



ASSESSMENT OF TOXIC ELEMENT ACCUMULATION WITH CONSUMPTION OF *Manihot esculenta* (Crantz) CULTIVATED IN PROXIMITY TO A QUARRY SITE.

Authors: Gloria C. ADIELE^a, Emmanuel O. ADESINA^{b*}, Abdulrasaq O. ABDULGANIYU^c,
Ismail O. SULEIMAN^d, Oluwadamilola O. LAWRENCE^e, Opeyemi J. ILUYEMI^f, Temilade A.
ADENEKAN^g, Barokah F. ABDULWASII^h, Mary B. OLAWUYIⁱ, Funmilayo V. ADISA^j and,
Fausat R. TIJANI^l

^{a,b,c,e-i}Department of Environmental Biology, School of Science and Technology,
The Federal Polytechnic, Ede, Osun State.

^dDepartment of Biochemical Sciences, The Federal Polytechnic Ede, Osun State, Nigeria.

Corresponding Author: adesinaemmanuel726@gmail.com OR adiele.gloria@federalpolyede.edu.ng.

^a(ORCID ID 0009-0009-5919-582X) [+2348068552846](https://orcid.org/0009-0009-5919-582X)

ABSTRACT: Quarrying generates dust that can transfer heavy metals into nearby agricultural soils and crops. This study examined concentrations of selected metals in soils and in roots and leaves of cassava grown at varying distances from active quarry operations in Ede North, Osun State, Nigeria, and evaluated the associated non-carcinogenic and carcinogenic risks from consumption. Soil and plant samples were collected from near (0–100 m) zones, prepared by acid digestion, and analysed by atomic absorption spectrophotometry. Bioaccumulation factors (BAF) estimated daily intake (EDI), target hazard quotient (THQ), hazard index (HI) and incremental lifetime cancer risk (ILCR) for lead were calculated for adult and child consumers using standard exposure parameters. Soil metal levels showed spatial variation consistent with proximity to the quarry. Cassava roots generally retained higher absolute concentrations of several metals than leaves, yet cadmium exhibited elevated BAF values (>3) in both tissues, indicating preferential uptake. Adult and child HI values remained below 1 for both root and leaf consumption under the assumed intake rates, with cadmium and lead contributing the largest shares of the cumulative risk. Lead ILCR estimates fell within the conventional screening range. The findings indicate that while immediate non-carcinogenic risk appears limited under current consumption patterns, continued cultivation of cassava in the immediate vicinity of quarries warrants monitoring, particularly for cadmium and lead, and supports the need for buffer-zone guidance to protect staple-crop safety in similar extractive landscapes.

Keywords: Cassava, Heavy metals, Quarry dust, Bioaccumulation, Health risk assessment.

1. INTRODUCTION

The contamination of agricultural environments by potentially toxic elements is an important food-safety and environmental-health concern because elements released into soil can persist for long periods and may subsequently enter food chains (Kwarteng, 2012). Unlike many organic contaminants, metallic elements cannot be destroyed through biological degradation. Their environmental behaviour instead depends on processes such as adsorption, precipitation, complexation, dissolution and plant uptake. Consequently, contamination introduced into agricultural soils may remain relevant long after the original emission has occurred.

Quarrying represents one potential source of trace-element redistribution. Drilling, blasting, crushing, screening, stockpiling and transportation of quarried materials can generate particulate emissions. According to Adewoyin et. al (2023), the mineralogy of the quarried material and the characteristics of the surrounding environment depends on, deposited particles may modify the elemental composition of neighbouring soils and vegetation.

The food-chain implications are particularly important where farming takes place immediately around extractive operations. Soil is both a reservoir and a pathway for potentially toxic elements. Some elements may remain relatively immobile within mineral or organic fractions, whereas others can become sufficiently available for uptake by plant roots. Soil pH, organic matter, clay content, cation-exchange capacity and the chemical form of

an element can influence this process (Karimi, 2023). The movement of elements from contaminated soil into crops is consequently not governed solely by the total concentration present in the soil.

The importance of soil-to-crop transfer has been emphasized in international literature. Rai et al. (2019) identified contaminated soil–food-crop systems as an important route of human exposure and highlighted the influence of soil properties, plant physiology and contaminant characteristics on metal transfer.

Cassava is particularly relevant to this problem in Nigeria. The crop is widely cultivated and consumed, and its storage roots are processed into several staple foods (Adjei-Mensah, 2021). Because cassava is frequently grown under smallholder conditions, agricultural plots may occur close to roads, industrial activities, mining areas and quarry sites.

