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Translocation of Trace Metals in Selected Crops Grown At Rimin Zayam Mining Area – Toro, Local Government, Bauchi State, Nigeria

Ogunleye A.O[1], Hassan U.F[2], Adamu H.M[2], Boryo D.E.A[2]

[1]*Department of Chemistry, Federal College of Education (T), Bichi, Kano State, Nigeria*
[2]*Department of Chemistry, Abubakar Tafawa Balewa University, Bauchi State, Nigeria.*

(*)Corresponding Author's: lizzycrown478@gmail.com, Phone no +234703206185

Abstract
Most farmlands close to mining sites are susceptible to pollution due to the activities of miners, which result in both natural and anthropogenic pollution. Soil–bound heavy metals are of great concern for human health due to potential exposure via food chain transfer. This research aimed to determine the concentration of Cr, Cu, Fe, Mn, Ni, Pb and Zn in the soil of the farmland Rimin Zayam at Toro Local government of Bauchi State, Nigeria and to investigate heavy metals in the soil-crop transfer coefficient based on their total and bio-concentration in the soils. Three different crops were collected from the farmland, *Zea mays*maise), *A. Hypogeal* (groundnut) and *A. esculentus* (Okra), together with the soil in the vicinity, were prepared and analysed for the heavy metals using standard methods. The heavy metals in the soil and crops were determined using Micro–Plasma Atomic Emission Spectroscopy (OMP-AES 4200 Model). The trend of a bio-concentration factor of the heavy metal accumulations in *Z. mays* collected from farms around the active mining area is in the order: copper (1.600) > zinc (0.800) > chromium (0.106) > manganese (0.031) > nickel (0.013) > iron (0.004). *A. Esculentus* are in the order: copper (2.375) > zinc (0.800) > manganese (0.091) > chromium (0.070) > nickel (0.014) > iron (0.004). The trend of biological concentration factor (BCF) of heavy metal accumulations in *A. hypogea* is in the order: copper (0.615) > chromium (0.357) > zinc (0.256) > manganese (0.063) > iron (0.001). Iron had the highest BCF values and the lowest value of the three crops investigated. The soil-plant transfer coefficient values for chromium, copper, iron, lead, manganese, nickel, and zinc accumulated by crops obtained from the active mining site were 10.60, 160.00, 0.400, 3.10, 1.30, 0.00 and 30.90, respectively for *Z. mays*. In *A. esculentus,* these were 7.00, 23.75, 0.90, 9.10, 1.40, 0.00 and 80.00, respectively. For *A. hypogea,* the soil plant transfer coefficient values were 35.70, 66.50, 0.10, 6.30, 0.00 and 25.60 for chromium, copper, iron, manganese, nickel and zinc, respectively. The soil-plant transfer coefficients of the crops from the non-mining sites (control) were 6.80, 108.30, 0.70, 100.00, 11.60, 0.00 and 61.50, respectively, for *Z. mays*. In *A. esculentus,* TF values are 13.70, 183.30, 1.60, 200.00, 25.60,0.00 and 105.00, respectively. For *A. hypogea,* TF values were 10.60, 133.30, 0.40, 50.00, 6.20, 1.90 and 68,00 mg/kg for chromium, copper, iron, lead, manganese, nickel and zinc, respectively. The trend of biological concentration factors of heavy metal accumulations in all the crops collected from both locations showed that it was highest with copper and least with iron, same with the trend of soil-plant transfer coefficient, thus indicating that there was no bioaccumulation of toxic heavy metals in the plant's tissues. The study indicated that metal pollution at the site does not occur. However, a study of the health risks of long-term consumption of the crops should be carried out, and monitoring of mining activities to avert pollution is recommended.

Keywords: Soil- Plant Translocation, Heavy Metals, Transfer in Crops

Introduction

Soil serves as a critical landscape for the ecosystem and is an essential resource for food production; however, it is being threatened by many toxicants, among which heavy metals are of great concern [1, 2]. Metals in arable lands partially originated from natural sources, but in many cases, they are from anthropogenic activities, such as fossil fuel combustion, mining, smelting, traffic, wastewater irrigation and sewage sludge reuse, and the excessive application of pesticides and fertilizers [3, 4].

Soil-bound heavy metals in farmlands are likely to accumulate in agricultural products, e.g. vegetables and grains, which pose risks to the human population that consumes the polluted agricultural food or indirectly consumes animals feeding on the agricultural products via the food chain [5, 7]. Therefore, the transfer process of soil-bound heavy metals in soil-crop systems has attracted increasing attention in recent years [8]. Accumulation of heavy metals from soil to plants mainly depends on the uptake mechanisms, the physicochemical properties of the soil and the chemical speciation of the metals and metalloids in soils [9, 10]. Conventional risk assessment of soil-bound heavy metals is performed based on total metal concentrations in soils, which may overestimate the risk [11] and further result in unnecessary and expensive soil remediation [12, 13].

