



Risk Assessment of Heavy Metal Levels in Vegetables Grown in the Vicinity of Local Mining Areas in Odu, Dekina Local Government Area, Kogi State, Nigeria

^{*1}Ameh, E.M., ¹Oteno, F., ¹Sale, J. F., ¹Umoru, E. P., ¹Ocheme, G. W., ²Okpanachi C. B.

¹Department of Pure & Industrial Chemistry, Faculty of Natural Science Kogi State University, Anyigba, PMB 1008, Anyigba, Kogi State Nigeria

²Department of Industrial Chemistry, Federal University of Applied Sciences, Kachia, Kaduna State Nigeria

Corresponding Author's Email: markameh2004@yahoo.com

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ABSTRACT

This study assessed the concentrations of selected heavy metals and the associated non-carcinogenic health risk in vegetables cultivated in the vicinity of the Odu local mining area in Dekina Local Government Area, Kogi State, Nigeria. Five vegetable species—*Amaranthus hybridus*, *Abelmoschus esculentus*, *Lycopersicon esculentum*, *Capsicum frutescens*, and *Solanum incanum*—were collected from mining-affected locations. The samples were dried, pulverized, digested by a wet-acid procedure using aqua regia, and analyzed for cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), and arsenic (As) using atomic absorption spectrophotometry. The reported concentrations of Cd, Cr, Cu, Ni, and Pb ranged from 0.01–0.05, 0.01–0.11, 0.04–0.09, 0.04–0.09, and 0.03–0.21 mg/kg, respectively, while As was below the instrumental detection limit in all samples. Comparison with the permissible limits reported in the original study indicates that Cd and Pb warrant particular attention, while Ni exceeded some of the cited guideline values in three vegetable samples. The calculated target hazard quotients (THQs) and summed health risk indices (HRIs) were below 1 for the reported exposure scenario. These findings indicate that, although the calculated non-carcinogenic risk was below the conventional threshold, continued consumption of vegetables cultivated near mining areas may warrant precaution because heavy metals can persist in environmental media and enter the food chain. Regular monitoring, farmer education, and cultivation of vegetables away from potentially contaminated mining-affected soils are recommended.

Keywords: vegetables; heavy metals; mining area; health risk assessment.

1.0 INTRODUCTION

Heavy-metal contamination is a persistent environmental problem because metals released into the environment can remain in soils, sediments, water, and biological tissues for extended periods. Vegetables cultivated in contaminated environments can provide an important pathway for the transfer of potentially toxic metals into the human food chain (Suruchi & Khanna, 2011; Atikpo et al., 2021).

The occurrence of metals in agricultural environments may arise from natural and anthropogenic processes. Mining and mineral processing are particularly important sources because excavation, processing, and disposal of mine wastes can redistribute metal-bearing materials into surrounding environments. Recent studies in mining-affected areas have demonstrated that metals present in soils can be transferred to vegetables and other food crops, with uptake varying among plant species (Wang et al., 2021; Orji et al., 2021). In Nigeria, these findings reinforce the importance of monitoring agricultural environments located near mining activities.

Vegetables may absorb metals from soil through their roots and may also accumulate metals deposited on

above-ground plant surfaces. The extent of uptake depends on the metal, soil characteristics, plant species, and environmental conditions. Consequently, vegetables cultivated in contaminated areas may provide a pathway for metal movement from soil into the human food chain (Atikpo et al., 2021; Oiganji et al., 2024; Chowdhury et al., 2024). Recent investigations have reported measurable concentrations of potentially toxic metals in vegetables and differences among vegetable species, emphasizing the importance of crop-specific assessment (Oiganji et al., 2024; Chowdhury et al., 2024).

The toxicological significance of a metal depends on its concentration, chemical form, duration of exposure, and biological availability. Some metals have biological functions at appropriate concentrations, but excessive exposure can be harmful. Cadmium and lead are of particular concern because prolonged dietary exposure may contribute to adverse health effects. The occurrence of multiple metals in food also makes it important to consider combined exposure rather than relying solely on individual metal concentrations (Suruchi & Khanna, 2011; Chowdhury et al., 2024).

Research on vegetables from mining-affected environments has demonstrated the relevance of dietary exposure assessment. Harmanescu et al. (2011) evaluated health risks associated with consumption of vegetables grown in an old mining area, while more recent Nigerian studies have assessed heavy-metal contamination and dietary health risks in crops and vegetables cultivated near mining-affected areas (Atikpo et al., 2021; Orji et al., 2021). These studies support the need for site-specific assessments in communities where food crops are cultivated close to potential sources of contamination.

