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Assessment of Toxic Metals in Cassava Varieties Cultivated in Damagum L.G.A, Yobe State, for Environmental and Health Impacts

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Abstract- This study investigated the assessment of toxic heavy metals in cassava cultivated in Damagum Local Government Area (L.G.A) of Yobe State. The focus was on determining the concentrations of five key heavy metals—chromium (Cr), lead (Pb), mercury (Hg), arsenic (As), and cadmium (Cd)—in cassava plants grown in the area. The variety of cassava used for this study was the TMS 300555. Samples of cassava roots and leaves were collected from farms located along three major roads with high traffic density and a rural road, which served as a control. Standard laboratory techniques, including Atomic Absorption Spectrophotometry, were employed to analyze the metal concentrations in the plant samples. The results revealed elevated concentrations of several metals in the cassava root, with chromium (Cr) recorded at 6.29±0.0346 mg/kg, mercury (Hg) at 8.49±2.243 mg/kg, lead (Pb) at 0.5267±0.3156 mg/kg, and cadmium (Cd) at 0.1167±0.0833 mg/kg. The metal concentration in cassava leaves followed the order: Hg > Cr > Pb > As > Cd. Soil-to-plant transfer factor values indicated moderate accumulation of metals in cassava plants across all sites. Furthermore, significant correlations were found between metal concentrations in the soil and cassava roots, with no notable differences in bioaccumulation across different parts of the cassava plant. Overall, the study highlighted evidence of contamination, suggesting heavy metal pollution in the soil and its potential uptake by cassava.

Keywords- Toxic Metals, Cassava, Damagum L.G.A, Health Impacts.

I. INTRODUCTION

Cassava (Manihot esculenta), a widely cultivated tropical root crop, serves as a staple food for millions of people worldwide. Its adaptability to a range of soil types and climatic conditions has contributed to its widespread cultivation, especially in sub-Saharan Africa, Southeast Asia, and Latin America (Obruche et al., 2025). Cassava is an essential source of carbohydrates, particularly in rural areas where it provides both food security and an income for many smallholder farmers (Abdul Kasheem & Singh, 2019). In Nigeria, cassava is not only a primary food source but also a crucial raw material for industrial products, such as flour, starch, and animal feed. As a result, the cultivation of cassava holds substantial economic and nutritional significance, particularly in regions like Yobe State, located in the northeastern part of Nigeria (Umudi et al., 2025).

However, while cassava is a valuable crop, it is also prone to contamination by various environmental pollutants, including toxic metals. These metals can enter the food chain through polluted soil, water,

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or air, posing significant risks to both human health and the environment. Toxic metals such as leads (Pb), cadmium (Cd), Zinc (Zn), Nickel (Ni), Chromium (Cr), Mercury (Hg), Arsenic (Ar) and Copper (Cu) are known to accumulate in plants, especially in the roots, which are the edible parts of cassava (Itodo et al., 2021). These metals can enter the food supply through the use of contaminated water for irrigation, the deposition of pollutants from industrial activities, mining activities, and agricultural practices involving the use of contaminated fertilizers or pesticides (Abegunde et al., 2015).

Prolonged exposure to these toxic metals can lead to a range of health issues, including kidney damage, neurological disorders, and various types of cancers. Yobe State, which has an economy primarily based on agriculture, has been increasingly concerned with the environmental impacts of industrialization and unsustainable agricultural practices (Erienu et al., 2022). Damagum Local Government Area, located within Yobe State, is a significant cassava-growing region. However, limited research has been conducted to assess the extent of toxic metal contamination in the soil and cassava crops grown in this area (Obruche et al., 2019). The proximity of Damagum to industrial zones, as well as potential issues with agricultural practices such as irrigation and fertilizer use, raises concerns about the presence of toxic metals in the soil and in cassava roots.

The presence of toxic metals in cassava is particularly worrying because the tubers are often consumed directly in a variety of dishes, from boiled tubers to fufu and gari (Ekpo et al., 2023). This makes cassava a potential route for human exposure to these metals. For instance, lead exposure is particularly harmful to children, leading to developmental delays and cognitive deficits. Cadmium, on the other hand, can cause kidney damage and is linked to various cancers (Chiroma et al., 2017). Arsenic is a well-established carcinogen, and long-term exposure can lead to skin lesions, lung cancer, and even death. Mercury, although less commonly found in agricultural environments, can accumulate in food crops and pose serious risks, especially in the case of fish consumption, though its effects on other crops remain under-researched (Umudi et al., 2025).