This study aims to determine soil-plant transfer coefficient values and bio-acumination factors.

Materials and Methods

Edible plant samples maise grain (*Zea mays*), Okra fruits (*Abelmuschus esculentus*), and groundnut seeds (*Arachi hypogeal*) grown in farmland designated as F147S (Lat. 10.16659 and Long 9.31794), F149S (Lat. 10.16655 and Long 9.31791) and F153S (Lat. 10.16391 and Long 9.31681), within the vicinity of the mining site, Rimin zayam at Toro local government of Bauhi State, were collected randomly using a stainless steel knife and assigned with descriptors F147SM, F149SO and F153SG. Similar plant samples of the same species were collected as control from farmlands designated as F162C (Lat. 10.16830 and Long 9.30800), F156C (Lat. 10.16694 and Long 9.31022) and F159C (Lat. 10.16902 and Long 9.31681) Toro local government and assigned with descriptors F162CM, F156CO and F159CG in September 2020. The maps showing the study area are depicted in Figure 1 below.

Visible soils were washed off and removed from the plant after collection and washed vigorously in tap water and subsequently in deionised water, then allowed draining from the plant after drained then separated into fruit, after which each component was sliced into uniform size and dried in an oven at 40 ^{0}C for 24 hours. The dried samples were ground into fine particles using a ceramic mortar and pestle and then preserved in sealed plastic containers for subsequent use [14].

A 5.00 g of fine particles of vegetables was measured into a 100 cm^3 beaker. Then 5 cm^3 of concentrated HNO_3 and 2 cm^3 of concentrated

$HClO_4$ were added and digested at 70 ^{0}C for 15 min on a hot plate until a light-coloured solution was obtained. The sample solution was cooled, filtered into 50 cm3 volumetric flasks, and made up to the mark with distilled water [14].

A 50 cm^3 of 0.05 mol/ dm^3 EDTA was added to 10 g (5:1) of the sieved soil samples in a 100 cm^3 conical flask. The mixture was shaken using an end shaker at 220 rpm for 60 min and filtered through a Whatman No 41 filter paper. The filtrate was preserved for plant-available metal analyses [14].
The total heavy metal concentration of soils is a poor indicator of metal availability for plant uptake; accumulation factors were calculated based on metal availability and its uptake by a particular plant. The calculation for biological concentration factor (BCF) was determined as described in equation 1 [15], [16] and translocation factor (TF) as described in equation 2 [2], [17].

$$BCF = \frac{Metal\ concentration\ (mgkg{-1})in\ root}{Metal\ concentration\ (mgkg{-1})soil} \quad \text{eq. (1)}$$

$$TF = \frac{Mean\ metal\ concentration\ (mgkg{-1})\ shoot\ (Roots+stems+leaves)}{Metal\ concentration\ (mgkg{-1})in\ roots} \quad \text{eq. (2)}$$

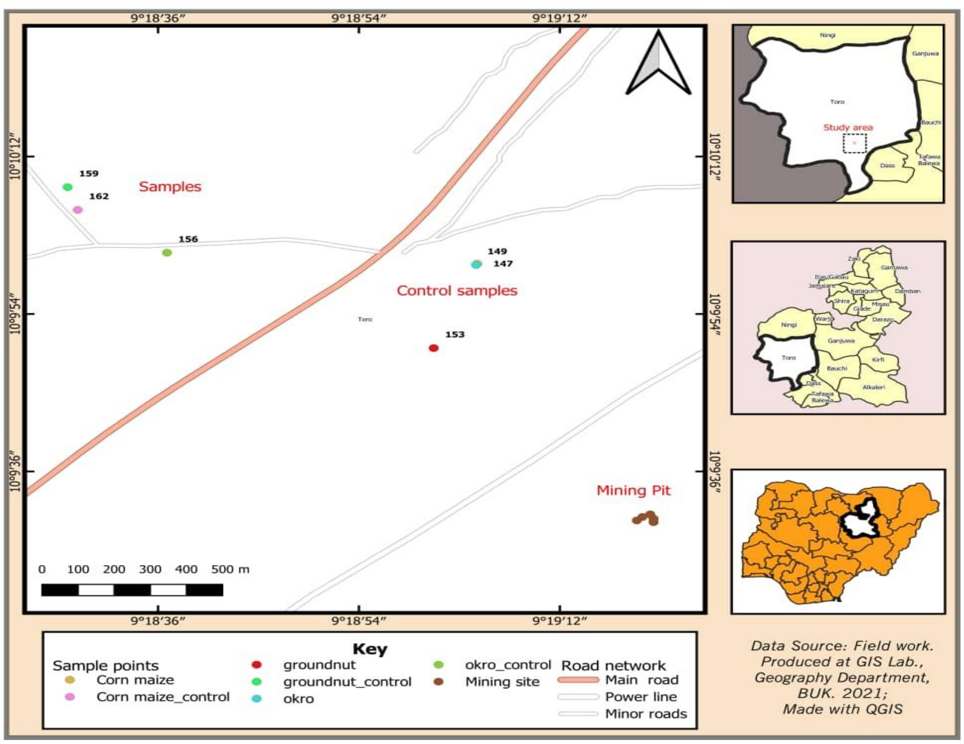

Figure 1. Locations of the farms within the vicinity of mining areas in Rimin Zayam, Toro LGA, Bauchi State