Health-risk assessment provides an additional means of interpreting measured metal concentrations. Estimated daily intake (EDI) can be used to approximate dietary exposure, while the target hazard quotient (THQ) provides a screening measure of potential non-carcinogenic risk relative to an oral reference dose. When exposure involves several metals, the summed THQ or health risk index can be used to characterize combined non-carcinogenic exposure under the assumptions of the assessment model (Oiganji et al., 2024; Chowdhury et al., 2024). Such indices are screening tools and depend on exposure assumptions, reference doses, body weight, consumption rates, exposure duration, and analytical data quality.

The Odu local mining area in Dekina Local Government Area of Kogi State is an environment in which agricultural production and mineral extraction occur in close proximity. Vegetables cultivated around mining-affected locations may therefore be exposed to metals mobilized or redistributed by mining activities,

as documented in recent studies from Nigerian mining regions (Sikakwe et al., 2024; Yaradua et al., 2023; Falae et al., 2025). Despite the importance of vegetables as components of the local diet, information on potentially toxic metals in crops cultivated around the Odu mining area is limited. The present study was therefore undertaken to determine the concentrations of cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), and arsenic (As) in selected vegetables grown in the vicinity of the mining area and to estimate the associated non-carcinogenic health risk from vegetable consumption.

The specific objectives were to (i) determine the concentrations of Cd, Cr, Cu, Ni, Pb, and As in selected vegetables; (ii) compare the measured concentrations with the guideline values reported in the study; and (iii) estimate dietary exposure and non-carcinogenic health risk using EDI, THQ, and HRI. The study provides baseline information that may support environmental monitoring, agricultural management, and public-health decision-making in mining-affected communities.

2.0 MATERIALS AND METHODS

2.1 Study Sample Identification and Study Area Description

Vegetable samples were collected from five mining-affected locations in the study area. The vegetable species and voucher identification numbers reported for the samples are presented in Table 1. The plants were identified by S. S. Usman and A. O. Sule of the Department of Plant and Biotechnology, Kogi State University, Anyigba.

Table 1. Vegetable samples analyzed.

Sample code	Common name	Scientific name	Voucher ID number
1	Spinach	<i>Amarathus hybridus-</i>	KSU-PT-B-021
2	Okro	<i>Abelmoschus esculentus</i>	KSU-PT-B-001
3	Tomato	<i>Lycopersicon esculentum</i>	KSU-PT-B-200
4	Hot pepper	<i>Capsicum frutescens</i>	KSU-PT-B-067
5	Garden egg	<i>Solanum incanum</i>	KSU-PT-B-280

The Odu mining site is located in Dekina Local Government Area of Kogi State, North-Central Nigeria. The area is situated within a region characterized by active mining and agricultural activities, with local communities depending largely on farming and other natural-resource-based livelihoods. Mining activities at Odu involve the extraction and processing of mineral-bearing materials, which may generate waste materials capable of affecting the

surrounding soil, water, and vegetation. The study area was therefore selected to assess the potential environmental implications of mining activities, particularly with respect to the occurrence and distribution of heavy metals in the surrounding environment. Soil and/or other environmental samples were collected from locations influenced by mining activities and from relatively less-disturbed areas for comparison.

