Nigerian Journal of Physics (NJP)
ISSN online: 3027-0936
ISSN print: 1595-0611
DOI: https://doi.org/10.62292/njp.v35i4.2026.642
Volume 35(4), December 2026

Human Health Risk Assessment of Heavy Metals in Cassava Cultivated Near 33 kV High-Voltage Power Lines in Benue State, Nigeria

Aba Solomon Akiki and *Jande Sylvester Gemanam

Rev. Fr. Moses Orshio Adasu University Makurdi Benue State, Nigeria.

*Corresponding Author's Email: akikiaba1@gmail.com

Keywords:
Heavy Metals,
Health Risk Assessment,
Cassava,
Electromagnetic Field,
Power Lines,
Benue State.

Submitted: 07 July 2026

Accepted: 16 July 2026

Published: 02 August 2026

ABSTRACT

High-voltage power lines generate electromagnetic fields (EMF) that may theoretically influence soil metal bioavailability and plant uptake. Cassava, a staple root crop, can accumulate toxic metals with chronic health implications for consumers. To assess human health risks associated with heavy metal (Pb, Cd, Cu, Zn, Fe) content in cassava tubers cultivated at varying distances from a 33 kV power line in Benue State, Nigeria. Cassava tubers (TME 419) were collected at 0, 5, 10, 15, 20, and 50 m from a 33 kV power line in Apir, Makurdi. Heavy metal concentrations were determined by atomic absorption spectrophotometry. Estimated Daily Intake (EDI) and Hazard Quotient (HQ) were calculated for adult populations (body weight 60 kg, ingestion rate 0.5 kg/day). Soil homogeneity was confirmed by physicochemical analysis. Heavy metal concentrations showed irregular variations across distances with no consistent EMF-related pattern. Lead ranged from below detection to 0.118 mg/kg; cadmium from below detection to 0.012 mg/kg; copper from 0.064 to 0.104 mg/kg; zinc from 0.253 to 0.822 mg/kg. All values remained within permissible safety limits. EDI values ranged from 0.00000 to 0.00098 mg/kg/day for Pb and 0.00000 to 0.00010 mg/kg/day for Cd. HQ values for all metals across all distances were below unity (HQ < 1), with the highest being 0.28 for Pb at 0 m. No significant non-carcinogenic health risk is associated with cassava consumption from the study area. Heavy metal concentrations are primarily influenced by soil characteristics rather than EMF exposure. However, the relatively higher HQ for Pb (0.28) suggests continued monitoring is warranted.

INTRODUCTION

Heavy metal contamination of food crops is a major public health concern in sub-Saharan Africa due to rapid industrialisation, artisanal mining, and unregulated agricultural practices (Nriagu, 2019). In addition to point sources, non-ionising radiation from high-voltage power lines has been hypothesised to alter soil chemistry and metal uptake in plants through mechanisms such as changes in soil pH, redox potential, microbial activity, and root membrane permeability (Maffei, 2015; Belyavskaya, 2020).

Cassava (Manihot esculenta) is a staple food for over 500 million people in sub-Saharan Africa (FAO, 2022). As a deep-rooting, high-biomass crop, cassava can accumulate trace metals from soil. Benue State, Nigeria, is a major cassava-producing region (NAERLS, 2022; NBS, 2012). The expansion of rural electrification has resulted in 33 kV electricity distribution lines passing through many agricultural communities, including cassava growing areas, thereby raising concerns about the long-term effects of electromagnetic field exposure on crop quality and food safety. Although direct health effects of EMF are debated, indirect pathways via food chain contamination remain underexplored, particularly in West African agricultural contexts.

Heavy metals such as lead (Pb) and cadmium (Cd) are nephrotoxic and neurotoxic, with no known beneficial biological functions. Chronic dietary exposure, even at low levels, is associated with adverse health outcomes (USEPA, 2021). The World Health Organization and FAO have established provisional tolerable daily intakes (PTDI) for these metals. The hazard quotient (HQ) framework, developed by USEPA, compares estimated daily intake (EDI) to reference doses (R_fD), with HQ > 1 indicating potential non-carcinogenic risk.