Previous Nigerian research has demonstrated that cassava can accumulate potentially toxic elements in environments affected by extractive activities. Ihejirika et al. (2021), for example, investigated cassava cultivated on quarry-affected soils in Umunneochi, Abia State, and detected heavy metals in both soil and cassava tubers. Their study reported significant differences between quarry-associated samples and controls for several metals and identified relationships between soil and cassava concentrations.

Adewoyin et al. (2023) similarly investigated cassava grown around a limestone-mining environment in Ewekoro, Ogun State. Their study sampled locations at 150 and 300 m from the mining site and a distant control and identified measurable concentrations of multiple elements in soil and cassava tubers. Other Nigerian studies have demonstrated the broader food-safety significance of metal contamination. Atikpo et al. (2021) investigated Pb, Cd, Zn and Cr in agricultural soils and vegetables in western Nigeria and incorporated dietary exposure and health-risk indices into their assessment. Their results demonstrated that risk estimates could vary substantially between contaminants and that children may experience higher exposure per unit body weight than adults. Orji et al. (2021) also assessed trace metals in soils and food crops around mining sites in Ebonyi State and showed the usefulness of integrating environmental concentrations with human-health risk assessment.

Although these studies provide important evidence, the environmental behaviour of metals around quarrying sites cannot be assumed to be identical across geographical settings. Differences in parent rock, quarrying technique, soil characteristics, atmospheric conditions, agricultural practices and crop varieties can alter both environmental concentrations and plant uptake. The existing Nigerian literature establishes that quarrying and mining can be associated with metal accumulation in agricultural soils and crops. However, comparatively little information is available for quarry-adjacent cassava production in Ede North, Osun State.

The present study adds local evidence by examining the distribution of multiple trace elements between soil and two cassava tissues—leaf and storage root—and by translating measured concentrations into dietary exposure estimates. An additional feature of the study is the comparison of bioaccumulation between cassava tissues. This is relevant because the leaf and storage root occupy different positions within the plant and are exposed to contaminants through partly different pathways.

The study aimed to assess heavy-metal accumulation and potential human-health risks associated with consumption of cassava cultivated in proximity to a stone quarry in Ede North, Osun State, Nigeria.

2. METHODOLOGY

2.1. Study Area

The study was undertaken in Iwoye community, Ede North Local Government Area of Osun State, southwestern Nigeria. The area supports smallholder agricultural activities, including cassava production, while quarrying constitutes an important land-use activity in parts of the locality. The geographic coordinates of the sampling location are illustrated in the map below:

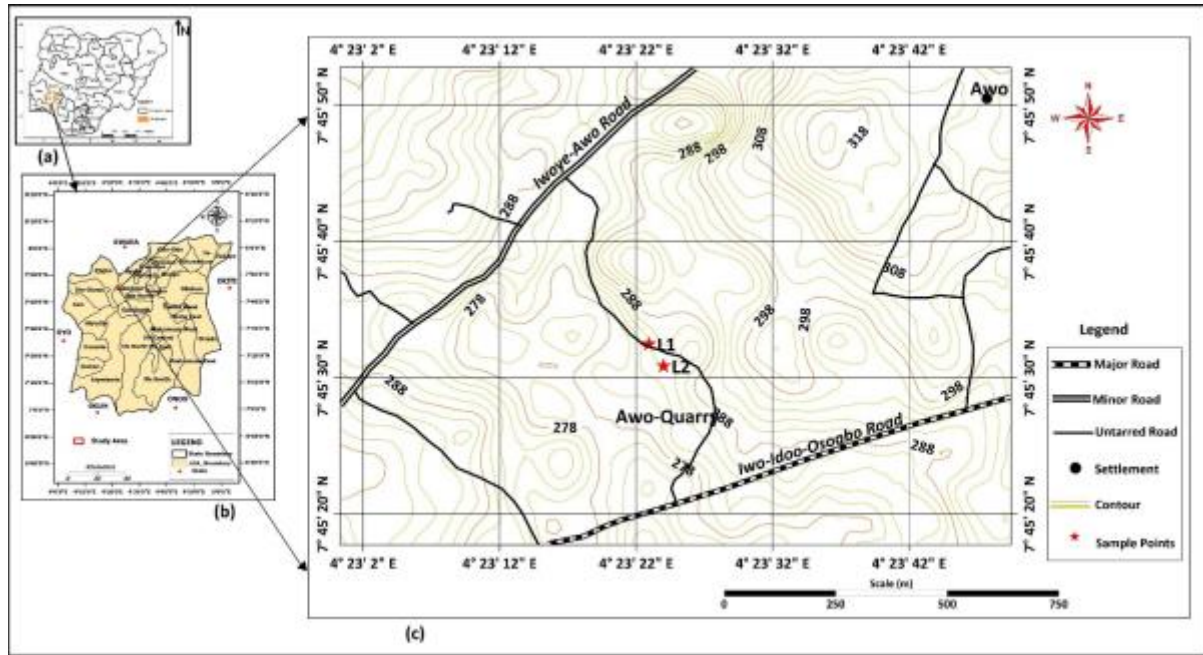


Fig. 1. Topographic map of the study area showing the Quarry site in Ede North Local Government Area, Osun State.

2.2 Collection and Processing of plant samples

Soil samples were collected from the upper 0–20 cm layer using a soil auger. This depth was selected to represent the principal soil zone interacting with cassava roots. Cassava plants were collected from the corresponding agricultural environment. The plants were separated into storage-root and leaf tissues. Samples were placed in labelled polyethylene bags and transported to the laboratory for preparation and analysis. Soil samples were air-dried and passed through a 2-mm sieve following removal of stones and visible debris. Cassava leaves and storage roots were washed with distilled water to remove adhering materials, dried at approximately 50–70 °C to constant weight and subsequently ground into fine powder (Adewoyin et. al. 2023).

The prepared samples were subjected to acid digestion using nitric acid and perchloric acid before instrumental determination. Atomic absorption spectrophotometry was used for elemental determination. For quality control and assurance, laboratory glassware was acid-washed before sample preparation and analyses in triplicates.

2.3 Estimation of Bioaccumulation factors

Bioaccumulation factor was calculated as:

$$BAF = \frac{C_{plant}}{C_{soil}}$$

where C_{plant} represents the concentration of an element in the relevant cassava tissue and C_{soil} represents its concentration in soil.

Separate BAFs were calculated for cassava leaves and storage roots.

A BAF greater than 1 indicates that the concentration in the plant tissue exceeds the corresponding soil concentration numerically; it should not automatically be interpreted as evidence of toxicological risk.

2.4 Estimated daily intake

Dietary exposure was calculated as:

$$EDI = \frac{C \times CF \times IR}{BW}$$

where:

- C = element concentration in plant tissue (mg/kg dry weight);
- CF = fresh-to-dry conversion factor;
- IR = daily ingestion rate (kg/day);
- BW = body weight (kg).

The supplied dataset used:

Exposure parameter	Adult	Child
Ingestion rate	0.187 kg/day	0.130 kg/day

Exposure parameter	Adult	Child
Body weight	71.3 kg	22.5 kg
Fresh-to-dry conversion factor	0.085	0.085

The ingestion and body-weight assumptions were based on the Nigerian study of Atikpo et al. (2021).

2.5 Target Hazard Quotient

For screening of non-carcinogenic effects:

$$THQ = \frac{EDI}{RfD}$$

where RfD is the applicable chronic oral reference dose or equivalent health-based reference point.

A THQ below 1 is conventionally interpreted as indicating that estimated exposure is below the selected reference value. A THQ above 1 indicates that the estimated exposure exceeds the reference point and warrants further evaluation.

2.6 Hazard index

The combined screening index was calculated as:

$$HI = \sum THQ_i$$

where THQ_i represents the target hazard quotient for each element included in the assessment.