The primary objective of this study is to assess the levels of toxic metals—specifically leads (Pb), cadmium (Cd), Zinc (Zn), Nickel (Ni), Chromium (Cr), Mercury (Hg), Arsenic (Ar) and Copper (Cu) —in cassava cultivated in Damagum L.G.A. of Yobe State.

II. MATERIALS AND METHOD

Study Area

Fune is a Local Government Area in Yobe State, Nigeria. Its headquarters are in the town of Damagum in the southwest of the area on the A3 highway at 11°40′39″N 11°20′04″E. It has an area of 4,948 km2 and a population of 300,760 at the 2006 census. The postal code of the area is 622. In 1987, the 8,000-year-old Dufuna canoe was discovered in Fune, near the village of Dufuna and the Komadugu Gana River. Damagum has a tropical wet climate with average temperature is 26.4°C; sits in the rain forest, and produces many agricultural products, such as yams, cassava, corn, rubber and palm products (Obruche et al., 2018).

Sample Collection

The method for data collecting was derived from the procedure detailed by (Obruche et al., 2019). Samples of soil, cassava leaves and roots were randomly collected from three farmlands situated in Damagum labeled as Farm 1, Farm 2 and Farm 3. The variety of cassava collected was the the variety of cassava (as shown in figure 1) used in carrying out this study was the TMS 300555. Control samples were collected from another cassava farmland in a rural settlement in Damagum. Samples were collected at 0 – 10 cm depth at distance intervals of 10, 15, and 20 meters from the roadway with

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sterilized auger in a polythene bag. Three soil samples were taken from three points from each distance and mixed together to form composite samples.

Figure 1: Harvested Cassava Plant (Manihot esculenta crantz)

Preparation, Digestion of Soil samples, and Pre-Treatment of cassava plant

The sample preparation, digestion and pre-treatment methods were similar to the one of Ekpo et al., (2025) with a few minor modifications Samples were air-dried and sieved through a 2 mm sieve to remove coarse particles before chemical analysis. Measured 0.5 g of air-dried ground soil was transferred into 250 ml conical flask; 5 ml of concentrated H2SO4 was added followed by 25 mL of concentrated HNO3 acid and 5 ml of concentrated HCl. The flask was heated at 200°C for 1hr in a fuming hood and then cooled to room temperature. After cooling, 20 mL of distilled water was added and the mixture was filtered to complete the digestion.

Finally, the mixture was transferred to a 50 mL volumetric flask, filled to the mark and left to settle for at least 15 hours. The filtrate was analysed for total leads (Pb), cadmium (Cd), Zinc (Zn), Nickel (Ni), Chromium (Cr), Mercury (Hg), Arsenic (Ar) and Copper (Cu) using Atomic Absorption Spectrometer (AA500F). The cassava samples (roots and leaves) were washed under running water to remove dust particles. The root samples were cut to small sizes using a knife. Both the roots and leaves were air-dried and then placed in a dehydrator at 80°C for 2-3 days and then dried in an oven at 100 °C. Dried samples of different parts of cassava plant were ground into fine powder (80 mesh) using a commercial blender (TSK- WestPoint, France) and stored in polyethylene bags, until used for acid digestion.

Digestion of Plant Samples

Weighed 5 g of the powder was put into a 250 ml conical flask: 5 ml of concentrated H2SO4 was added followed by 25 mL of concentrated HNO3 and 5 mL of concentrated HCl. The contents of the tube were heated at 200°C for 1 hour in a fuming hood and then cooled to room temperature. About 20 ml of distilled was added and the mixture was filtered using filter paper to complete the digestion of organic matter. Lastly, the mixture was transferred to a 50 mL volumetric flask, filled to mark, and allowed to settle for at least 15 hours. The resultant supernatant was analysed for Cr, Pb, Hg, Ar, and Cd using Atomic Absorption Spectrometer (AA500F) (Abeokuta et al., 2025).