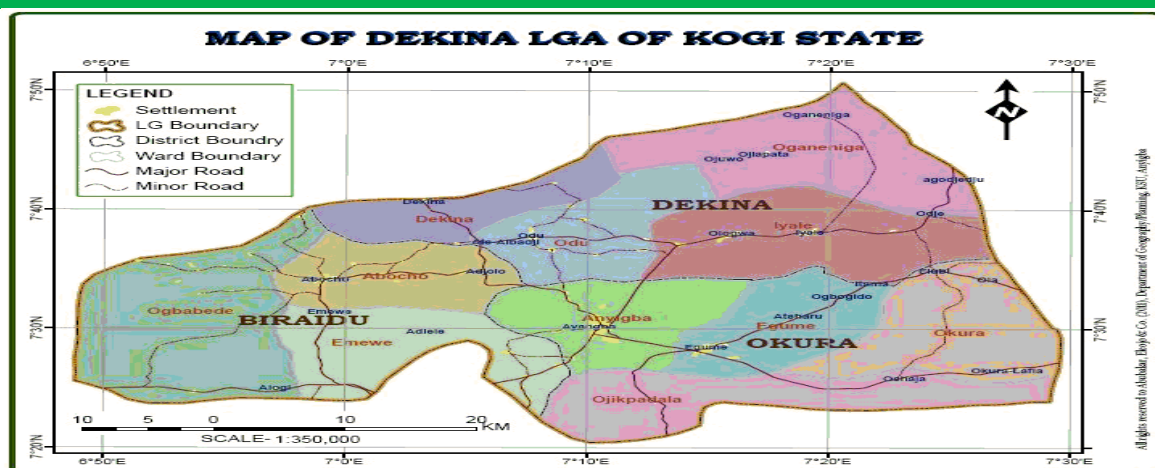


Figure 1. Map of Dekina Local Government area of Kogi State showing the mining site in Odu.

2.2 Sample Preparation

The collected vegetable samples were dried at room temperature and ground to a fine powder using a mortar and pestle. The powdered samples were sieved and stored in airtight containers until analysis. The original manuscript reports the use of an 800 nm mesh; this specification should be verified against the actual laboratory procedure because sieve mesh size is normally reported in mesh number or micrometres.

2.3 Wet Digestion

Approximately 1.0 g of each powdered vegetable sample was weighed into a 250 mL beaker, and 10 mL of aqua regia was added. The beakers were covered with watch glasses and heated on a water bath maintained at approximately 105 °C. The contents were swirled at 15-min intervals, and digestion was continued for 2 h. After cooling, the digest was filtered into a 25 mL volumetric flask. A reagent/sample blank was subjected to the same digestion procedure.

2.4 Instrumental Analysis

The digested samples were analyzed for Cd, Cr, Cu, Ni, Pb, and As using a BUCK Scientific 2210 VGR atomic absorption spectrophotometer (USA), as reported in the original manuscript. The instrument was calibrated using prepared metal standards at the appropriate analytical wavelengths. Sample concentrations were obtained from the instrument calibration response. Instrumental detection limits and quality-control recovery data were not reported in the source manuscript and should be added before submission to a journal, where available.

2.5 Human Health Risk Assessment

Non-carcinogenic risk was evaluated using estimated daily intake (EDI), target hazard quotient (THQ), and

health risk index (HRI). These measures are commonly applied in recent dietary heavy-metal assessments of vegetables and food crops (Atikpo et al., 2021; Oiganji et al., 2024; Chowdhury et al., 2024). The calculations used the exposure assumptions stated in the original manuscript: a vegetable ingestion rate of 65 g/person/day, an exposure frequency of 365 days/year, and an exposure duration of 70 years.

The reported EDI equation was:

$$EDI = (C \times IR \times EF \times ED) / (BW \times AT \times 1000)$$

where C is the metal concentration in vegetables (mg/kg), IR is the ingestion rate (g/person/day), EF is exposure frequency (days/year), ED is exposure duration (years), BW is body weight (kg), AT is averaging time (days), and 1000 is the conversion factor from grams to kilograms.

Target hazard quotient was calculated as:

$$THQ = EDI / RfD$$

where RfD is the oral reference dose for the respective metal. The reference doses reported in the source manuscript were Cd = 0.001, Cr = 0.003, Ni = 0.02, Cu = 0.04, and Pb = 0.0035 mg/kg/day.

The health risk index was expressed as the sum of the individual THQs:

$$HRI = \sum THQ$$

An HRI or THQ below 1 was interpreted in the original study as indicating that the estimated non-carcinogenic risk under the stated exposure assumptions was below the conventional screening threshold.

2.6 Statistical Analysis

Statistical analysis was reportedly performed using SPSS version 23.0. Descriptive statistics were used to summarize the results, and one-way analysis of variance (ANOVA) was reported with a significance level of $p < 0.05$.

3.0 RESULTS AND DISCUSSION

Table 2. Concentrations of heavy metals in the vegetable samples.