Previous studies on heavy metals in cassava near power lines have reported conflicting results. Some have suggested EMF-associated metal accumulation (Ekeocha et al., 2014), while others attribute variations primarily to soil characteristics (Adegbite et al., 2018). A study by Adelekan et al. (2023) assessed cassava farms near 33kV lines in Oyo State and found lower tuber starch content (8–12% reduction) compared to control sites. The researchers attributed this to electromagnetic interference with carbohydrate metabolism, consistent with global findings on root crops (Adelekan et al, 2023). Another study by Akinola et al. (2023) examined maize and cassava fields under 11kV distribution lines in Lagos. Results showed increased cyanogenic potential in cassava tubers, raising food safety concerns. The study suggested that EMF-induced stress may activate cyanogenic glycoside synthesis as a defense mechanism, similar to responses observed under drought or soil toxicity (Akinola et al, 2023). Additionally, Ogunkanmi et al. (2022) investigated oxidative stress markers in cassava leaves near power lines in southwestern Nigeria. They reported higher malondialdehyde (MDA) levels, indicating lipid peroxidation due to prolonged EMF exposure. Belyavskaya (2004), Akpolat et al. (2018), and Nwankwo and Ibeh (2015), reported no substantial EMF effects on proximate composition, supporting the conclusions drawn in this study. Similarly, previous studies have shown that acidity and cyanogenic content in cassava are unaffected by EMFs.

In Benue State, no localized health risk assessment has been conducted for cassava grown near 33 kV power lines. There is no quantitative health risk assessment for consumers of cassava grown near high-voltage power lines in Benue State, despite plausible EMF–metal interaction hypotheses and local farming practices that place cassava directly beneath power lines. In light of these, this study seeks to evaluate human health risks (non-carcinogenic) from heavy metal exposure through cassava cultivated at varying distances from a 33 kV power line in Benue State.

MATERIALS AND METHODS

Materials

The following materials were used for this work: a TriField® EMF Meter (Model TF2) for electromagnetic field measurements, GPS-enabled smartphone for geolocation data. Essential field tools consist of a 50m measuring tape, digital weighing scale with 0-10kg capacity, an analytical balance, UV-Vis spectrophotometer, centrifuge, temperature-controlled water bath (30-100°C), hot air oven, pH meter, magnetic stirrer, vortex mixer, a set of micro pipettes, beakers, flasks, and test tubes

Study Area and Sampling

The study was conducted in Apir, Makurdi, Benue State, Nigeria (Latitude 7.72495°N, Longitude 8.53587°E). Cassava tubers (variety TME 419, 12 months maturity) were collected at six distances from a 33 kV power line: 0 m, 5 m, 10 m, 15 m, 20 m, and 50 m (control). Samples were washed, peeled, sliced, and oven-dried at 60°C to constant weight.

Soil analysis

Soil samples were collected at 0 m, 20 m, and 50 m from the power line. Parameters analysed included pH (H_2O), organic carbon (OC), organic matter (OM), total nitrogen (N), available phosphorus (AP), exchangeable cations (Ca, Mg, K, Na), total exchangeable bases (TEB), cation exchange capacity (CEC), exchangeable acidity (EA), base saturation (BS), and particle size distribution (sand, silt, clay). All three samples were classified as loamy sand with similar chemical properties. Soil analysis confirmed homogeneity of the soil across all sampling points (Table 1).