Transfer Factor of Metal from Soil to Plant

Metal concentrations in the extracts of soils and plants were calculated on the basis of dry weight. The plant Transfer factor was calculated as follows:

$$\mathrm{Tf} = \frac{\mathrm{C\ plant}}{\mathrm{C\ soil}}$$

Where; Tf is Transfer factor, C plant and C soil represent the heavy metal concentration in extracts of plants and soils on dry weight basis, respectively (Cui et al., 2005).

Statistical Data Analysis and Precision

All assessments of heavy metals and polycyclic aromatic hydrocarbons were conducted in triplicate, with results expressed as mean ± standard deviation to evaluate the precision of the measuring instruments. This precision reflects the closeness of the results from replicate samples or indicates the reproducibility of findings obtained under identical conditions. The SPSS version 20 software was employed to compute the mean values from the triplicate data, ascertain the standard deviation, and perform analysis of variance (ANOVA) at a significance threshold of less than 0.05 ($P<0.05$). Furthermore, Principal Component Analysis (PCA) was executed based on the Pearson Correlation matrix analysis and component plot in rotated space statistics (Obruche et al., 2019).

III. RESULTS AND DISCUSSION

This section presents the analyzed results regarding the levels of toxic metals—specifically leads (Pb), cadmium (Cd), Zinc (Zn), Nickel (Ni), Chromium (Cr), Mercury (Hg), Arsenic (Ar) and Copper (Cu)—in cassava cultivated.

Concentrations of Heavy metals in cassava plants in farmlands

The mean concentrations of heavy metals (Cu, Pb, Zn, Ni, Cd,) obtained for the cassava root samples planted at 5 m, 10 m, and 15 m distances from the rural farms are summarized in Table 1. The levels of heavy metals in the roots ranged between 8.49 mg/kg and 0.113 mg/kg along Farm 1, Farm 2, and Farm 3 with Zn recording highest value (8.49 mg/kg) in samples from Farm 1 and Cd, the least (0.07 mg/kg) in samples from Farm 3. The heavy metal levels tended to be lower in control samples. This gives excellent agreement with the previously reported by Umanah et al. (2025), who reported similar results in a nearby river

Table 1. Mean concentrations of heavy metals in cassava roots

Metal	Farm 1	Farm 2	Farm 3	Control
Cu	6.29±0.0346	6.2±0.0361	6.2033±0.0252	3.1667±0.0251
Pb	0.48±0.2100	0.5267±0.3156	0.41±0.2100	0.1867±0.0058
Zn	8.49±2.2430	5.6267±0.3980	5.98±0.0265	4.0067±0.0115
Ni	0.113±0.0058	0.12±0.0400	0.0833±0.0058	0.0007±0.0006
Cd	0.1167±0.0833	0.0867±0.0306	0.0677±0.0244	0.02±0.0100

Figures 1a – 1e present values of different metal concentration (Cr, Pb, Hg, Ar, Cd) in cassava samples harvested at 10 m, 15 m, and 20 m distance away from the highway. The level of copper in cassava root grown along Farm 3 ranged from 6.18 mg/kg - 6.23 mg/kg while Farm 1 recorded highest copper content (6.33 mg/kg) at 15 m distance. The level of Pb at 10 m, 15 m, 20 m were 0.62 mg/kg, 0.41 mg/kg, and 0.20 mg/kg respectively, along Farm 3 while values along Farm 2 differed. Zn levels in samples from Farm 1 were 9.82 mg/kg, 9.755 mg/kg, and 5.90 mg/kg, at 10 m, 15 m, and 20 m respectively.