No.	Metal	<i>Amaranthus hybridus</i> (mg/kg)	<i>Abelmoschus esculentus</i> (mg/kg)	<i>Lycopersicon esculentum</i> (mg/kg)	<i>Capsicum frutescens</i> (mg/kg)	<i>Solanum incanum</i> (mg/kg)
1	Cd	0.05 ± 0.001	0.01 ± 0.00	0.03 ± 0.01	0.02 ± 0.01	0.01 ± 0.00
2	Cr	0.11 ± 0.01	0.02 ± 0.00	0.05 ± 0.01	0.03 ± 0.01	0.01 ± 0.00
3	Cu	0.05 ± 0.01	0.06 ± 0.01	0.09 ± 0.02	0.05 ± 0.01	0.04 ± 0.01
4	Ni	0.07 ± 0.02	0.09 ± 0.02	0.07 ± 0.02	0.05 ± 0.01	0.04 ± 0.01
5	Pb	0.12 ± 0.01	0.03 ± 0.00	0.05 ± 0.01	0.11 ± 0.01	0.21 ± 0.01
6	As	BDL	BDL	BDL	BDL	BDL

BDL = below detection limit

Table 3. Permissible concentrations reported in the original manuscript (mg/kg).

Organization	As	Cd	Cr	Cu	Mn	Ni	Pb
FEPA	0.1	0.005	0.5	1.0	1.0	0.015	0.1
USEPA	0.05	0.005	0.1	1.0	NS	0.05	0.01
WHO	0.01	0.003	0.05	1.0–2.0	0.1–0.5	0.02	0.01

Table 4. Estimated daily intake (EDI) reported for the vegetable samples (mg/kg/day).

Metal	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Cd	0.0000464	0.00000928	0.0000279	0.0000186	0.00000928
Cr	0.000102	0.0000186	0.0000464	0.0000279	0.00000928
Cu	0.0000464	0.0000557	0.0000836	0.0000464	0.0000371
Ni	0.000065	0.0000836	0.000065	0.0000464	0.0000371
Pb	0.000111	0.0000279	0.0000464	0.0000102	0.000195
As	BDL	BDL	BDL	BDL	BDL

Table 5. Target hazard quotients (THQ) and summed health risk indices (ΣTHQ).

Metal	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Cd	0.0464	0.00928	0.0279	0.0186	0.00928
Cr	0.0340	0.0062	0.015467	0.0093	0.0030933
Cu	0.00116	0.0013925	0.00209	0.00116	0.00009275
Ni	0.00325	0.00418	0.00325	0.00232	0.001855
Pb	0.031714	0.0079714	0.013257	0.02914	0.0557143
As	BDL	BDL	BDL	BDL	BDL
ΣTHQ	0.116524	0.290230	0.061964	0.06052	0.07003535

Cadmium concentrations ranged from 0.01 to 0.05 mg/kg, with the highest value reported in *Amaranthus hybridus*. Based on the guideline values reproduced in Table 3, the reported Cd concentrations exceed the cited FEPA, USEPA, and WHO values in several or all samples. Because cadmium is a toxic metal of public-health concern, its occurrence in edible vegetables warrants attention and continued monitoring.

Chromium concentrations ranged from 0.01 to 0.11 mg/kg, with the highest concentration occurring in *Amaranthus hybridus*. The reported values are below the FEPA value of 0.5 mg/kg but exceed the WHO value of 0.05 mg/kg in some samples and exceed the USEPA value of 0.1 mg/kg only in *Amaranthus hybridus*. Interpretation should therefore be tied to the specific standard being applied rather than described as uniformly below permissible limits.

Copper concentrations ranged from 0.04 to 0.09 mg/kg and were below all of the copper guideline concentrations reproduced in Table 3. On the basis of those values alone, Cu appears to be less of a concern than Cd, Ni, and Pb in the analyzed vegetables.

Nickel concentrations ranged from 0.04 to 0.09 mg/kg. The concentrations in *Amaranthus hybridus*,

Abelmoschus esculentus, and *Lycopersicon esculentum* exceed the WHO value of 0.02 mg/kg reproduced in Table 3, whereas the concentrations in *Capsicum frutescens* and *Solanum incanum* are also above the FEPA value of 0.015 mg/kg but above the WHO value as well. These results indicate that Ni deserves attention in the assessment of vegetables cultivated near the mining area.

Lead concentrations ranged from 0.03 to 0.21 mg/kg, with the highest value in *Solanum incanum*. These concentrations exceed the USEPA and WHO values reproduced in Table 3 and exceed the FEPA value in *Amaranthus hybridus*, *Capsicum frutescens*, and *Solanum incanum*. Given the toxicological significance of lead exposure, the observed concentrations support the need for precautionary monitoring of vegetables produced in the study area.

