05	0.001	0.001	**0.083**						
P05	0.004	0.01	0.006	0.003	0.02	**0.043**						
P06	0.007	0.04	0.003	0.002	0.001	**0.053**						
P07	0.018	0.02	0.003	0.002	0.004	**0.047**						
P08	0.005	0.01	0.01	0.001	0.005	**0.031**						
P09	0.001	0.07	0.005	0.003	0.002	**0.081**						
P10	0.006	0.03	0.01	0.002	0.004	**0.052**						
P11	0.002	0.04	0.003	0.001	0.002	**0.048**						
P12	0.005	0.03	0.002	0.002	0.005	**0.044**						
	0.006	**0.03**	**0.009**	**0.002**	**0.005**	0.050						

Table 3. Concentration of Soil Samples in mg/kg.

H/M S/P	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
			Bassa						**Jos South**			
P01	49.8	67.9	22.8	3.21	57.9	**201.61**	59.8	66.2	22.1	2.21	52.9	**203.21**
P02	33.3	82.8	10.5	2.97	92.8	**222.37**	35.3	82.1	12.5	3.97	72.8	**206.67**
P03	47.4	98.8	17.7	2.09	88.8	**254.79**	47.5	98.5	18.7	4.09	92.8	**261.59**
P04	28.5	71.0	11.5	2.69	81.0	**194.69**	38.5	69.0	12.5	1.69	61.0	**182.69**
P05	45.3	93.9	16.9	3.00	83.9	**243.00**	44.3	93.0	16.2	5.00	87.9	**246.40**
P06	46.3	86.9	13.4	1.82	96.9	**245.32**	45.3	86.1	11.4	2.82	66.6	**212.22**
P07	54.6	78.4	35.1	2.69	68.4	**239.19**	54.7	74.4	25.1	4.69	58.4	**217.29**
P08	51.2	98.9	19.6	2.00	78.9	**250.60**	31.2	88.9	29.6	3.00	88.9	**241.60**
P09	33.3	82.8	10.5	2.97	92.8	**222.37**	37.3	83.8	14.5	2.37	52.8	**190.77**
P10	28.5	71.0	11.5	2.69	81.0	**194.69**	22.5	71.0	11.1	2.61	86.0	**193.21**
P11	54.6	78.4	35.1	2.69	68.4	**239.19**	54.1	74.4	45.1	2.59	68.9	**245.09**
P12	47.4	98.8	17.7	2.09	88.8	**254.79**	47.1	92.8	19.1	2.49	84.8	**246.29**
	43.4	**84.1**	**18.5**	**2.58**	**81.6**	230.22	**43.1**	**81.7**	**19.8**	**3.13**	**72.8**	220.59
			Barkin Ladi						**Mangu**			
P01	49.3	56.3	33.2	3.32	63.8	**205.92**	38.4	60.0	22.2	3.72	75.2	**199.52**
P02	46.2	71.0	23.6	4.98	61.7	**207.48**	42.5	75.0	22.5	3.93	77.7	**221.63**
P03	37.2	87.4	29.8	5.18	81.7	**241.28**	37.2	87.4	29.8	5.18	81.7	**241.28**
P04	28.4	58.0	23.6	2.72	72.5	**185.22**	51.4	63.3	26.2	5.71	69.5	**216.11**
P05	47.3	82.0	27.2	6.10	77.8	**240.40**	47.3	82.0	27.2	6.10	77.8	**240.40**
P06	42.5	75.0	22.5	3.93	77.7	**221.63**	54.1	81.7	30.2	3.54	73.3	**242.84**
P07	51.4	63.3	26.2	5.71	69.5	**216.11**	49.2	72.7	28.6	3.48	63.9	**217.88**
P08	39.4	77.8	30.7	4.23	77.8	**229.93**	34.4	67.8	37.7	4.23	71.8	**215.93**
P09	49.2	72.7	28.6	3.48	63.9	**217.88**	39.4	77.8	30.7	4.23	77.8	**229.93**
P10	38.4	60.0	22.2	3.72	75.2	**199.52**	46.2	71.0	23.6	4.98	61.7	**207.48**
P11	63.5	63.6	56.2	3.62	79.2	**266.12**	63.5	63.6	56.2	3.62	79.2	**266.12**
P12	54.1	81.7	30.2	3.54	73.3	**242.84**	28.4	58.0	23.6	2.72	72.5	**185.22**
	45.6	**70.7**	**29.5**	**4.21**	**72.8**	222.86	**44.3**	**71.7**	**29.9**	**4.29**	**73.5**	223.70
			Jos East									
P01	38.0	65.4	23.4	4.72	75.2	**206.72**						
P02	40.5	71.6	22.1	3.13	77.7	**215.03**						
P03	27.2	81.4	21.8	3.18	81.7	**215.28**						
P04	55.4	53.3	21.2	5.11	69.5	**204.51**						
P05	42.3	62.3	23.2	4.21	77.8	**209.81**						
P06	51.1	86.7	20.2	3.14	73.3	**234.44**						
P07	41.2	61.3	21.6	3.78	63.9	**191.78**						
P08	37.4	60.8	17.7	3.23	71.8	**190.93**						
P09	31.4	71.8	20.3	4.26	77.8	**205.56**						
P10	42.2	71.9	26.6	4.18	61.7	**206.58**						
P11	69.5	69.6	46.2	3.32	79.2	**267.82**						
P12	21.4	58.3	29.6	2.12	72.5	**183.92**						
	41.5	**67.9**	**24.5**	**3.70**	**73.5**	211.03						