Results and Discussions

The concentrations of the following heavy metals: chromium, copper, iron, lead, manganese, nickel and zinc, in soil taken from the farms designated as F147S, F149S and F153S at the mining areas and of those collected from the farmlands designated as F162C, F156C and F159C, from the non-mining area, which were used as control are depicted in Table 1 and 2, respectively.

Table 1: Concentrations of Heavy Metals (*mg/kg*) at Cultivated soil in Active Mining Site at Rimin Zayam

	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
F147S	0. 57 ±0.03	0.10 ±0.02	195.57 ±3.14	4.45± 0.16	3.52 ±0.17	0.38 ±0.93	0.55 ±2.31
F149S	0.45 ±0.45	0.08 ±0.01	204.82 ±0.68	4.50± 0.13	2.30 ±0.01	0.35 ±0.84	0.40 ±1,43
F153S	0.28 ±0.02	0.07 ±0.55	203.32 ±1.14	4.47 ±0.17	1.73 ±0.04	0.13 ±2.45	0.39 ±072

Mean ± standard deviation (n = 3)

Table 1 revealed that iron had the highest level of 204.82 mg/kg in Okra planted at the active mining site, while copper had the lowest value of 0.07 mg/kg in groundnut. The trend of heavy metals (mg/kg) determined in the cultivated soil at mining sites are in the following order for armaise Fe.>Pb > Mn > Cr >Zn > Ni > Cu., for okra Fe > Pb > Mn > Cr > Zn > Ni > Cu while for groundnut the observed trend are Fe > Pb > Mn > Zn > Cr> Ni > Cu. The observed values of chromium found in cultivated soil of the mining site range from 0.28 in groundnut to 0.57 mg/kg, which was determined to be.

The experimental values in this research are higher than the literature values of 0.00 to 0.00 mg/kg found in wastewater irrigation in the Bauchi Suburb [18]. The cultivated soil values in this research are slightly lower than the literature values of 0.32 to 0.84 found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. observed values in this research are within the threshold value of 3.00 mg/kg [20].

The analytical values of copper in the cultivated soil spread between 0.07 determined in groundnut to 0.10 mg/kg found in maise. The observed values are close to the reported values of 0.34 to 0.91 mg/kg determined in wastewater irrigation in Bauchi Suburb [18]. Literature values of 8.00 to 15.30 mg/kg found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19] are higher than in this research. The value of copper falls within the threshold value of 30.00mg/kg [20].

Table 1 shows the experimental iron values in the cultivated soil, ranging from 195.57 found in maise to 204.82 mg/kg determined in Okra. The observed values are higher than the literature values of 0.27 to 0.64 mg/kg determined around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. The observed values are higher than the threshold value of 50.00 mgkg [20] for iron in soil. The observed values of managese in cultivated soil range from 1.73 found in groundnut to 3.52 mg/kg determined in maise. The observed values are very low compared to literature values of 524.50 to 561.00 mg/kg found in wastewater irrigation in the Bauchi Suburb [18]. The observed values fall within the threshold value of 100.00 mg/kg [20]. Experimental nickel values in cultivated soil spread between 0.13 in groundnut to 0.38 mg/kg determined in maise. The values obtained in this research are close to 0.21 to 0.42 found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. analytical values are within the threshold value of 100.00 mg/kg [20].

The lead levels in non-mining cultivated soil range from 0.01, determined in Okra, to 0.02, found in maise and groundnut. The analytical values are lower than the literature values of 0.10 to 0.53 mg/kg found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. The experimental values are also lower than 0.20 to 1.00 mg /kg reported in wastewater irrigation in the Bauchi Suburb [18]. The observed values are lower than the permissible limits of 100.00 mg/kg [20].

The observed values of zinc in the cultivated soil of the mining site range from 0.39 determined in groundnut, to 0.55 mg/kg found in maise (depicted in Table 1). The observed values are slightly higher than the literature values of 0.30 to 0.40 mg/kg found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. The experimental values are much lower than the literature values of 19.50 to 63.20 determined in wastewater irrigation in the Bauchi Suburb [18]. The observed values are within the permissible limit of 300. 00 mg/kg [20].