Table 1: Soil Analysis

Soil sample	pH	NEP				Exchangeable Properties								Particle Size Dist.			
DES	H^2O	OC	OM	N	AP	Ca	Mg	K	Na	TEB	CEC	EA	BS	Sand	Silt	Clay	Texture
Unit	1:1		%		Mg/l				Cmol/kg				%		%		Class
0 m	5.58	1.20	2.06	0.101	6.53	4.50	1.35	0.34	0.17	6.36	7.59	1.43	81.90	81.52	9.28	9.20	Loamy sand
20 m	5.71	1.00	1.92	0.098	6.39	4.20	1.32	0.30	0.15	5.97	7.10	1.13	84.08	79.52	10.28	9.20	Loamy sand
50 m	5.55	1.10	1.89	0.103	6.68	4.37	1.24	0.32	0.16	6.09	7.41	1.32	82.19	79.52	9.28	9.20	Loamy sand

Heavy Metal Analysis

Dried cassava samples were digested using wet acid digestion (HNO_3/HCl). Heavy metal concentrations (Pb, Cd, Cu, Zn, Fe) were determined using atomic absorption spectrophotometry (AAS). Results were expressed in mg/kg dry weight.

Health Risk Assessment

Estimated Daily Intake (EDI)

$$EDI = \frac{C_{cassava} \times IR}{BW_{avg}}$$

Where $C_{cassava}$ = metal concentration $(mg/kg), IR =$ ingestion rate of cassava (0.5 kg/day) for adults, BW_{avg} = average body weight (60 kg for adults). These values follow USEPA (2011) and local consumption patterns.

Hazard Quotient (HQ)

$$HQ = \frac{EDI}{R_f D}$$

$where\ R_f D = reference\ dose\ (mg/kg/day).$

$R_f D\ values\ (USEPA, 2021): Pb = 0.0035$

where $R_f D$ = reference dose (mg/kg/day). $R_f D$ values (USEPA, 2021): Pb = 0.0035, Cd = 0.001, Cu = 0.04, Zn = 0.30, Fe = 0.70. HQ < 1 indicates no significant non-carcinogenic risk; HQ ≥ 1 indicates potential risk.

Statistical Analysis

Trend-based analysis was employed. Values are presented as means ± standard deviations where available.

RESULTS AND DISCUSSION

Heavy Metal Concentrations in Cassava Tubers

Heavy metal concentrations showed irregular variations across distances, with no systematic increase or decrease corresponding to distance from the power line (Table 1). All values remained within permissible safety limits for food crops as compared to Codex Alimentarius Commission (2025), Pb and Cd have the maximum limits of 0.30 mg/kg and 0.20 mg/kg respectively while Cu, Zn and Fe with the limits of 40.00 mg/kg, 60.00 mg/kg and 425.00 mg/kg respectively according to Kabata-Pendias and Pendias (2001).

Table 2: Heavy Metal Concentrations in Cassava Tubers at Different Distances (Mg/Kg, Mean ± SD)

Distance	0 m	5 m	10 m	15 m	20 m	50 m
Pb	0.118±0.0011	0.077±0.0013	0.009±0.0014	-0.042±0.0018	0.033±0.0019	0.068±00002
Fe	2.914±0.002	2.368±0.0018	3.778±0.0006	3.116±0.0015	6.066±0.0024	1.706±0.0011
Zn	0.408±0.0007	0.437±0.0014	0.442±0.0016	0.253±0.0016	0.480±0.0015	0.822±0.0016
Cd	-0.016±0.008	0.012±0.0004	0.009±0.0021	-0.012±0.0017	-0.016±0.0008	0.007±0.0007
Cu	0.064±0.0001	0.067±0.0001	0.076±0.0006	0.070±0.0003	0.104±0.0003	0.066±0.0005

Lead (Pb) concentrations ranged from below detection to 0.118 mg/kg, with the highest at 0 m. Cadmium (Cd) was detected only at 5 m (0.012 mg/kg), 10 m (0.009 mg/kg), and 50 m (0.007 mg/kg). Copper (Cu) ranged from 0.064 to 0.104 mg/kg. Zinc (Zn) ranged from 0.253 to 0.822 mg/kg. Iron (Fe) ranged from 1.706 to 6.066 mg/kg. No metal exhibited a monotonic trend with increasing distance from the power line.