Table 4. Concentration of Edible Plants Samples in mg/kg.

H/M / Edible Plants	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
	Bassa						**Jos South**					
Zogale	4.9	0.9	0.02	0.02	1.9	**7.70**	5.2	0.8	0.03	0.03	1.95	**7.99**
Kuka	5.4	0.8	0.01	0.01	2.0	**8.20**	4.4	0.5	0.02	0.02	1.78	**6.67**
Rama	9.5	0.8	0.02	0.02	1.6	**11.9**	6.3	0.6	0.03	0.03	1.43	**8.38**
Yateya	7.5	1.1	0.01	0.03	2.2	**10.8**	4.1	0.9	0.02	0.04	1.73	**6.81**
Alayyahu	4.4	1.0	0.02	0.01	2.1	**7.52**	6.6	0.9	0.03	0.02	2.11	**9.63**
Shuwaka	8.3	0.6	0.01	0.02	1.4	**10.4**	8.3	0.7	0.02	0.03	1.56	**10.7**
Yakuwa	6.6	0.8	0.04	0.02	1.9	**9.39**	3.6	0.7	0.05	0.03	1.87	**6.19**
Karkashi	5.3	1.0	0.02	0.02	1.8	**8.10**	7.0	1.0	0.03	0.03	1.67	**9.72**
Ugu	4.6	0.7	0.03	0.02	1.8	**7.16**	6.7	0.7	0.04	0.03	1.94	**9.32**
Rogo	6.3	0.9	0.02	0.01	1.5	**8.72**	4.9	0.9	0.03	0.03	1.45	**7.35**
Water Leaf	5.2	0.8	0.03	0.02	1.3	**7.36**	3.0	0.7	0.04	0.03	1.31	**5.15**
Kabeji	4.1	0.7	0.04	0.03	1.9	**6.78**	5.1	0.7	0.05	0.04	1.81	**7.69**
Mean	**6.0**	**0.8**	**0.02**	**0.02**	**1.8**	**8.67**	**5.4**	**0.8**	**0.03**	**0.03**	**1.72**	**7.96**
	Barkin Ladi						**Mangu**					
Zogale	4.8	0.9	0.02	0.02	2.0	7.72	3.7	0.7	0.02	0.03	1.93	6.38
Kuka	5.3	0.8	0.02	0.02	2.5	8.69	4.2	0.8	0.02	0.03	2.47	7.53
Rama	8.5	0.8	0.04	0.05	1.5	10.9	7.4	0.6	0.04	0.04	1.35	9.40
Yateya	7.0	1.1	0.02	0.01	2.2	10.4	6.0	1.0	0.02	0.04	2.13	9.21
Alayyahu	4.3	1.0	0.02	0.02	2.1	7.47	5.1	0.7	0.02	0.02	2.14	8.00
Shuwaka	5.3	0.5	0.01	0.02	1.4	7.29	4.2	0.3	0.01	0.02	1.24	5.84
Yakuwa	6.0	0.7	0.03	0.03	2.0	8.84	5.1	0.7	0.02	0.03	1.63	7.49
Karkashi	5.2	1.0	0.03	0.03	1.8	8.08	4.3	0.9	0.03	0.03	1.38	6.66
Ugu	4.6	0.5	0.02	0.02	1.9	7.05	4.2	0.4	0.04	0.03	1.35	5.99
Rogo	8.5	0.9	0.02	0.02	1.7	11.2	7.3	0.6	0.03	0.03	1.42	9.32
Water Leaf	5.7	0.9	0.02	0.04	1.3	7.97	4.8	0.5	0.02	0.03	1.45	6.78
Kabeji	4.2	0.7	0.05	0.03	1.9	6.86	3.7	0.6	0.03	0.02	1.03	5.37
Mean	**5.8**	**0.8**	**0.03**	**0.03**	**1.9**	**8.54**	**5.0**	**0.6**	**0.03**	**0.03**	**1.63**	**7.33**
	Jos East											
Zogale	7.3	0.6	0.03	0.03	1.4	9.30						
Kuka	4.2	0.4	0.04	0.03	1.4	6.00						
Rama	4.8	0.5	0.02	0.03	1.5	6.80						
Yateya	6.0	1.0	0.01	0.06	2.2	9.30						
Alayyahu	4.2	0.8	0.02	0.03	2.5	7.50						
Shuwaka	4.2	0.3	0.01	0.02	1.2	5.80						
Yakuwa	3.7	0.7	0.02	0.03	1.9	6.40						
Karkashi	4.3	0.9	0.03	0.03	1.4	6.70						
Ugu	4.2	0.4	0.04	0.03	1.4	6.00						
Rogo	7.3	0.6	0.03	0.03	1.4	9.30						
Water Leaf	3.7	0.6	0.03	0.02	1.0	5.40						
Kabeji	3.3	0.2	0.05	0.02	1.5	5.10						
Mean	**4.8**	**0.6**	**0.03**	**0.03**	**1.6**	**7.00**						