3.0 RESULTS AND DISCUSSION

3.1 Physiochemical Properties of Soil samples

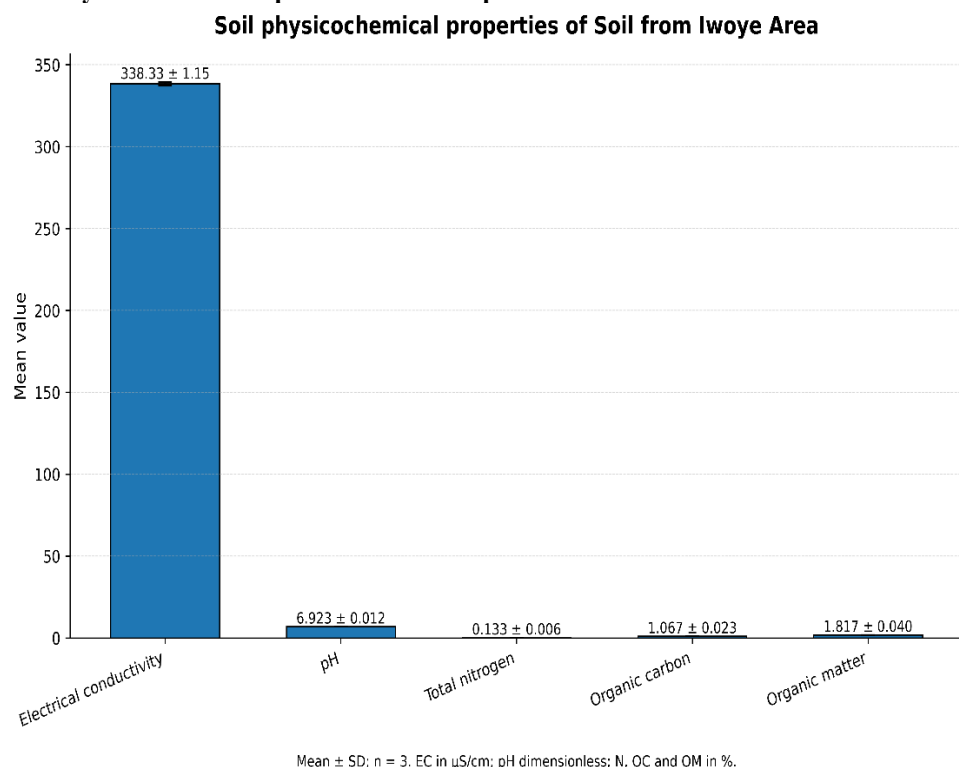


Figure 2. Soil physicochemical properties of samples collected from the Iwoye area. Bars represent mean values $\pm$ standard deviation (SD), n = 3.

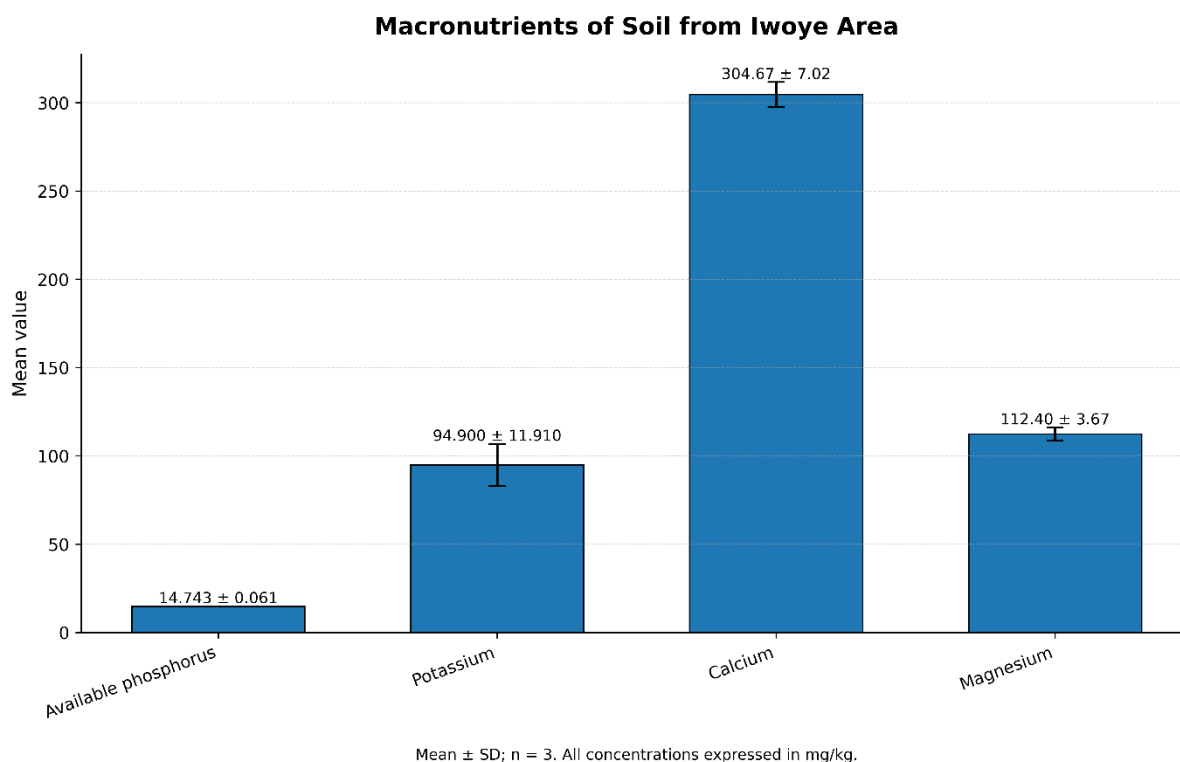


Figure 3. Macronutrient concentrations in soil samples collected from the Iwoye area. Bars represent mean values ± standard deviation (SD), n = 3.