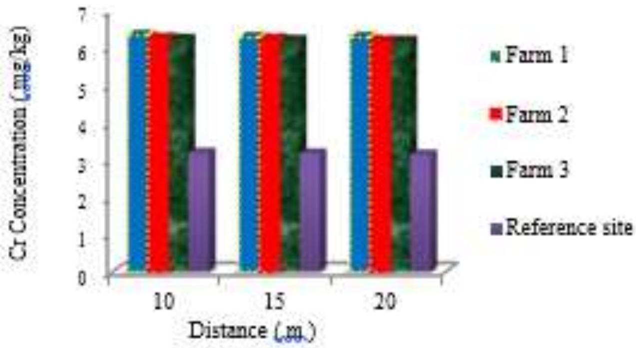

Figure 1a: Total Cr level in cassava root

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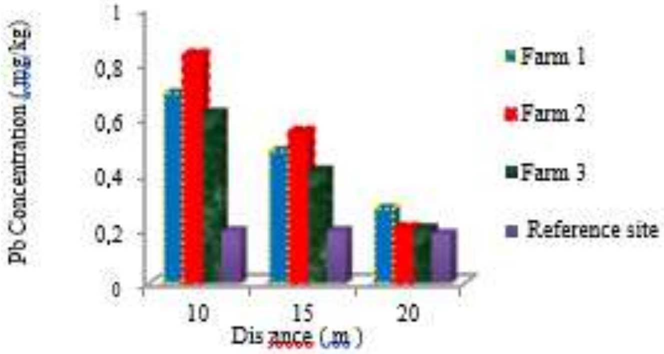

Figure 1b: Total Pb level in cassava root

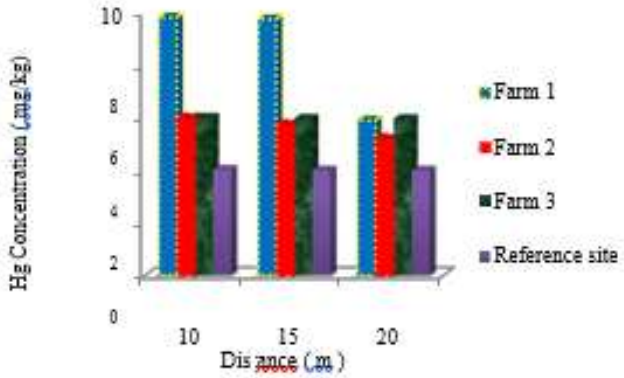

Figure 1c: Total Hg level in cassava root

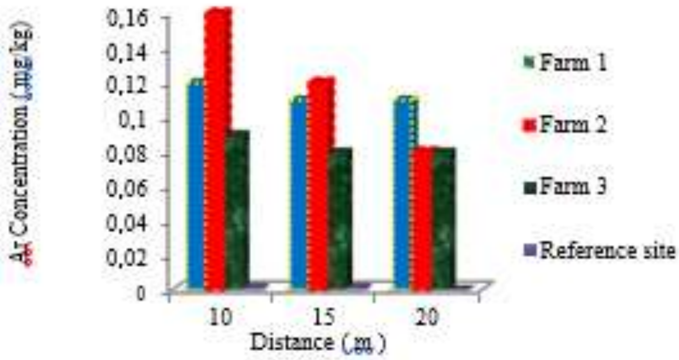

Figure 1d: Total Ar level in cassava root

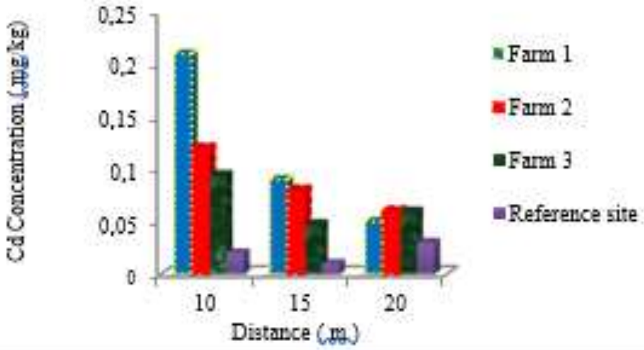

Figure 1e. Total Cd level in cassava root

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The total mean concentrations of Chromium, Lead, Mercury, Arsenic and Cadmium obtained from the cassava leaves samples at the four sites are presented in Table 2. The mean values of Cd along all the highways and control ranged between 6.31±0.02 and 3.33±0.11 mg/kg; Pb, 0.95±0.39 – 0.17±0.001 mg/kg; Hg, 6.26±0.58 – 4.03±0.13 mg/kg; Ar, 0.14±0.02 – 0.12±0.02 mg/kg; Cd, 0.16±0.03 – 0.07±0.01.