3.2 Results Analysis

The results for the concentration of heavy metals in water, soil and edible plants are presented in Tables 2-4 respectively, and are further used to calculate the soil-plant and soil-water transfer factors as presented in Tables 5-9.

Table 5. Soil-Edible Plants and Soil-Water Transfer Factor for Bassa

	Soil-Edible Plants						Soil-Water					
H/M / S/P	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
P01	0.0006	0.056	0.25	0.15	0.0005	**0.46**	0.00006	0.0007	0.00022	0.0009	0.00002	**0.002**
P02	0.0002	0.060	0.60	0.10	0.0025	**0.76**	0.00003	0.0006	0.00057	0.0003	0.00005	**0.002**
P03	0.0005	0.060	1.00	0.10	0.0038	**1.16**	0.00011	0.0005	0.00113	0.0010	0.00007	**0.003**
P04	0.0003	0.019	1.00	0.17	0.0023	**1.19**	0.00007	0.0003	0.00087	0.0019	0.00006	**0.003**
P05	0.0011	0.061	0.31	0.08	0.0047	**0.46**	0.00011	0.0006	0.00030	0.0003	0.00012	**0.002**
P06	0.0004	0.034	0.15	0.09	0.0014	**0.28**	0.00006	0.0002	0.00015	0.0011	0.00002	**0.002**
P07	0.0018	0.051	0.03	0.17	0.0016	**0.25**	0.00022	0.0005	0.00003	0.0011	0.00004	**0.002**
P08	0.0011	0.010	0.53	0.23	0.0033	**0.77**	0.00012	0.0001	0.00051	0.0025	0.00008	**0.003**
P09	0.0007	0.069	0.19	0.13	0.0005	**0.39**	0.00009	0.0006	0.00048	0.0010	0.00001	**0.002**
P10	0.0008	0.054	0.87	0.14	0.0040	**1.07**	0.00018	0.0007	0.00174	0.0007	0.00007	**0.003**
P11	0.0006	0.024	0.06	0.11	0.0015	**0.20**	0.00005	0.0003	0.00006	0.0007	0.00003	**0.001**
P12	0.0002	0.072	0.14	0.03	0.0026	**0.25**	0.00001	0.0005	0.00034	0.0005	0.00006	**0.001**
	0.0007	**0.048**	**0.43**	**0.13**	**0.0024**	**0.60**	**0.00009**	**0.0005**	**0.00053**	**0.0010**	**0.00005**	**0.002**

P = Points; = Mean; Cr = Chromium; Cd = Cadmium; As = Arsenic; Pb = Lead; Ni = Nickel.