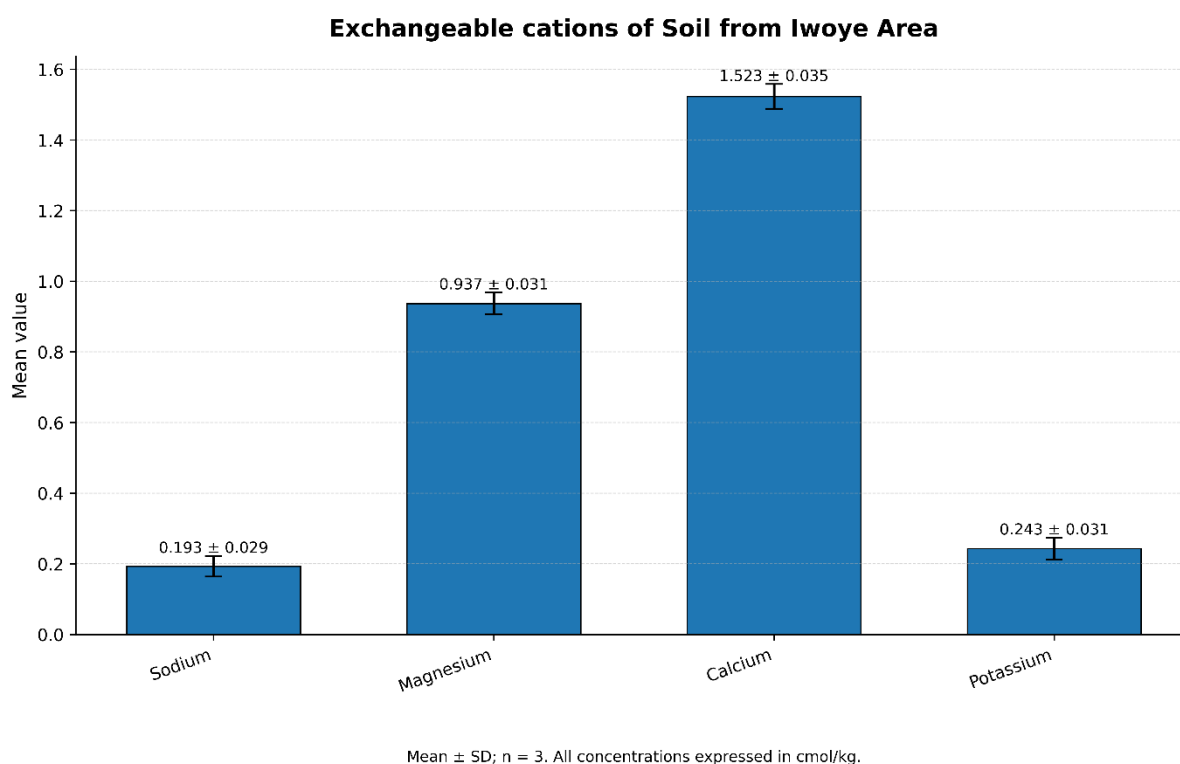


Figure 4. Exchangeable cation concentrations in soil samples collected from the Iwoye area. Bars represent mean values ± standard deviation (SD), n = 3.

The soil was characterized by near-neutral pH (6.923 ± 0.012), moderate EC ($338.33 \pm 1.15 \mu\text{S}/\text{cm}$), and relatively consistent nutrient/organic-matter levels, with Ca being the dominant measured macronutrient and exchangeable

base cation. The low SDs for most parameters indicate good replicate consistency, while the comparatively higher variability in K (94.90 ± 11.91 mg/kg) suggests greater heterogeneity in its distribution.