Table 2. Concentration of Heavy Metals (*mg/kg*) at Cultivated soil from Non -Mining Site of Rimin Zayam

	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
F162C	0.44±0.0.5	0.12±0.56	89.80 ±1.32	0.02 ±0.09	0.95±0.01	0.21 ± 0.07	0.26±0.04
F156C	0.15±0,08	0.06 ±0.02	46.58±0.81	0.01±0.10	0.59 ±0.01	0.10±0.06	0.20 ±0.03
F159C	0.38±0.71	0.12 ±0.07	115.19±0.35	0.02±0.02	1.76±0.03	0.26±0.04	0.25±0.06

Mean ± standard deviation (n = 3)

BDL = Below Detection Limit

Table 2 shows the levels (mg/kg) of metals in the soil from the mining site. The values of heavy metals spread from 0.01 (mg/kg) detected lead found in Okra (F156CO) to 11.19 (mg/kg) in iron from the control of groundnut (F159CG). The concentrations of the heavy metals in terms of abundance are in the order Fe > Pb > Mn > Cr > Zn > Ni > Cu in the soils, which indicates that Fe is the most sufficient across the mining and non-mining sites. The observed concentration of chromium in the cultivated soil of non-mining sites spread from 0.15, as determined in Okra, to 0.44 mg/kg, and was found to be The observed values are lower literature values of 0.30 to 0.91 found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. The experimental value is within the permissible value of 50.00 mg/kg.

The analytical values of copper in the cultivated soil spread between 0.06 determined in Okra to 0.12 mg/kg found in maise and groundnut. The observed values are within the reported values of 0.34 to 0.91 mg/kg determined in wastewater irrigation in the Bauchi Suburb [7, 15], 18]. Literature values of 8.00 to 15.30 mg/kg found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [14], [19] are higher than in this research. The value of copper falls within the threshold value of 30.00mg/kg [20].

Table 2 depicts the concentration of iron from the cultivated soil of non-mining sites spread from 46.58 to 115.19 mg/kg determined in groundnut. The observed values are very high compared to literature values of 0.34 to 0.91 mg/kg determined around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. The analytical values are also higher than 8.00 to 15.30 found in wastewater irrigation in the Bauchi Suburb [18]. The observed values exceed the threshold value of 50.00 mg/kg. The observed values of managese in cultivated soil range from 0.59 found in Okra to 1.76 mg/kg determined in groundnut. The observed values are very low compared to literature values of 524.50 to 561.00 mg/kg found in wastewater irrigation in the Bauchi Suburb [18].

The observed values fall within the threshold value of 100.00 mg/kg [20]. Experimental nickel values in cultivated soil spread between 0.10 in Okra to 0.26 mg/kg determined in groundnut. The values obtained in this research are lower, with values of 0.21 to 0.42 mg/kg found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. observed values are lower than the literature value of 8.67 mg/kg found in soil-to-vegetable possible health risk assessment [21]. analytical values are within the threshold value of 100.00 mg/kg [20]. The lead levels in non-mining cultivated soil range from 0.01, determined in Okra, to 0.02, found in maise and groundnut. The analytical values are lower than the literature values of 0.10 to 0.53 mg/kg found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19].

The experimental values are also lower than 0.20 to 1.00 mg /kg reported in wastewater irrigation in the Bauchi Suburb [18]. The observed values are lower than the permissible limits of 100.00 mg/kg [20]. The observed zinc values in the cultivated soil of non-mining sites range from 0.20, which was determined in Okra, to 0.26 mg/kg and was found to be maise. The observed values are lower than the literature values of 0.30 to 0.40 mg/kg found in dumpsites around Lafia Metropolis, Nasarawa State, Nigeria [19]. The experimental values are much lower than the literature values of 19.50 to 63.20 determined in wastewater irrigation in the Bauchi Suburb [18]. The observed values are within the permissible limit of 300. 00 mg/kg [20].

The concentration of the same heavy metals in the crops taken from the farms designated as F147S, F149S and F153S were assigned descriptors

F147SM, F149SO and F153SG, as well as those with descriptors F162CM, F156CO and F159CG are presented in Tables 3 and 4, respectively.