Table 2: Mean concentrations of heavy metals in cassava leaves

Metal	Farm1	Farm 2 Concentrations	Farm 3 (mg/kg)	Control
Cr	5.90667±0.6813	6.31±0.0200	6.2267±0.0252	3.333±0.1069
Pb	0.7833±0.2250	0.95±0.3904	0.713±0.2829	0.1667±0.00578
Hg	6.2633±0.5781	5.953±0.0252	5.99±0.0265	4.03±0.1308
Ar	0.1367±0.0058	0.1333±0.0379	0.1233±0.0208	0.1433±0.0153
Cd	0.1033±0.0153	0.158±0.0327	0.0763±0.0068	0.0667±0.0115

The total metal concentration deposition on cassava leaves from 10 m, 15 m, and 20 m distance at different sampling locations are presented in Figures 2a - 2e.

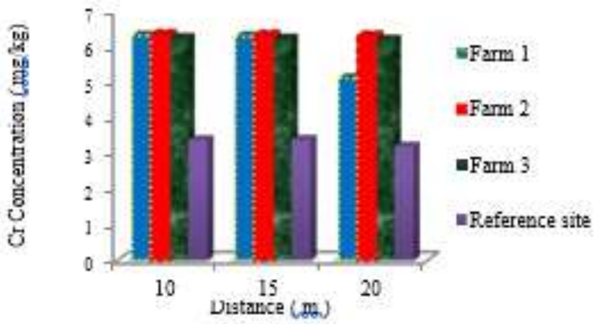

Figure 2a. Total Cr content in cassava leaves

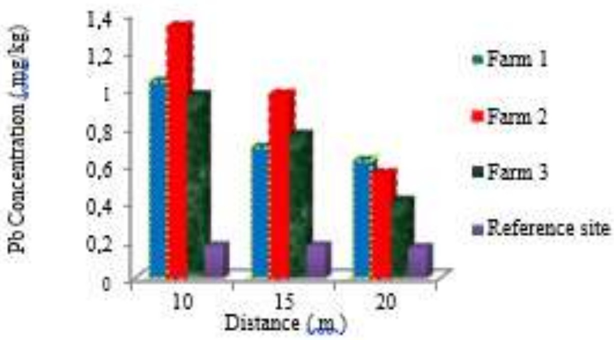

Figure 2b. Total Pb content in cassava leaves

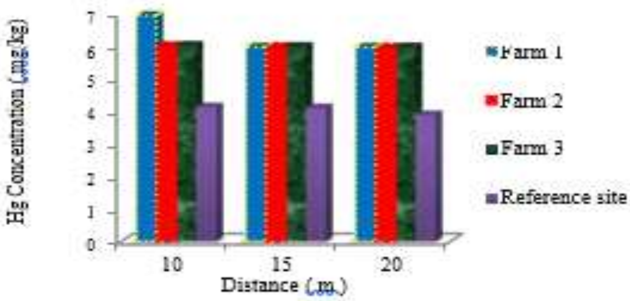

Figure 2c. Total Hg content in cassava leaves

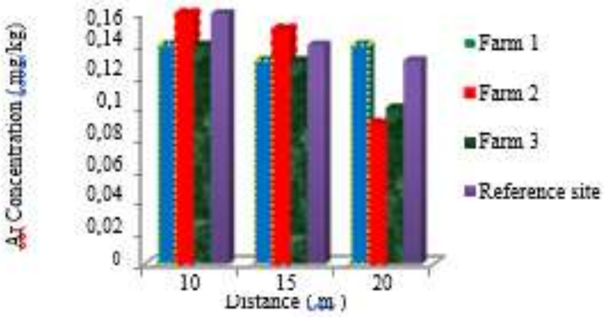

Figure 2d. Total Ar content in cassava leaves

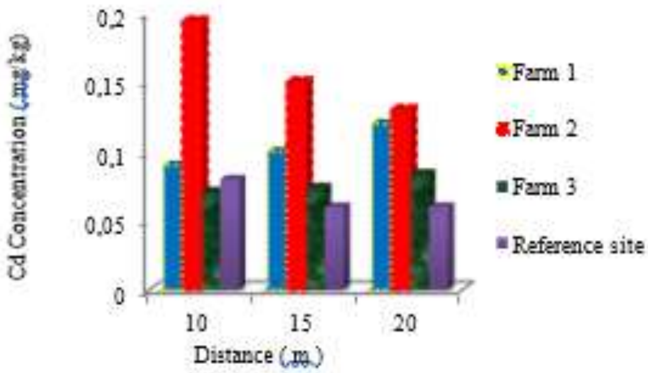

Figure 2e. Total Cd content in cassava leaves

Transfer Factor (TF)