3.1.2 Element concentrations in soil and Plant Tissues

Table 1. Concentrations of investigated elements

Element	Concentration (mg/kg)	Cassava storage root (mg/kg)	Cassava leaf (mg/kg)
Mn	117.78 ± 0.20	1.060	0.314
Zn	48.94 ± 0.04	2.300	1.267
Cr	12.14 ± 0.04	3.301	0.111
Co	9.83 ± 0.04	0.059	0.013
Pb	19.46 ± 0.07	2.316	0.121
Cd	0.33 ± 0.03	1.127	1.101
Mo	0.71 ± 0.03	0.017	0.009

The tissue profiles differed considerably between leaves and storage roots. Storage roots contained higher concentrations of Mn, Zn, Cr, Co, Pb and Mo than leaves. Cadmium was also slightly higher in the storage root than in the leaf.

The most pronounced root–leaf difference occurred for chromium and lead.

3.1.3 Soil-to-Plant bioaccumulation

Table 3. Bioaccumulation factors

Element	Leaf BAF	Root BAF
Mn	0.003	0.009
Zn	0.026	0.047
Cr	0.009	0.272
Co	0.001	0.006
Pb	0.006	0.119
Cd	3.336	3.415
Mo	0.013	0.024

Cadmium exhibited a markedly different accumulation pattern from the other investigated elements. The leaf BAF for Cd was 3.336, while the root BAF was 3.415. Both values exceeded 1, indicating strong numerical enrichment of Cd in the plant tissues relative to the measured soil concentration. For the other elements, BAF values were below 1. Chromium showed the second-highest root BAF at approximately 0.272, followed by Pb at approximately 0.119.

3.1.4 Estimated daily intake

Using the supplied exposure assumptions, recalculated EDI values are presented below.

Table 4. Estimated daily intake through cassava consumption

Element	Adult leaf EDI	Adult root EDI	Child leaf EDI	Child root EDI
Mn	7.00×10^{-5}	2.36×10^{-4}	1.54×10^{-4}	5.21×10^{-4}
Zn	2.82×10^{-4}	5.13×10^{-4}	6.22×10^{-4}	1.13×10^{-3}
Cr	2.47×10^{-5}	7.36×10^{-4}	5.45×10^{-5}	1.62×10^{-3}
Co	2.90×10^{-6}	1.32×10^{-5}	6.38×10^{-6}	2.90×10^{-5}
Pb	2.70×10^{-5}	5.16×10^{-4}	5.94×10^{-5}	1.14×10^{-3}
Cd	2.45×10^{-4}	2.51×10^{-4}	5.41×10^{-4}	5.53×10^{-4}
Mo	2.01×10^{-6}	3.79×10^{-6}	4.42×10^{-6}	8.35×10^{-6}

The estimated exposure was generally greater for the child scenario because the assumed body weight was substantially lower.

3.1.5 Target hazard quotient and hazard index

Using the reference doses supplied in the original dataset, the recalculated screening THQs and HIs were:

Table 5. Non-carcinogenic screening indices

Tissue	Consumer HI
Cassava leaf Adult	0.255
Cassava leaf Child	0.562
Cassava root Adult	0.404
Cassava root Child	0.890

The largest individual contribution was associated with cadmium (Cd), followed by lead (Pb) under the reference-dose assumptions used in the original dataset.

All calculated combined screening HIs were below 1.

However, these values should not be interpreted as definitive evidence that the cassava presents no health concern. In particular, lead WHO likewise emphasizes that there is no known exposure level for lead without harmful effects. ([World Health Organization](#))

3.2 DISCUSSION

The soil exhibited near-neutral pH and relatively consistent physicochemical characteristics, with calcium constituting the dominant measured macronutrient and exchangeable base cation. This pattern provides an important physicochemical baseline for interpreting heavy-metal mobility and cassava uptake, consistent with previous Nigerian investigations around quarrying, limestone-mining, bitumen-mining and mining environments (Ihejirika et al., 2021; Adewoyin et al., 2023; Atikpo et al., 2021; Orji et al., 2021), although direct numerical comparison is limited by differences in soil types, sampling designs and analytical parameters.

The measured soil profile was dominated numerically by Mn, followed by Zn and Pb which is in line with Adewoyin et. al. (2023). These elements are naturally present in geological materials, and their occurrence in quarry-adjacent soils can therefore have both geogenic and anthropogenic explanations (Ihejirika et. al, 2021). The present dataset therefore supports the observation that the investigated soil contained measurable quantities of several trace elements.