Table 6. Soil-Edible Plants and Soil-Water Transfer Factor for Jos South

	Soil-Edible Plants						Soil-Water					
H/M / S/P	Ni	Cr	As	Cd	Pb	**Total**	Ni	Cr	As	Cd	Pb	**Total**
P01	0.0002	0.060	0.10	0.03	0.0026	**0.197**	0.00002	0.0008	0.00014	0.0005	0.00009	**0.0014**
P02	0.0005	0.065	0.10	0.15	0.0011	**0.317**	0.00006	0.0004	0.00016	0.0008	0.00003	**0.0050**
P03	0.0008	0.064	2.00	0.17	0.0028	**2.234**	0.00011	0.0004	0.00322	0.0012	0.00004	**0.0039**
P04	0.0007	0.077	1.00	0.05	0.0006	**1.128**	0.00008	0.0010	0.00160	0.0012	0.00002	**0.0016**
P05	0.0006	0.011	0.15	0.17	0.0142	**0.348**	0.00009	0.0001	0.00025	0.0008	0.00034	**0.0028**
P06	0.0005	0.028	0.29	0.15	0.0026	**0.474**	0.00009	0.0002	0.00061	0.0018	0.00006	**0.0012**
P07	0.0039	0.059	0.04	0.03	0.0032	**0.144**	0.00026	0.0005	0.00008	0.0002	0.00010	**0.0030**
P08	0.0007	0.041	1.33	0.09	0.0012	**1.467**	0.00016	0.0005	0.00135	0.0010	0.00002	**0.0033**
P09	0.0002	0.076	0.03	0.18	0.0021	**0.282**	0.00003	0.0006	0.00007	0.0025	0.00008	**0.0072**
P10	0.0012	0.022	1.76	0.12	0.0041	**1.912**	0.00027	0.0003	0.00541	0.0011	0.00007	**0.0006**
P11	0.0003	0.013	0.07	0.03	0.0008	**0.119**	0.00002	0.0001	0.00007	0.0004	0.00001	**0.0030**
P12	0.0010	0.089	0.08	0.12	0.0022	**0.286**	0.00011	0.0006	0.00021	0.0020	0.00005	**0.0029**
	0.0009	**0.050**	**0.59**	**0.11**	**0.0031**	**0.742**	**0.00011**	**0.0005**	**0.00120**	**0.0011**	**0.00008**	**0.0030**

P = Points; = Mean; Cr = Chromium; Cd = Cadmium; As = Arsenic; Pb = Lead; Ni = Nickel.

Table 7. Soil-Edible Plants and Soil-Water Transfer Factor for Barkin Ladi

	Soil-Edible Plants						Soil-Water					
H/M / **S/P**	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
P01	0.0008	0.04	0.20	0.10	0.0030	0.348	0.00008	0.0007	0.00015	0.0006	0.00009	0.0009
P02	0.0008	0.02	0.15	0.10	0.0012	0.276	0.00009	0.0003	0.00013	0.0004	0.00005	0.0037
P03	0.0008	0.04	1.75	0.08	0.0032	1.870	0.00019	0.0003	0.00235	0.0008	0.00006	0.0029
P04	0.0007	0.06	1.50	0.10	0.0009	1.658	0.00018	0.0010	0.00127	0.0004	0.00003	0.0016
P05	0.0014	0.02	0.33	0.20	0.0186	0.574	0.00013	0.0002	0.00018	0.0005	0.00051	0.0017
P06	0.0011	0.02	0.67	0.17	0.0021	0.864	0.00014	0.0001	0.00036	0.0010	0.00004	0.0014
P07	0.0026	0.04	0.12	0.07	0.0035	0.238	0.00031	0.0005	0.00011	0.0004	0.00010	0.0027
P08	0.0013	0.03	1.72	0.08	0.0017	1.835	0.00018	0.0004	0.00163	0.0005	0.00004	0.0022
P09	0.0007	0.08	0.08	0.24	0.0026	0.401	0.00006	0.0006	0.00007	0.0014	0.00008	0.0042
P10	0.0009	0.01	3.33	0.08	0.0041	3.433	0.00021	0.0002	0.00315	0.0005	0.00009	0.0010
P11	0.0005	0.02	0.18	0.05	0.0015	0.259	0.00005	0.0003	0.00007	0.0006	0.00003	0.0021
P12	0.0017	0.07	0.10	0.13	0.0026	0.297	0.00013	0.0006	0.00017	0.0011	0.00007	0.0022
	0.0011	**0.04**	**0.84**	**0.12**	**0.0038**	**1.004**	**0.00014**	**0.0004**	**0.00080**	**0.0007**	**0.00010**	**0.0022**

P = Points; = Mean; Cr = Chromium; Cd = Cadmium; As = Arsenic; Pb = Lead; Ni = Nickel.

