UJMR, Vol. 9 No. 1, June, 2024, pp. 84 - 92 *E-ISSN: 2814 – 1822; P-ISSN: 2616 – 0668*

https://doi.org/10.47430/ujmr.2491.009

Received: 31 March 2024 **Accepted:** 01 June 2024

Health Risk Assessment of Lead and Cadmium in Roadside Roasted Corn from Selected Areas of Bwari Local Government Area, FCT, Nigeria

Abraham Gana Yisa[a], Ahmed Sekinat Oziamo[a], Maureen Nkemdilim Chukwu[a], Uduak Irene Aletan[a], Sonnie Joshua Oniye[a], Abiodun Emmanuel Adams[a], Osegbo Adaora[a], Oluremi Aduke Saliu[b], Edogbo Blessing[b], Omada Stephen[a], Idowu Oluwafemi Ayodeji[b] and Crescentia Ojenikoh Sekegor[c]

[a]Department of Biological Sciences, National Open University of Nigeria
[b]Department of Environmental Health Science, National Open University of Nigeria
[c]Department of Biology Education, Delta State College of Education, Mosogar, Nigeria
Corresponding author: ayisa@noun.edu.ng, Telephone +2348032614193.

Abstract

This research examined the presence of lead and cadmium in roasted corn sold by roadside vendors. Five locations (Market Square, Ade Femi Street, Abiola Road, SCC Road, and Primary School) were selected for the research according to the availability of vendors and vehicular activities. Roasted corns were oven-dried at 80^{o}C and digested according to standard methods. The concentrations of lead (Pb) and cadmium (Cd) were determined with an Atomic Absorption Spectrophotometer. The data generated was analyzed with the R statistical program version 4.3.0. Lead and cadmium concentrations in the roasted corn varied significantly ($p < 0.05$) across the study locations. The Pb content of the roasted corn varied from 0.08±0.00 mg Kg^{-1} - to 0.29±0.00 mg kg^{-1}, While Cd was found to be within the range of 0.006±0.00 mg kg^{-1} - 0.09±0.00 mg kg^{-1}. Lead levels in roasted corn at Market Square were above WHO limits of 0.2 mg kg^{-1}. However, the Cd levels were within the acceptable limit of 0.1 mg kg-1. The strong positive correlation observed between Pb-Cd pairs in the roasted corn was a strong indication of similarity in the origin of the contamination. The potential risk associated with Pb and Cd exposure in roasted corn was determined by the Average Daily Intake of metals (ADI, Health Risk Index (HRI), and Incremental Lifetime Cancer Risk (ILCR). The risk assessment indices revealed that HRI was < 1, indicating a non-potential health risk for adults and children. Also, the estimated ILCR for Pb and Cd was within the acceptable limit of 1 x 10^{-4} - 1x 10^{-6}. This study shows that consumers of roasted corn sold at Market Square may be at risk of lead toxicity with continuous exposure.

Keywords: Risk, Assessment, Heavy metals, Roasted Corn, Carcinogenic risk

INTRODUCTION

Heavy metals are common potentially toxic contaminants in the environment (Gadzama *et al.*, 2014). Lead is released into the environment as a result of several human activities such as smelting, lead recycling, mineral explorations, refining, use of leaded petrol, application of lead in aviation fuel, manufacturing, plumbing materials and alloys, lead-acid batteries, paints, soldering, and as constituents of electrical and electronics (Levin *et al.*, 2020; Collin *et al.*, 2022; Wan *et al.*, 2024). In a 2019 report by the WHO, lead was implicated to have caused nearly 1 million deaths. Similarly, Cd occurs naturally in the earth's crust, with almost 0.099 mg/L found impure as a lead or zinc deposit (Fatima *et al.*, 2019; Hocaoglu & Genc, 2020). Cadmium is often used in the production of pigments, anticorrosive coatings, radiation shielding, polyvinyl chloride stabilizers, solar cell semiconductors, and alloys (Arshad *et al.*, 2020; Liu *et al.*, 2020; Abrar *et al.*, 2022; Afridi *et al.*, 2022).

Heavy metals in agricultural produce such as grains have been frequently linked to contamination from anthropogenic and natural activities (Liu *et al.*, 2020; Wan *et al.*, 2024). Crops such as maize have a high absorption potential for heavy metals when grown in heavy metals contaminated soils or water (Afonne & Ifediba, 2020; Armienta *et al.*, 2020). However, heavy metals from the exhaust of automobiles on busy roads may get deposited on carelessly exposed roadside or street foods (Hong et al., 2020).

Foods and drinks prepared and sold in public spaces for instant or future consumption without extra processing are called "roadside or street foods" (WHO, 2005). They are usually very affordable and the most convenient option for several individuals in transit (Oyelola *et al.*, 2013; Onipede & Rahman, 2017). However, there are growing concerns that roasting maize on major roads with significant traffic exposes the corn to harmful amounts of heavy metal contamination from automotive emissions (Onipede & Rahman, 2017; Bello *et al.*, 2022).