Table 3 shows the transfer factor (Tf) of heavy metals from the soil to plants, which is the ratio of the concentration of metals in plants to the total concentration in the soil. Cr and Hg recorded high transfer factors along different sites sampled.

Table 3. Plant Transfer factor (Tf) of mean of metals

Metal	Farm 1	Farm 2	Farm 3	Reference
Cr	0.99	1.03	0.99	1.06
Pb	0.24	0.52	0.20	0.11
Hg	1.07	0.97	1.00	0.99
Ar	0.17	0.23	0.18	0.06
Cd	0.20	0.21	0.09	0.13

Statistical correlation of heavy metals in soil at different distance and cassava plants

The result for the mean difference in concentration of the heavy metals between distance and Cassava root showed no significant increase or decrease (Table 4), but the values showed an increasing trend from the 20 m region to the 10 m region.

Table 4: Mean difference in concentrations between distance and Cassava root.

Metal	10 – 15 m	Sig. diff	15 – 20 m	Sig. Diff	10 – 20 m	Sig. diff
Cr	0.03000±020680	0.197	0.0300±0.020683	0.197	0.000±0.020683	1.000
Pb	0.05250±0.15777	0.751	0.1900±0.157770	0.274	0.1375±0.15777	0.417
Hg	0.77000±0.83730	0.393	0.92750±83730	0.310	0.15750±0.83730	0.857
Ar	0.01500±0.01438	0.337	0.01975±01438	0.219	0.00475±01438	0.753
Cd	0.04425±0.03193	0.215	0.00300±0.03193	0.928	0.04125±0.03193	0.244

Correlation between heavy metals in the soil and root of cassava crops

In determining the correlation between heavy metals in the soil and root of cassava crops, Cr, Ar and Cd showed no correlation at α = 0.05 (Table 5). Hg showed a positive correlation while Pb showed a negative correlation even at α = 0.001 for both Hg and Pb. This implies that increase in the concentration of Hg in soil causes a highly significant increase in Hg in the root of Cassava crop while an increase in concentration of Pb in soil causes significant decrease in the in the root concentration of Cassava crop.

Table 5: Correlation between concentration of heavy metals in soil and root of Cassava crop.

Metal	Spearman's corr. Coefficient	Sig diff
Cr	0.632	0.368
Pb	-1.000	0.000
Hg	-1.000	0.000
Ar	-0.500	0.667
Cd	0.200	0.800

α = 0.05

IV. DISCUSSION

The levels of heavy metals bioaccumulation in cassava root and leaves reported in this study are generally lower than the WHO/FAO (2016) safe limit. There were also evidences of decrease in concentration with increase in distance at each site. Possibly due to low pH, Cd was found to bio-accumulate in cassava roots and leaves. Several studies have reported that cadmium is a highly mobile metal, easily absorbed by plants through root surface and moves to wood tissue and transfers to upper parts (Ololade IA, Ologundudu., 2007), which is synonymous with the findings as recorded in this study. Obruche et al. (2012) reported that there is a direct relation between the levels of cadmium in the root zone and its absorption by plant.

Thus, in this study, soil Cd concentration is higher than plant Cd concentration. Mercury accumulated more in cassava root (9.82 mg/kg) than the leaves which is an evidence of root mineral absorption. Chiroma et al. (2017) in their study on heavy metal contamination of vegetables and soils irrigated with sewage water in Yola, Argeria, reported that heavy metal concentrations vary in different parts of the plant with Fe accumulating in roots and leaves while Hg accumulated in roots and possibly translocated gradually to the leaves. Amusan et al. (2017) studied heavy metal uptake by plants and found that Pb uptake by water leaf (Talinum traingulare) and Okra (Abelmoschus esculentus) increased by 200% and 733% respectively in leaves and by 126% on the fruit of Okra relative to the control. There are reports of direct relationship between levels of lead in plants and traffic density (Opaluwa et al., 2012; Osuocha et al., 2014; Umudi et al., 2025). One possible explanation for this situation is that the Pb uptake can be promoted by the pH of soil and the levels of organic matter. According to Ogwuche and Obruche (2020), only 3% of Pb in soil is translocated through the root to the shoot of plants while the rest is through foliage.