Estimated Daily Intake (EDI)

EDI values were calculated for adults (body weight 60 kg, cassava intake 0.5 kg/day). The highest EDI values were for Fe (0.05055 mg/kg/day at 0 m) and Zn (0.00685 mg/kg/day at 50 m) (Table 3). Pb EDI was highest at 0 m (0.00098 mg/kg/day), which is below the provisional tolerable daily intake (PTDI) of 0.0035 mg/kg/day.

Table 3: Estimated Daily Intake (EDI) for Adults (mg/kg/day)

Distance (m)	Pb	Cd	Cu	Zn	Fe
0	0.00098	0.00000	0.00053	0.00340	0.02428
5	0.00064	0.00010	0.00056	0.00364	0.01973
10	0.00008	0.00008	0.00063	0.00368	0.03148
15	0.00000	0.00000	0.00058	0.00211	0.02597
20	0.00028	0.00000	0.00087	0.00400	0.05055
50	0.00057	0.00006	0.00055	0.00685	0.01422

Hazard Quotient (HQ)

HQ values for all metals across all distances were below unity (HQ < 1), indicating no significant non-carcinogenic health risk from cassava consumption (Table 4; Figure 1).

Table 4: Hazard Quotient (HQ) for Adults

Distance (m)	Pb	Cd	Cu	Zn	Fe
0 (Under)	0.28	0.00	0.01	0.01	0.03
5	0.18	0.10	0.01	0.01	0.03
10	0.02	0.08	0.02	0.01	0.04
15	0.00	0.00	0.01	0.01	0.04
20	0.08	0.00	0.02	0.01	0.07
50	0.16	0.06	0.01	0.02	0.02

The highest HQ was observed for Pb at 0 m (0.28), followed by Cd at 5 m (0.10). All values are substantially below the threshold of 1.0.

Figure 1 is a bar chart showing HQ values for Pb, Cd, Cu, Zn, and Fe across six distances. Y-axis: Hazard Quotient (0–0.30). X-axis: Distance (m). Pb bars are highest at 0 m (0.28) and decline irregularly.

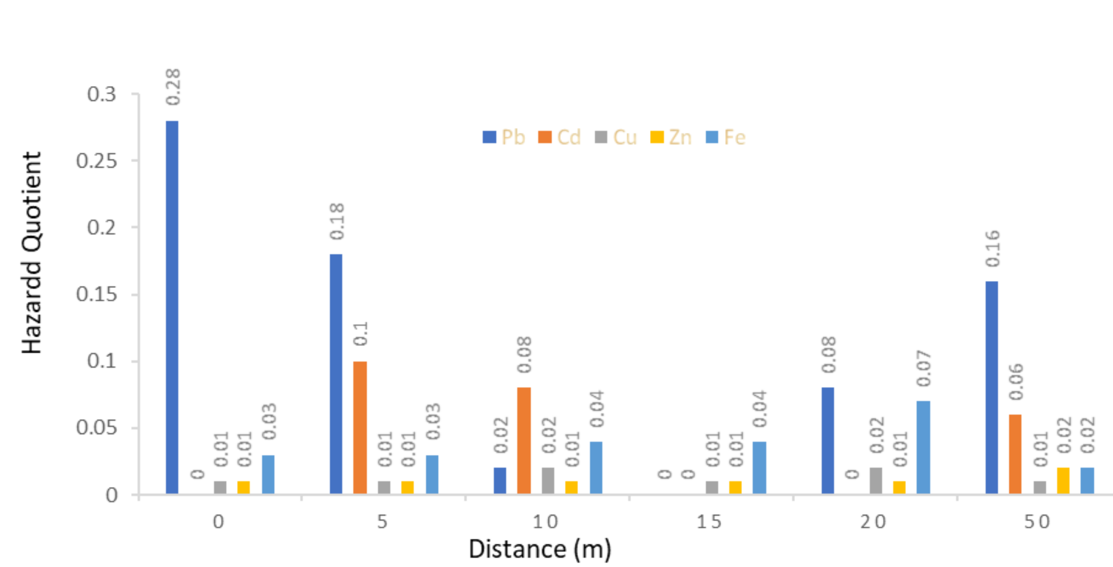

Figure 1: Risk Assessment

Soil Analysis Correlation

Soil analysis (Table 2 of dissertation) confirmed that soil properties were statistically identical at all three sampling points (0 m, 20 m, 50 m). All samples were classified as loamy sand, with pH 5.55–5.71, low organic matter (1.89–2.06%), and similar cation exchange capacity (7.10–7.59 $Cmol/kg$). This homogeneity indicates that observed variations in tuber metal concentrations are not attributable to soil differences.