The storage root contained greater concentrations than the leaf for Mn, Zn, Cr, Co, Pb and Mo. This pattern demonstrates that element distribution within cassava is element-specific rather than uniform across tissues. The root concentration of Cr was approximately 3.30 mg/kg, compared with 0.111 mg/kg in the leaf. Similarly, Pb was approximately 2.32 mg/kg in the root and 0.121 mg/kg in the leaf. The observed pattern differs from the simple assumption that atmospheric deposition must necessarily result in greater contamination of leaves. Leaf contamination can be influenced strongly by surface deposition, but internal accumulation depends on uptake, transport, sequestration and the chemical characteristics of the element (Ihejirika et. al, 2021).

Cadmium was the most notable element in the bioaccumulation analysis. Although the soil Cd concentration was only 0.33 mg/kg, concentrations of 1.101 mg/kg in leaves and 1.127 mg/kg in roots produced BAFs greater than 3. This observation illustrates why environmental assessment based solely on soil concentration can be misleading. A relatively low soil concentration does not necessarily imply negligible crop exposure because plant uptake depends on bioavailability rather than total concentration alone. This is similar to Pam et al. (2013) report on variations of metal concentrations in soil and plant tissues. Cadmium is of particular food-safety interest because chronic dietary exposure can affect the kidneys and skeletal system. The World Health Organization identifies cadmium among environmental contaminants for which dietary exposure is an important route of human exposure. ([World Health Organization](#)) Lead concentration in the storage root was 2.316 mg/kg compared with 0.121 mg/kg in the leaf. Lead is toxic and has no known beneficial biological function in humans. (Orji t. al., 2021) Consequently, the relatively low numerical THQ generated by the reference dose used in the original dataset should not be interpreted as establishing a safe exposure level for Pb.

The calculated child EDIs were higher than adult EDIs for all investigated elements. This difference results primarily from the relationship between the assumed ingestion rate and body weight. A given quantity of contaminated food represents a larger dose per kilogram of body weight in a smaller individual. The pattern is consistent with previous Nigerian dietary-risk studies. Sc et. al., (2016), Adjei-Mensah et, al. (2021) Atikpo et al. (2021) also reported higher exposure-related risk estimates for children in contaminated agricultural environments. Nevertheless, child risk estimates are sensitive to the assumed body weight and consumption rate.

The calculated HIs were below 1 for both adult and child scenarios. On the refence doses used, the combined exposure estimates were below the conventional non-carcinogenic screening threshold. The child cassava-root HI

of approximately 0.89 was closer to the screening threshold than the other scenarios. This finding warrants further investigation but should not be described as evidence of imminent toxicity or definitive measure of health safety.

The supplied document calculated an incremental lifetime cancer risk for lead using a slope factor of $0.0085 \text{ (mg/kg-day)}^{-1}$. Although the EPA CompTox database currently displays a cancer slope factor of 0.0085 for lead, the current EPA IRIS page does not provide an oral RfD and the IRIS cancer assessment is based on an older assessment framework. (US EPA, 2025)

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

The investigated soil contained measurable concentrations of Mn, Zn, Cr, Co, Pb, Cd and Mo, while all seven elements were detected in cassava tissues. The elemental distribution differed substantially between cassava storage roots and leaves.

Cadmium exhibited the strongest apparent soil-to-plant accumulation, with BAF values exceeding 3 in both leaf and storage-root tissues. The storage root generally contained greater concentrations of Mn, Zn, Cr, Co, Pb and Mo than the leaf.

Under the supplied dietary-exposure assumptions, estimated exposure was greater for children than adults. The calculated combined non-carcinogenic screening indices were below 1 for both age groups, although the child root-consumption scenario approached the conventional screening threshold. These findings provide preliminary evidence that cassava cultivated in a quarry-influenced environment can accumulate selected trace elements, particularly cadmium.

The results therefore support the need for expanded field sampling incorporating multiple independent farms, appropriate reference locations, physicochemical soil characterization and locally derived dietary exposure parameters.

4.2 Recommendation

It is Recommended that: where elevated concentrations are confirmed through expanded sampling, environmental monitoring of agricultural land surrounding quarry operations should be strengthened.