Table 8. Soil-Edible Plants and Soil-Water Transfer Factor for Mangu

	Soil-Edible Plants						Soil-Water					
H/M / **S/P**	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
P01	0.0014	0.089	0.09	0.03	0.004	0.21	0.00013	0.0010	0.00009	0.0003	0.00009	0.002
P02	0.0012	0.052	0.04	0.09	0.002	0.18	0.00012	0.0005	0.00004	0.0008	0.00005	0.003
P03	0.0008	0.083	1.19	0.07	0.004	1.35	0.00016	0.0006	0.00168	0.0006	0.00007	0.002
P04	0.0007	0.080	0.48	0.06	0.001	0.62	0.00008	0.0013	0.00038	0.0004	0.00004	0.002
P05	0.0014	0.055	0.20	0.13	0.023	0.41	0.00015	0.0005	0.00011	0.0003	0.00064	0.002
P06	0.0009	0.087	0.50	0.13	0.003	0.72	0.00007	0.0004	0.00020	0.0008	0.00005	0.001
P07	0.0029	0.074	0.04	0.04	0.004	0.16	0.00030	0.0007	0.00003	0.0003	0.00009	0.002
P08	0.0005	0.056	0.94	0.04	0.003	1.04	0.00006	0.0007	0.00080	0.0002	0.00006	0.002
P09	0.0009	0.169	0.03	0.15	0.004	0.35	0.00010	0.0008	0.00003	0.0009	0.00008	0.003
P10	0.0004	0.053	2.00	0.03	0.006	2.09	0.00006	0.0004	0.00214	0.0002	0.00013	0.001
P11	0.0010	0.087	0.10	0.03	0.002	0.22	0.00008	0.0006	0.00004	0.0003	0.00004	0.003
P12	0.0022	0.124	0.09	0.13	0.006	0.36	0.00028	0.0012	0.00013	0.0011	0.00008	0.002
	0.0012	**0.084**	**0.47**	**0.08**	**0.005**	**0.64**	**0.00013**	**0.0007**	**0.00047**	**0.0005**	**0.00012**	**0.002**

P = Points; = Mean; Cr = Chromium; Cd = Cadmium; As = Arsenic; Pb = Lead; Ni = Nickel.

Table 9. Soil-Edible Plants and Soil-Water Transfer Factor for Jos East

	Soil-Edible Plants						Soil-Water					
H/M / **S/P**	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
P01	0.0011	0.05	0.04	0.06	0.0035	0.2	0.00021	0.0005	0.00004	0.0004	0.00007	0.001
P02	0.0005	0.03	0.06	0.07	0.0022	0.2	0.00005	0.0001	0.00009	0.0006	0.00004	0.002
P03	0.0019	0.04	0.48	0.13	0.0028	0.7	0.00033	0.0002	0.00046	0.0013	0.00005	0.003
P04	0.0002	0.03	4.55	0.02	0.0004	4.6	0.00002	0.0006	0.00236	0.0002	0.00001	0.002
P05	0.0009	0.01	0.25	0.09	0.0081	0.4	0.00009	0.0002	0.00026	0.0007	0.00026	0.001
P06	0.0017	0.12	0.25	0.08	0.0008	0.5	0.00014	0.0005	0.00015	0.0006	0.00001	0.002
P07	0.0048	0.03	0.13	0.06	0.0021	0.2	0.00044	0.0003	0.00014	0.0005	0.00006	0.001
P08	0.0012	0.01	0.31	0.04	0.0036	0.4	0.00013	0.0002	0.00056	0.0003	0.00007	0.002
P09	0.0002	0.20	0.14	0.11	0.0015	0.4	0.00003	0.0010	0.00025	0.0007	0.00003	0.002
P10	0.0008	0.05	0.40	0.06	0.0028	0.5	0.00014	0.0004	0.00038	0.0005	0.00006	0.002
P11	0.0005	0.07	0.09	0.04	0.0019	0.2	0.00003	0.0006	0.00006	0.0003	0.00003	0.002
P12	0.0015	0.18	0.04	0.10	0.0033	0.3	0.00023	0.0005	0.00007	0.0009	0.00007	0.002
	0.0013	**0.07**	**0.56**	**0.07**	**0.0028**	**0.7**	**0.00015**	**0.0004**	**0.00040**	**0.0006**	**0.00006**	**0.002**

P = Points; = Mean; Cr = Chromium; Cd = Cadmium; As = Arsenic; Pb = Lead; Ni = Nickel.