Discussion

This study provides the first quantitative health risk assessment for cassava grown near a 33 kV power line in Benue State, Nigeria. The results demonstrate that heavy metal concentrations in cassava tubers are within permissible safety limits and that EMF exposure from the power line does not pose a significant non-carcinogenic health risk through dietary intake.

Heavy Metal Concentrations

The maximum Pb concentration (0.118 mg/kg at 0 m) is below the Codex Alimentarius (2019) permissible limit for root vegetables (0.3 mg/kg). Cd levels (maximum 0.012 mg/kg) are well below the Codex limit of 0.1 mg/kg. These values are comparable to or lower than previously reported concentrations in Nigerian cassava from non-industrial areas. Adegbite et al. (2018) reported Pb levels of 0.05–0.20 mg/kg mg/kg and Cd levels of 0.01–0.05 mg/kg in cassava from power line corridors in southwestern Nigeria, consistent with the present findings.

Absence of EMF Effect on Metal Uptake

The irregular variation in metal concentrations across distances with no monotonic trend strongly suggests that EMF exposure does not systematically influence heavy metal accumulation in cassava. This observation is consistent with earlier study on the same experimental site, where EMF exposure from the same 33 kV power line did not produce consistent changes in cassava proximate composition, cyanogenic glycosides, pH or oxidative stress biomarkers despite a clear reduction in electric field strength with distance (Gemanam and Akiki, 2026). Together, these findings suggest that the EMF levels encountered under the studied power line are insufficient to induce measurable biochemical alterations or enhance heavy metal accumulation in cassava. This finding is also supported by the soil analysis, which confirmed homogeneity across sampling points in pH, organic matter, cation exchange capacity, and texture. If EMF were enhancing metal bioavailability, one would expect higher concentrations closer to the power line, which was not observed. For example, Pb was highest at 0 m (0.118 mg/kg) but also relatively high at 50 m (0.068 mg/kg) and below detection at 15 mg/kg. This pattern is consistent with natural spatial variability rather than an EMF dose-response relationship.

Comparison with R_fD and PTDI

The calculated EDI for Pb at 0 m (0.00098 mg/kg/day) is approximately 28% of the RfD (0.0035 mg/kg/day). For Cd at 5 m (EDI = 0.00010 mg/kg/day), this is 10% of the R_fD (0.001 mg/kg/day). All other metals have EDI values well below their respective R_fDs. The FAO/WHO (2009) PTDI for Pb is 0.0035 mg/kg/day, and the observed EDI values are substantially lower.

HQ Interpretation

The highest HQ (0.28 for Pb at 0 m) being below 1.0 indicates that even under worst-case exposure assumptions (consumption of cassava grown directly beneath the power line at the highest observed Pb concentration), there is no significant non-carcinogenic health risk. The margin of exposure $\left(\frac{R_fD}{EDI}\right)$ is approximately 3.6 for Pb at 0 m, providing a safety buffer. For other metals and distances, the margins are substantially larger.

Comparison with Previous Studies

The conclusion that EMF from 33 kV power lines does not significantly affect heavy metal concentrations in cassava aligns with earlier research by Adelekan et al. (2023) and Ogunkanmi et al. (2022), who reported that EMF effects on cassava nutrient composition and metal uptake were minimal and inconsistent. It also supports the broader literature indicating that heavy metal variability in crops is primarily determined by soil geochemistry, agricultural practices, and atmospheric deposition rather than EMF exposure (Adegbite et al., 2018; Ekeocha et al., 2014).