REFERENCES

- Adewoyin, O. O., Omeje, M., Conrad, O., Nwinyi, O. C., Arijaje, T. E., Ayanbisi, O., & Ogunrinola, I. (2023). Assessment of heavy metal contents in farm produce around Ewekoro and its health implications on consumers. *SN Applied Sciences*, 5, 340. <https://doi.org/10.1007/s42452-023-05550-1>
- Adjei-Mensah R, Ofori H, Tortoe C, Johnson PT, Argue D, Frimpong SK (2021) Effect of home processing methods on the levels of heavy metal contaminants in four food crops grown in and around two mining towns in Ghana. *Toxicol Rep* 8:1830–1838. <https://doi.org/10.1016/j.toxrep.2021.11.001>.
- Atikpo, E., Okonofua, E. S., Uwadia, N. O., & Michael, A. (2021). Health risks connected with ingestion of vegetables harvested from heavy metals contaminated farms in Western Nigeria. *Heliyon*, 7(8), e07716. <https://doi.org/10.1016/j.heliyon.2021.e07716>
- Dikioye, E. P., Charity, E., & Kpobari, W. N. (2018). Potential human health risk assessment of heavy metals via consumption of root tubers from Ogoniland, Rivers State, Nigeria. *Biological Trace Element Research*, 186, 568–578. <https://doi.org/10.1007/s12011-018-1330-1>
- Håkanson, L. (1980). An ecological risk index for aquatic pollution control: A sedimentological approach. *Water Research*, 14(8), 975–1001. [https://doi.org/10.1016/0043-1354\(80\)90143-8](https://doi.org/10.1016/0043-1354(80)90143-8)
- Ihejirika, C. E., Ndubuisi, E. C., Njoku, J. D., Emereibeole, E. I., Ebe, T. E., Njoku-Tony, R. F., Ihejirika, O. C., Imo, E. O., Nwachukwu, I. N., Chinakwe, E. C., Uyo, C. N., Ezikeudu, C. E., & Ursula, N. N. (2021). Heavy metal contamination of cassava (*Manihot esculenta* Crantz) grown on quarry soils in Umunneochi, Abia State and its health implications. *EQA—International Journal of Environmental Quality*, 45, 1–9. <https://doi.org/10.6092/issn.2281-4485/12563>
- Karimi A, Naghizadeh H, Biglari R, Peirovi A, Ghasemi A, Zarei, (2020) Assessment of human health risks and pollution index for heavy metals in farmlands irrigated by effluents of stabilization ponds. *Environ Sci Pollut Res Int* 27:10317–10327. <https://doi.org/10.1007/s11356-020-07642-6>

Kwarteng G (2012) Environmental Impact of Mining and the Well-being of the People in Akwatia: a Case Study in Akwatia Town, Ghana. Master Thesis, Swedish University of Agricultural Science, Uppsala, Sweden.

Orji, O. U., Ibiam, U. A., Awoke, J. N., Obasi, O. D., Uraku, A. J., Alum, E. U., & Eze, A. G. (2021). Assessment of levels and health risks of trace metals in soils and food crops cultivated on farmlands near Enyigba mining sites, Ebonyi State, Nigeria. *Journal of Food Protection*, 84(8), 1288–1294. <https://doi.org/10.4315/JFP-20-295>

Pam A.A., Ato R.S., Offem J.O. (2013) Contribution of Automobile Mechanic Sites to Heavy Metals in Soil: A case study of North Bank Mechanic village, Makurdi, Benue State, Central Nigeria. *Journal of Chemical, Biological and Physical Sciences*, 3(3):2337-2347, ISSN: 2249-1929

Rai, P. K., Lee, S. S., Zhang, M., Tsang, Y. F., & Kim, K.-H. (2019). Heavy metals in food crops: Health risks, fate, mechanisms, and management. *Environment International*, 125, 365–385. <https://doi.org/10.1016/j.envint.2019.01.067>

Sc O, Chukwu A, Davies TC (2016) Heavy metals and health risk assessment of arable soils and food crops around Pb-Zn mining localities in Enyigba southeastern Nigeria. *J Afr Earth Sc* 116:182–189. <https://doi.org/10.1016/j.jafrearsci.2015.12.025>

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., & Sutton, D. J. (2012). Heavy metal toxicity and the environment. In A. Luch (Ed.), *Molecular, clinical and environmental toxicology* (Vol. 101, pp. 133–164). Springer. https://doi.org/10.1007/978-3-7643-8340-4_6

United States Environmental Protection Agency. (2026). *Integrated Risk Information System (IRIS): Lead and compounds (inorganic)*. U.S. Environmental Protection Agency.

World Health Organization. (2024). *Human health effects of benzene, arsenic, cadmium, nickel, lead and mercury: Report of an expert consultation*. World Health Organization.

World Health Organization. (2026). *Lead poisoning and health*. World Health Organization.