The Cr plant concentration was highest in the root (6.29±0.0346 mg/kg) and lowest in the leaf (3.333±0.1069 mg/kg). The Chromium levels found in cassava plant were within safe limits in all samples. A report by Ugochukwu et al., (2025) showed that cassava leaf contained higher concentration of the heavy metals at high traffic than low traffic density roads. In the same vein, regions closer to the roads had plant leaves higher in the metal concentrations than 20 - 30 m away from the roads. Obruche et al. (2019) studied the response of three vegetables to Cr toxicity and found that Cr levels in both root and shoot increased, but root Cr concentration increased more sharply than shoot with increasing Cr levels in growth media. Cr mainly accumulated in roots while a small fraction (10%) of absorbed Cr was transported to shoot.

Moshen and Moshen (2008) found that Cr concentration in the shoots was significantly influenced by Cr concentration in soil. The statistical analysis result showed that there was no significant difference in the bioaccumulation of heavy metals in the different parts of cassava crop which implies that cassava crop is not a hyper-accumulator plant. Reports show that leafy vegetables have greater potential for accumulating heavy metals in their edible parts than grains and fruit crops, due to their higher transpiration rate (Jacob, 2010). The values of heavy metal transfer recorded are considered high because values close to or above 1 (one) are considered high Tf values (Uwah et al., 2009). The high Tf value may be due to its weak adsorption onto the organic matter which renders it more bio-available to plants. Pb showed low Tf values with the highest being 0.52, indicating that cassava plants from the study area did not have a high Pb contamination.

From the results obtained, the highest transfer factor recorded was in Hg, with all values above 0.5, indicating that cassava plants were contaminated with Hg probably from anthropogenic sources, and this is based on the suggestion that the greater the transfer coefficient value above 0.50, the greater the chances of plant-metal contamination (Ugochukwu et al., 2025). Chiroma et al. (2017) showed that Hg accumulates in roots and translocates gradually to the leaves. This implies that the bioaccumulation of heavy metals in plant was very high and food processed from such could lead to hypertension, arthritis, diabetes, anaemia, cancer, cardiovascular disease, cirrhosis, reduced fertility; hypoglycemia, headaches, osteoporosis, kidney disease, and stroke (Umudi et al., 2012) due to Hg poisoning. Cd had very low Tf in all the samples which is in contrast with work carried out by Obruche et al., (2019) who recorded a mean Cd value of 3.214 mg/kg.

The difference may be due to location of study, considering the fact that soil from different locations differ in properties. The bioaccumulation of heavy metal in cassava root and leaves showed a mean value with no significant difference for the three locations and control. Plants are known to take up and accumulate trace metals from contaminated soil (Abdul Kasheem and Singh, 2019), hence detection in plant leaves and crop samples was not surprising. Although the levels of these metals were within normal range for plants, continual consumption could lead to accumulation and adverse health implications particularly for Pb, As, and Cd (Opaluwa, 2012). Furthermore, values obtained in soil and crop plant samples could be attributed to vehicular emission deposit on farmlands and crops.

V. CONCLUSION

This study was carried out on the Assessment of some toxic metals in variety of cassava Cultivated in Damagum L.G.A of Yobe State. The overall results showed evidence of some heavy metal pollution on the soils and bio-accumulation in cassava plants, from farmlands in Damagum LGA. The heavy metal levels tended to be lower in control samples. Cr and Hg recorded high transfer factors along different sites sampled. While Hg showed a positive correlation, Pb showed a negative correlation. This implies that increase in the concentration of Hg in soil causes a highly significant increase in Hg in the root of Cassava plant while an increase in concentration of Pb in soil causes significant decrease in the in the root concentration.

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