Table 10. Summary of the Results presented in Tables 5-9 for the Soil-Edible Plants and Soil-Water Transfer Factor in Bassa, Jos South, Barkin Ladi, Mangu and Jos East

	Soil-Edible Plants						**Soil-Water**					
H/M / **Villages**	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
Bassa	0.001	0.05	0.4	0.1	0.002	**0.6**	0.0001	0.0005	0.0005	0.001	0.0001	**0.002**
Jos South	0.001	0.05	0.6	0.1	0.003	**0.7**	0.0001	0.0005	0.0012	0.001	0.0001	**0.003**
Barkin Ladi	0.001	0.04	0.8	0.1	0.004	**1.0**	0.0001	0.0004	0.0008	0.001	0.0001	**0.002**
Mangu	0.001	0.08	0.5	0.1	0.005	**0.6**	0.0001	0.0007	0.0005	0.001	0.0001	**0.002**
Jos East	0.001	0.07	0.6	0.1	0.003	**0.7**	0.0002	0.0004	0.0004	0.001	0.0001	**0.002**
Mean	**0.001**	**0.06**	**0.6**	**0.1**	**0.003**	**0.7**	**0.0001**	**0.0005**	**0.0007**	**0.001**	**0.0001**	**0.002**

P = Points; = Mean; Cr = Chromium; Cd = Cadmium; As = Arsenic; Pb = Lead; Ni = Nickel.

It was also observed from Table 10 that the soil-edible plant and soil-water transfer factors has the mean values of 0.7 mg/kg and 0.002 mg/L respectively.

On soil-edible plant transfer factor, the total transfer factor has its trend is in descending order with Barkin Ladi (1.0) mg/kg > Jos South and Jos East (0.7) mg/kg > Bassa and Mangu (0.6) mg/kg.

On soil-water transfer factor, the total transfer factor has its trend is in descending order with Jos South (0.003) mg/kg > Barkin Ladi, Bassa, Jos East and Mangu (0.002) mg/kg.

Comparison of Results with World Health Organization (WHO)

The results presented in Table 10 were used to plot charts in order to compare the results of the present study with World Health Organization (WHO) as seen in Figures 4 and 5.

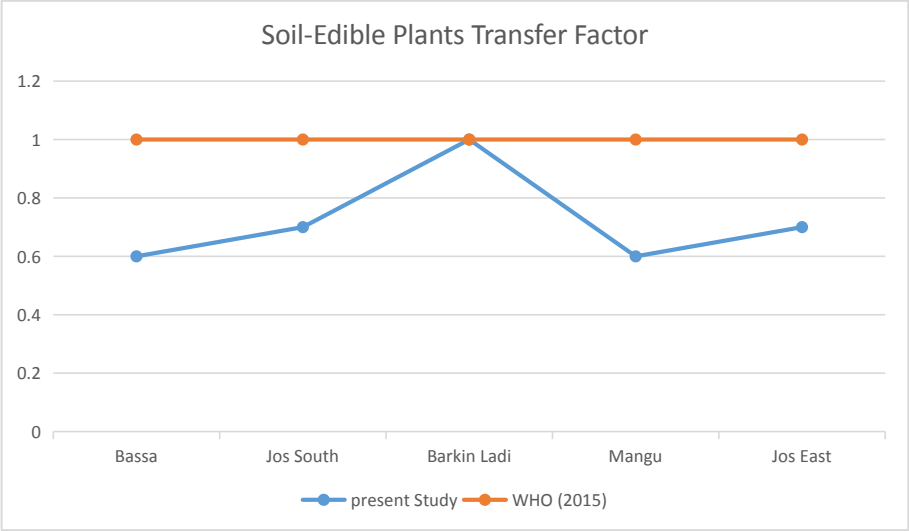

Figure 4. Chart of Soil-Edible Plants Transfer Factor with World Health Organization