Table 3. Concentrations of Heavy Metals (mg/kg) in crops Cultivated at Active Mining Sites

	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
F147SM	0.06 ±0.76	0.16 ±0.32	0.785 ±1.10	0.02±3.13	0.11 ±0.10	0.005 ±19.23	0.17 ±1.70
F149SO	0.03 ±1.27	0.19 ±0.73	1.850 ±0.95	0.02±2.76	0.12 ±0.25	0.005 ±12.28	0.32 ±2.79
F153SG	0.01 ±1.20	0.04 ±0.37	0.210 ±2.07	0.01±2.32	0.11 ±0.22	BDL	0.10 ±1.45

Mean ± standard deviation (n = 3)
BDL = Below Detection Limit

Table 4: Concentrations of Heavy Metals (mg/kg) in crops Cultivated at Non – Mining Sites

	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
F162CM	0.03 ±1.18	0.13 ±0.59	0.665± 0.54	0.02 ±2.60	0.11 ±0.29	BDL	0.16 ±7.26
F156CO	0.02 ±1.23	0.11 ±0.62	0.775 ±0.63	0.02 ±1.54	0.15 ±0.29	BDL	0.21 ±3.29
F159CG	0.04 ±0.66	0.16 ±0.10	0.490 ±2.03	0.01±01.23	0.11 ±0.48	0.005 ±13.18	0.17 ±3.29

Mean ± standard deviation (n = 3)
BDL = Below Detection Limit

The chromium levels in maise from mining and non-mining sites are 0.06 and 0.03 mg/kg, respectively. Observed values are within literature values for chromium in maise (0.01 to 0.12 mg/kg) found in agricultural soils in maise tissues from selected Tanzania districts [5]. The experimental value is lower than the reported value of 0.60 mg/kg chromium in corn found in agricultural products in the mining area of Henan Province, China [22]. Chromium concentrations in Okra from mining and non-mining sites are 0.03 and 0.02 mg/kg, respectively. The observed values are lower than the literature value of chromium in Okra (0.21 mg/k) found in vegetables and potential risk for human health [4], [23].

The analytical values of chromium in groundnut from mining and non-mining sites are 0.01 and 0.04, respectively. The observed values are lower than chromium values of 0.06, 0.21 and 0.26 found in groundnut reported around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. The observed values in this research are within the threshold value of 1.65 mg/kg [20] for chromium in plants. Chromium in food can be beneficial or harmful depending on the valent state. The hexavalent state of chromium is harmful [3], [20]. Chromium is known to maintain blood glucose levels as it enhances insulin's work [22]. Chromium (IV) compounds are assumed to be cancerous when exposed.

Tables 3 and 4 depict the levels of copper in maise from both mining and non-mining sites (0.16 and 0.13 mg.kg) res[respectively. The experimental values are lower than the literature on copper in maise (0.24,0.48 mg/kg) found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. Observed copper values are higher than reported values of 0.08 and 0.09 mg/kg found in maise crop plants around Itakpe Iron Mine, Okene, Nigeria [24]. The observed copper values are lower than the literature values of 1.02 to 9.71 mg/kg determined in agricultural products in the mining area of Henan Province, China [24]. The observed copper values in Okra are 0.19 and 0.11 mg/kg, respectively, from mining and non-mining sites. The experimental values are within literature values of 0.01, 0.36 and 0.47 mg/kg determined in Okra around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19].

The analytical values in this research are lower than the value of copper 0.22 mg/kg found in crop plants around Itakpe Iron Mine, Okene, Nigeria [24]. The observed copper values in groundnut from mining and non-mining sites are 0.04 and 0.16 mg/kg, respectively. The experimental values for copper in groundnut are higher than the literature values of 0.07 and 0.08 mg/kg around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. The observed copper values in crops are within the permissible value of 0.20 mg/kg [20]. Copper is essential to human life as a metalloprotein and functions as an enzyme [10], [22]. The concentrations of iron maise from both mining and non-mining sites are 0.79 and 0.67 mg/kg, respectively.

The observed iron values in maise are higher than the literature values of 0.21 and 0.34 found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. This might be due to the difference in the anthropogenic nature of the research location. The iron levels in Okra from both mining and non-mining sites are 1.85 and 0.78 mg/kg, respectively. The experimental iron values in Okra are higher than the observed literature values of 0.23 and 0.28 mg/kg determined around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. The concentration of iron in groundnut is 0.21 and 0.49 mg/kg, respectively. The observed iron value in groundnuts is slightly above the literature values of 0.28 and 0.31 found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. observed values in this research are within the threshold value of 4.25 mg/kg [20].

Iron is present in red blood cells as part of animals' and humans' haemoglobin. Excessive iron in the body causes poisoning or toxicity [7]. The levels of lead imaise from mining and non-mining sites are 0.02 and 0.01 mg/kg, respectively. The observed lead values in maise align with a value of lead in maise (0.01 to 0.02 mg/kg) determined in agricultural soils in maise tissues from selected districts in Tanzania [22]. The experimental lead values in maise slightly differ from the reported values of 0.02,0.23, and 0.03 mg/kg found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. The lead concentrations in Okra are 0.02 and 0.01mg/kg from mining and non-mining sites, respectively. The lead values in Okra in this research are the same as the literature values of 0.01 and 0.02 mg/kg in Okra reported around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19].