Public Health Implications

The findings indicate that cassava cultivated near 33 kV power lines in Benue State is safe for human consumption with respect to heavy metal content. Communities consuming cassava from power line corridors do not face elevated non-carcinogenic risks from Pb, Cd, Cu, Zn, or Fe. However, the relatively higher HQ for Pb (0.28) compared to other metals suggests that continued monitoring is warranted, particularly if farming practices change or if power line loads increase.

CONCLUSION

This health risk assessment of heavy metals in cassava cultivated near a 33 kV power line in Benue State, Nigeria, concludes that: Heavy metal concentrations (Pb, Cd, Cu, Zn, Fe) in cassava tubers are within permissible safety limits, no consistent distance-dependent EMF effect on metal accumulation was observed, all Estimated Daily Intake (EDI) values are below reference doses (RfD), all Hazard Quotient (HQ) values are below unity (HQ < 1), indicating no significant non-carcinogenic health risk, and cassava from the study area is safe for consumption with respect to heavy metal exposure.

ACKNOWLEDGEMENTS

The authors thank the Department of Physics, Rev. Fr. Moses Orshio Adasu University Makurdi, and the Centre for Food Technology Research (CEFTER) for technical support.

REFERENCES

Adegbite, A. A., Ogunjimi, L. A. O., & Oladapo, O. O. (2018). *Heavy metal uptake in food crops near powerline installations*. Environmental Monitoring and Assessment, 190(7), 432.

Adelekan, B. A., Ogunjinmi, O. E., & Adekoya, M. A. (2023). *Impact of power line EMFs on cassava nutrient composition*. Journal of Agricultural Science, 15(4), 112-125.

Belyavskaya, N. A. (2020). *Biological effects of electromagnetic fields on plants: The missing link in the interaction mechanisms*. Environmental Research, 191, 110180.

Codex Alimentarius. (2019). *General standard for contaminants and toxins in food and feed*. (CXS 193-1995). FAO/WHO.

Ekeocha, A. H., Nwosu, C. M., & Nduka, J. K. (2014). *Heavy metal content of edible crops grown around powerline corridors*. Nigerian Journal of Environmental Sciences, 8(2), 55-62.

FAO. (2022). Global cassava development strategy. FAO Agricultural Series No. 45.

FAO/WHO. (2009). *Risk assessment of heavy metals in food*. Joint FAO/WHO Expert Committee on Food Additives.

Gemanam, J. S., & Akiki, A. S. (2026). *Effects of electromagnetic Field Exposure from 33Kv Power Lines on the Physiochemical and Biochemical Properties of Cassava Tubers (Manihot esculenta Crantz) in Benue State, Nigeria.* Nigerian Journal of Physics, 35(3), 157 – 162. https://doi.org/10.62292/njp.v35i3.2026.582

Kabata-Pendias, A., & Pendias, H. (2001). *Trace Elements in Soils and Plants* (3rd ed.) CRC Press.

Maffei, M. E. (2015). *Magnetic field effects on plant growth, development, and evolution*. Frontiers in Plant Science, 5, 445.

National Agricultural Extension and Liaison Research Services. (2022) *Agricultural Performance Survey of the*

2022 Wet Season in Nigeria. Amadu Bello University, Zaria.

National Bureau of Statistics. (2012). *Annual Abstract of Statistics 2012.* Abuja, Nigeria

Nriagu, J. (2019). *Heavy metal contamination in Africa: A review. Environmental Research*, 176, 108557.

Ogunkanmi, L. A., Adeyemo, F. A., & Akinola, O. B. (2022). *Antioxidant depletion in cassava due to EMFs*. Journal of Food Composition and Analysis, 109, 104512.

USEPA. (2011). Exposure factors handbook (EPA/600/R-09/052F). U.S. Environmental Protection Agency.

USEPA. (2021). Regional screening levels (RSLs) Generic tables. U.S. Environmental Protection Agency.