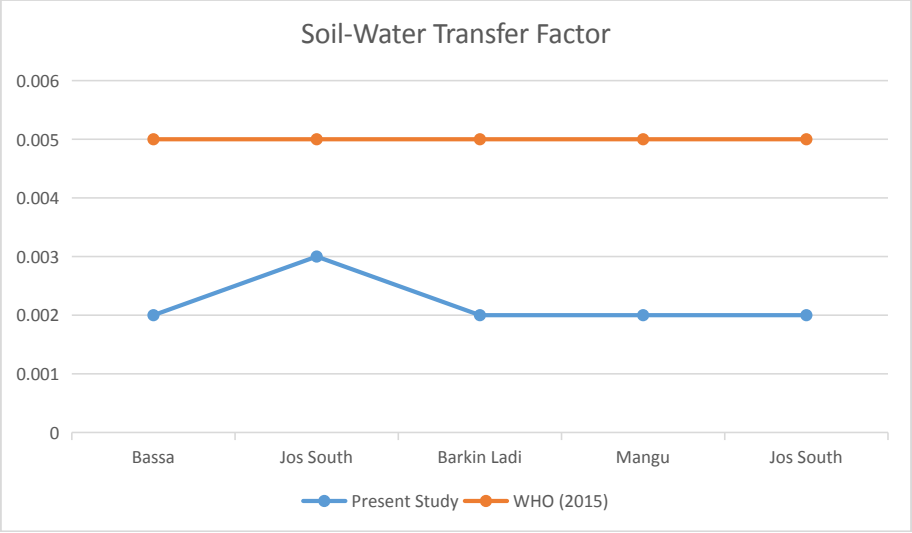

Figure 5. Chart of Soil-Water Transfer Factor with World Health Organization

Based on the results presented in Figure 4, the soil-edible plants transfer factor for Barkin Ladi seem to be closely equal to that recommended by the World Health Organization, on the other hand, the results presented in Figure 5 showed that the soil-water transfer factor for all villages are less than the World Health Organization recommended limit.

3.3 Discussion

Concentration of different elements in plants depends upon 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 soil-edible plant and soil-water Transfer Factor (TF) for various metals showed that the TF values differed slightly between the locations.

On soil-edible plant transfer, the mean TF for different heavy metals in soil-edible plants decreased in the following order: As (0.6) mg/kg > Cd (0.1) mg/kg > Cr (0.06) mg/kg > Pb (0.003) mg/kg > Ni (0.001) mg/kg. The total TF for different locations decreases in the following order: Barkin Ladi (1.0) mg/kg > Jos South and Jos East (0.7) mg/kg > Bassa and Mangu (0.6) mg/kg.

On soil-water transfer, the mean TF for different heavy metals in soil-edible plants decreased in the following order: Cd (0.001) mg/L > As (0.0007) mg/L > Cr (0.0005) mg/L > Pb (0.0001) mg/L and Ni (0.0001) mg/L. The total TF for different location decreases in the following order:

Jos South (0.003) mg/kg > Barkin Ladi, Bassa, Jos East and Mangu (0.002) mg/kg.

4. Conclusions

Based on the findings of this study, it can be concluded that the water and edible plants in the study area are good for public consumption, even though, regular checking of heavy metals in the study area is recommended.

Conflict of Interest

There is no conflict of interest.

References

[1] Balabanova, B., Stafilov, T., Šajn, R., et al., 2014. Comparison of response of moss, lichens and attic dust to geology and atmospheric pollution from copper mine. International Journal of Environmental Science and Technology. 11, 517-528.

[2] Moore, F., Kargar, S., Rastmanesh, F., 2013. Heavy metal concentration of soils affected by Zn-smelter activities in the Qeshm Island, Iran. Journal of Sciences, Islamic Republic of Iran. 24, 339-346.

[3] Ogunkunle, C.O., Fatoba, P.O., Awotoye, O.O., et al., 2013. Root-shoot partitioning of copper, chromium and zinc in Lycopersicon esculentum and Amaranthus hybridus grown in cement-polluted soil. Environmental and Experimental Biology. 11, 131-136.

[4] Yan, X., Zhang, F., Zeng, C., et al., 2012. Relationship between heavy metal concentrations in soils and grasses of roadside farmland in Nepal. International Journal of Environmental Research and Public Health. 9, 3209-3226.