The lead in Okra is within literature values of 0.01 to 0.05 mg/kg in Okra determined by selected food crop samples grown in Ohaji/Egbema LGA, Imo State, Nigeria [15]. The determined values of lead in groundnut are 0.01 and 0.01 in mining and non-mining sites, respectively. The observed values of lead in groundnut are lower than the literature values of 0.10, 0.12 and 0.03 mg/kg in groundnut determined around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. The experimental values are within the permissible limits 0.30 [20]. Excess lead in the body influences the nervous system by slowing down response and affecting learning abilities [14].

The levels of manganese in maize from the mining and non-mining sites are 0.11 and 0.08 mg/kg, respectively. The observed manganese values in maise are higher than literature values of 0.02 and 0.03 in maise determined in crop plants around Itakpe Iron Mine, Okene, Nigeria [24]. The manganese concentrations in Okra from mining and non-mining sites are 0.12 and 0.10 mg/kg, respectively. The experimental manganese values in Okra are higher than the reported value of 0.02 for Okra determined in crop plants around Itakpe Iron Mine, Okene, Nigeria [24]. The observed values of manganese in groundnut from mining and non-mining sites are 0.11 and 0.07 mg/kg, respectively. The observed values of manganese fall within the permissible limits of 0.20 [20]. The levels of nickel in maise from mining and non-mining are 0.05 and BDL mg/kg, respectively. The observed nickel values in maise are higher than 0.01 reported around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. The analytical nickel values imaise fall within literature values of 0.05 to 0.15 determined in crop plants around Itakpe Iron Mine, Okene, Nigeria [24]. The nickel concentration in groundnuts from mining and non-mining sites is BDL at 0.001, respectively. The observed nickel value in this research is almost the same as the literature value of ND, ND and 0.02 reported around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19].

The concentrations of zinc in maize from mining and non-mining sites are 0.17 and 0.12 mg/kg, respectively. The observed zinc values in maize are higher than the literature values of 0.01, 0.03 and 0.05 mg/kg found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. The experimental zinc values fomaise are also higher than the reported values of 0.01 and 0.02 mg/kg found in crop plants around Itakpe Iron Mine, Okene, Nigeria [24]. The observed zinc values in Okra from mining and non-mining sites are 0.32 and 0.16, respectively. The observed zinc values in Okra are higher than the reported values of 0.03, 0.04 and ND mg/kg found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19]. The analytical zinc values are also higher than the literature values of 0.05 to 0.06 determined in crop plants around Itakpe Iron Mine, Okene, Nigeria [24]. The zinc levels in groundnut from mining and non-mining sites are 0.10 and 0.06, respectively. The zinc values in this research are higher than the literature values of 0.02, 0.03 and 0.04 found around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria [19].

Biological Concentration Factor

The Biological Concentration Factor of heavy metals in the crops with descriptors F147S, F149S and F153S taken from the farms designated as 147S, F149S and F153S within the vicinity of the mining areas around Rimin Zayam, Toro LGA are presented in Table 5. Meanwhile, the biological concentration factors of heavy metals in crops with descriptors F162CM, F156CO, and F159CG taken from farms designated as F162C, F156C, and F159C are shown in Table 6.

Table 5. Concentration Factor of Heavy metals in crops from farmlands located in activities mining sites of Rimin Zayam,

	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
F147S	0.106	1.600	0.004	0.004	0.031	0.013	0.309
F149S	0.070	2.375	0.009	0.004	0.091	0.014	0.800
F153S	0.357	0.615	0.001	0.002	0.063	-	0.256

Table 6. Concentration Factor of Heavy metals in crops taken from farms near mining activities around Rimin Zayam, Toro LGA, Bauchi State.

	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
F162CM	0.068	1.083	0.001	1	0.116	-	0.615
F156CO	0.137	1.833	0.016	2	0.256	-	1.050
F159CG	0.106	1.333	0.004	0.5	0.062	0.019	0.630

Soil–Plant Transfer Coefficient

The soil-plant transfer coefficient values for chromium, copper, iron, lead, manganese, nickel and zinc accumulated by crop F147SM are 10.6, 160, 0.4, 3.1, 1.3 and 30.9, respectively. Those recorded for F149SO were 7, 23.75, 0.9, 9.1, 1.4 and 80, respectively. In contrast, those recorded for F153SG were 35.7, 61.5, 0.1, 6.3 and 25.6, respectively, for the heavy metals of chromium, copper, iron, manganese, nickel and zinc. The soil-plant transfer coefficient values from the crops with descriptors F162CM are 6.8, 108.3, 0.7, 100, 11.6 and 61.5, respectively, those of F156CO were 13.7, 183.3, 1.6, 200, 25.6 and 105, respectively, while those of F159CG were 10.6, 133.3, 0.4, 50, 6.2, 1.9 and 68, respectively, for the metals of chromium, copper, iron, lead, manganese, nickel and zinc, respectively.