Arsenic was reported as below the detection limit in all five samples. This finding should be interpreted as indicating that the measured concentrations were below the analytical detection capability of the method, rather than as proof that arsenic was completely absent. The reported THQs and summed HRIs were below 1 for all samples. Under the assumptions used in the original assessment, this indicates that the estimated



non-carcinogenic risk from the individual metals and their combined exposure was below the conventional screening threshold. However, this interpretation should not be equated with an absence of health risk. Risk estimates depend strongly on body weight, consumption rate, exposure duration, reference doses, analytical uncertainty, and the quality of the underlying concentration data. In addition, the present dataset does not establish that mining activity caused the measured concentrations because no uncontaminated control site, soil-metal concentrations, or source-apportionment analysis is reported.

4.0 CONCLUSION

The study demonstrates the occurrence of Cd, Cr, Cu, Ni, and Pb in vegetables cultivated in the vicinity of the Odu local mining area, while As was below the reported detection limit. The concentrations of Cd, Ni, and Pb, in particular, warrant continued environmental and food-safety attention when compared with the guideline values reproduced in the original manuscript. Although the reported THQ and HRI values were below 1, indicating a low estimated non-carcinogenic risk under the stated exposure assumptions, the presence of persistent metals in edible crops justifies a precautionary approach. Regular monitoring of vegetables and agricultural soils, farmer education, and cultivation of food crops away from potentially contaminated mining-affected areas are recommended.

REFERENCES

- 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>
- Chowdhury, A. I., Shill, L. C., Raihan, M. M., Rashid, R., Bhuiyan, M. N. H., Reza, S., & Alam, M. R. (2024). Human health risk assessment of heavy metals in vegetables of Bangladesh. *Scientific Reports*, 14, 15616. <https://doi.org/10.1038/s41598-024-65734-6>
- Falae, T. T., Ossai, C. P., Orosun, M. M., Abdulai, P. M., Udom, G. J., Nduka, J. K., Offor, C. C., & Orisakwe, O. E. (2025). Probabilistic health risk assessment of heavy metals in vegetables cultivated near tin mining sites in Jos Plateau State, Nigeria. *Journal of Hazardous Materials Advances*, 20, 100934. <https://doi.org/10.1016/j.hazadv.2025.100934>
- Harmanescu, M., Alda, L. M., Bordean, D. M., Gogoasa, I., & Gergen, I. (2011). Heavy metals health risk assessment for population via consumption of vegetables grown in old mining area: A case study: Banat County, Romania. *Chemistry Central Journal*, 5, 64. <https://doi.org/10.1186/1752-153X-5-64>
- Oiganji, E., Ichor, J., Unimke, J. U., & Lenka, R. Z. (2024). Levels and human health risk assessment of heavy metals in some vegetables in farmer's field, Jos North, Plateau State Nigeria. *Journal of Applied Sciences and Environmental Management*, 28(11), 3551–3557. <https://doi.org/10.4314/jasem.v28i11.7>
- 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>
- Sikakwe, G. U., Ojo, S. A., & Uzosike, P. C. (2024). Assessment of human health risk concerning edible plants contamination with toxic elements around functional and derelict mines. *Food and Chemical Toxicology*, 189, 114760. <https://doi.org/10.1016/j.fct.2024.114760>
- Suruchi, & Khanna, P. (2011). Assessment of heavy metal contamination in different vegetables grown in and around urban areas. *Research Journal of Environmental Toxicology*, 5(3), 162–179. <https://doi.org/10.3923/rjet.2011.162.179>
- Wang, Z., Bao, J., Wang, T., Moryani, H. T., Kang, W., Zheng, J., Zhan, C., & Xiao, W. (2021). Hazardous heavy metals accumulation and health risk assessment of different vegetable species in contaminated soils from a typical mining city, Central China. *International Journal of Environmental Research and Public Health*, 18(5), 2617. <https://doi.org/10.3390/ijerph18052617>
- Yaradua, A. I., Bungudu, J. I., Shuaibu, L., Nasir, A., Usman, A., Kankia, I. H., Matazu, N. U., et al. (2023). Health risk assessment of heavy metals in vegetable: The contribution of illegal mining and armed banditry to heavy metal pollution in Katsina State, Nigeria. *Journal of Scientific Research and Reports*, 29(5), 19–27. <https://doi.org/10.9734/jsrr/2023/v29i51744>