[5] Kouamé, I.K., Kouassi, L.K., Dibi, B., et al., 2013. Potential groundwater pollution risks by heavy metals from agricultural soil in Songon area (Abidjan, Côte d'Ivoire). The Journal of Environmental Protection. 4, 1441-1448.

[6] Shamuyarira, K.K., Gumbo, J.R., 2014. Assessment of heavy metals in municipal sewage sludge: A case study of Limpopo Province, South Africa. International Journal of Environmental Research and Public Health. 11, 2569-2579.

[7] Bi, X., Feng, X., Yang, Y., et al., 2006. Environmental contamination of heavy metals from zinc smelting areas in Hezhang County, western Guizhou, China. Environment International. 32, 883-890.

[8] Tarradellas, J., Bitton, G., Russel, D., 1996. Soil Ecotoxicology. (ed) CRC Lewis Publisher, New York.

[9] Panuccio, M.R., Sorgonà, A., Rizzo, M., et al., 2009. Cadmium adsorption on vermiculite, zeolite and pumice: batch experimental studies. Journal of Environmental Manage. 90, 364-374.

[10] Guala, S.D., Vegaa, F.A., Covelo, E.F., 2001. The dynamics of heavy metals in plant-soil interactions. Ecological Modelling. 221, 1148-1152.

[11] Mmolawa, K.B., Likuku, A.S., Gaboutloeloe, G.K., 2011. Assessment of heavy metal pollution in soils major roadside areas in Botswana. African Journal of Environmental Science and Technology. 5, 186-196.

[12] Freitas, H., Prasad, M.N.V., Pratas, J., 2004. Plant community tolerant to trace elements growing on the degraded soils of São Domingos mine in the south east of Portugal: environmental implications. Environment International. 30, 65-72.

[13] Ibrahim, A.K., Yakubu, H., Askira, M.S., 2014. Assessment of heavy metals accumulated in wastewater irrigated soils and lettuce (Lactuca sativa) in Kwadon, Gombe State Nigeria. American-Eurasian Journal of Agricultural & Environmental Sciences. 14, 502-508.

[14] Krstic, B., Stankovic, D., Igic, R., et al., 2007. The potential of different plant species for nickel accumulation. Biotechnology & Biotechnological Equipment. 21, 431-436.

[15] Naser, H.M., Sultana, S., Mahmud, N.U., et al., 2011. Heavy metal levels in vegetables with growth stage and plant species variations. Bangladesh Journal of Agricultural Research. 36, 563-574.

[16] Jolly, Y.N., Islam, A., Akbar, S., 2013. Transfer of metals from soil to vegetables and possible health risk assessment. Springer Plus. 2, 385.

[17] Filipović-Trajković, R., Ilić, S.Z., Šunić, L., 2012. The potential of different plant species for heavy metals accumulation and distribution. The Journal of Food, Agriculture and Environment. 10, 959-964.

[18] Rangnekar, S.S., Sahu, S.K., Pandit, G.G., et al., 2013. Study of uptake of Pb and Cd by three nutritionally important Indian vegetables grown in artificially contaminated soils of Mumbai, India. International Research Journal of Environmental Sciences. 2, 1-5.

[19] Usman, R., Kamal, A.M., Ugwu, E.I., et al., 2020. Assessment and Analysis of the Presence of Heavy Metals in Water in Ara and Laminga of Nasarawa State, Nigeria: Health Implication on the Populace. The Pacific Journal of Science and Technology. 21, 240-246.

[20] Rilwan Usman, A.M., Kamal, A., Mamman, M.M., et al., 2021. Health Implication of the Accumulation of Heavy Metals Concentration in Ara and Laminga Water Sources of Nasarawa Local Government Area in Nasarawa State, Nigeria. NAUB Journal of Science and Technology (NAUBJOST). 1(June Issue), 101-106.

[21] Rilwan, U., Abbas, A.A., Abdulrahman, H., 2020. Heavy Metal Contamination in Swampy Agricultural Soils of Kokona, Nasarawa, Nigeria. Asian Journal of Applied Chemistry Research. 5, 28-33.

[22] Rilwan, U., Abbas, A.A., Muhammad, S., 2020. Heavy Metal Contamination and Its Risk for Swampy Agricultural Soils of Keffi, Nasarawa West, Nigeria. Asian Journal of Applied Chemistry Research. 5, 1-11.