In comparing the soil–plant transfer coefficient of crops F147SM and F162CM, as presented in Figure 5, it shows that while there are no significant differences between those of chromium and iron, the differences in the soil–plant transfer coefficient of the others were very significant ($P < 0.005$).

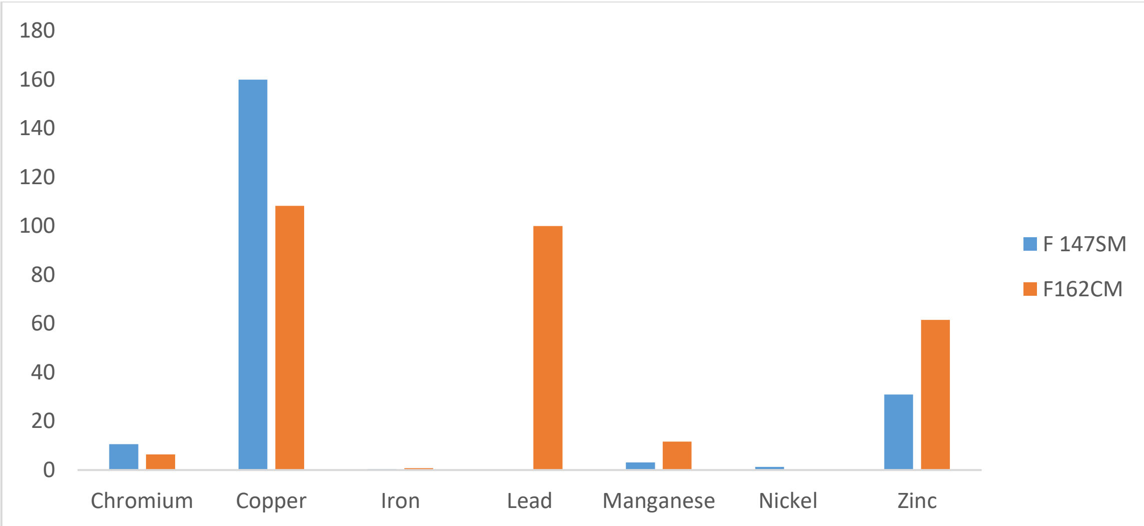

Figure 1. Soil–plant transfer coefficient of heavy metals of crops designated as F147SM and F162CM cultivated in farms at Rimin Zayam, Toro LGA, and Bauchi mining areas

The trend of soil-plant transfer coefficient values for heavy metal accumulations in groundnut collected from both locations was in the order of copper > lead > zinc > chromium > manganese > nickel > iron.

As for crops F149SO and F156CO, a comparison of the soil-plant transfer coefficient presented in Figure 1 shows that the differences in the soil–plan transfer coefficient of all the heavy metals were very significant (P < 0.005).

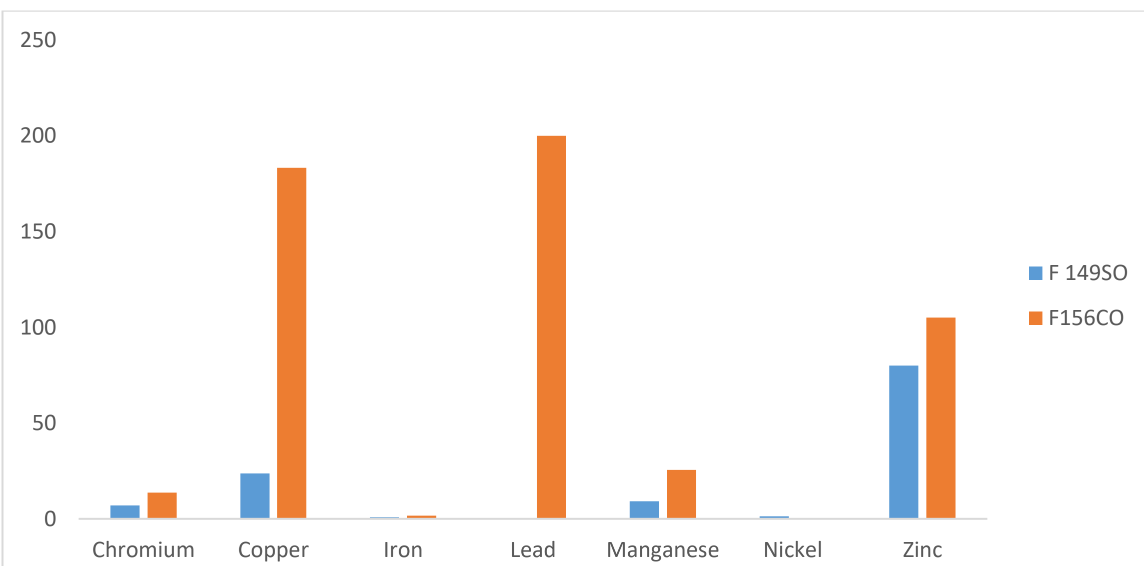

Figure 2. Soil Plant Transfer Coefficient of heavy metals of crops designated as F149SO and F156CO cultivated in farms at Rimin Zayam, Toro LGA, Bauchi mining areas

The trend of Soil Plant Transfer Coefficient values for heavy metal accumulations in Okra collected from both locations was in the order of copper > Lead > zinc > manganese > chromium > Nickel > iron. The soil-plant transfer coefficient of crops F153SG and F159CG, as presented in Figure 2, shows that while there are no significant differences between those of Iron and Manganese, In contrast, that of the others were statistically significa**nt** ($P < 0.005$). Statistically significa**nt** ($P < 0.005$).

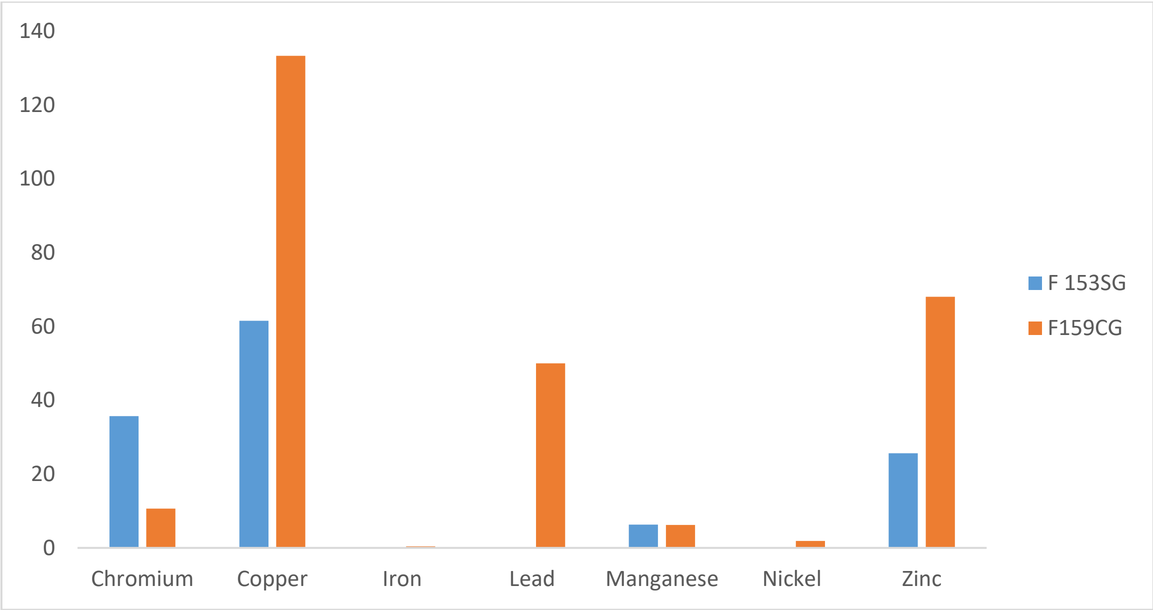

Figure 3. Soil Plant Transfer Coefficient of heavy metals of crops designated as F153SG and F159CG cultivated in farms at Rimin Zayam, Toro LGA, Bauchi mining areas

The trend of soil-plant transfer coefficient values for heavy metal accumulations in groundnut collected from both locations was in the order of copper > zinc > lead > chromium > manganese > nickel > iron. For F147SM, F149SO, F153SG, F162CM, F156CO and F159CG, the results showed that copper, followed by zinc, showed a more significant soil-plant transfer factor in the subject under study, while iron had the least. Adamu *et al.*, (2017) noted that the Soil–Plant Transfer Factor is a function of different factors in play, such as soil type, soil pH, soil organic matter, bioavailability of the metal, and soil particle size. Hence, [16] opined that soil, the plant Transfer Factor, is not necessarily a criterion for evaluating the risk associated with the metal content in any form.

Conclusion

From the results obtained, the trend of biological concentration factor values for heavy metal accumulations in all the crops collected from both locations showed that it was highest for copper and least for iron. A similar trend was observed for the soil plant transfer coefficient, thus indicating that there was no bioaccumulation of toxic mineral elements in the plant's tissues.

Based on the conclusion and the observation that there were significant levels of the bio-concentration factor for copper, levels of transfer and bioaccumulation in the plant tissues were indicated, respectively. This could form the basis to recommend that a potential health risk assessment be conducted on the plant crops to evaluate whether they are suitable for human and animal consumption without any health risk.

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