Consequently, advanced risk assessment indices and predictive models for determining potential heavy metal toxicity and carcinogenicity have been receiving global attention (Miranzadeh *et al.*, 2020; Moghaddam *et al.*, 2020; Dinake *et al.*, 2023). Health risk determination categorizes contaminants as carcinogenic or non-carcinogenic and also stipulates the procedure for determining the potential risks of the element of interest. The hazard quotient (HQ) determines the non-carcinogenic health hazards for each metal through ingesting food materials, while the health hazard index (HI) estimates the sum of HQs. Meanwhile, the assessment of non-carcinogenic risks can be arrived at by determining the hazard quotient (HQ) (Emergency & Response, 1989a).

Based on our literature search, risk assessment and monitoring of lead and cadmium in roasted corn in the study area is yet to be sufficiently reported. Hence, there is a need to investigate the potential toxicity of lead and cadmium contamination in the roasted maize consumed in the area. Hence, this study will provide baseline information for subsequent studies and can be used to develop healthy environmental policies to protect the exposed populace's lives

Table 1: Geographical information of the study location.

Locations	Longitude	Latitude	Elevation (m)
Market Square	N 9°13'5.13336"	E 7°24'45.48708"	564.18
Ade Femi Street	N 9°13'14.68956"	E 7°24'28.24524"	596.20
Abiola Road	N 9°13'14.95488"	E 7°24'23.19876"	596.20
Scc Road	N 9°13'3.17388"	E 7°24'14.52384"	561.44
Primary School	N 9°12'57.7656"	E 7°24'11.73096"	556.87

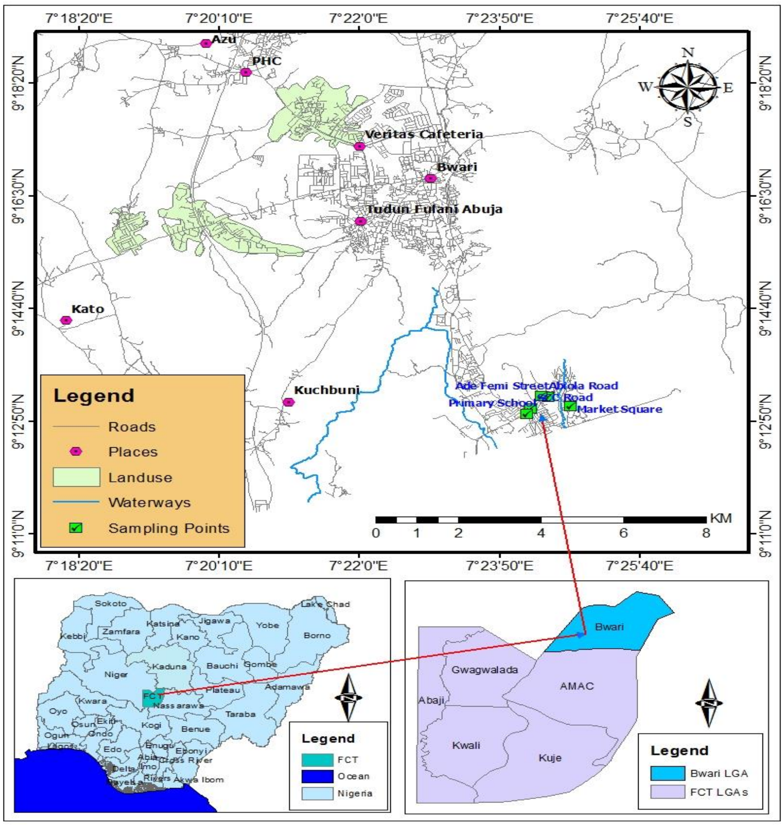

Figure 1: Map of the Study area showing the sampling locations and subjected to Atomic Absorption Spectrophotometry analysis for lead and cadmium determination. (AAS, ICE 3000 AA02134104 V1.30) (Chauhan and Chauhan, 2014).

MATERIALS AND METHODS

Study Location

Bwari Area Council, a local government in Nigeria's capital city, is host to beehives of several microeconomic activities. One is the vending of roasted maize (*Zea maize L.)* at strategic locations. Most vendors make a living from selling this locally processed food. Marketplaces, areas with high vehicular activity, car parks, junctions, and traffic light points are lucrative areas for marketing roasted corn in the study area.

This research used samples purchased from the Bwari Area Council of the Federal Capital Territory. For this study, five (5) sampling locations were chosen based on the presence of corn sellers and traffic points. (Table 1 & Figure 1).

Digestion of Samples for Atomic Absorption Spectrophotometry

Freshly roasted maize samples were obtained, wrapped in A4 paper, labeled, and transported to the Laboratory (Biology Research Laboratory, National Open University of Nigeria Headquarters, Jabbi, Abuja) for further analysis. Two collections were made from each location and made into a composite sample. The extraction of the maize seeds from the cobs was achieved manually. Seeds were kept in Petri dishes and oven-dried for 12 hours at 80°C. Two grams of finely ground maize seed from each site were acidified for digestion using 0.5 milliliters of tetraoxosulfate VI acid (H_2SO_4) and 1 milliliter of nitric acid (HNO3). This mixture was digested for 30 minutes at 100°C in a fume cupboard until a clear solution was obtained. The mixture was then transferred into a 100 ml volumetric flask, and to make it to the 100 ml mark, it was diluted with deionized water. Following cooling, the mixture was filtered through Whatman No. 1 filter paper.

Quality Assurance

The study implemented stringent quality assurance measures, utilizing analytical grade reagents and chemicals while ensuring careful handling and thorough washing of glassware to prevent cross-contamination. Instrument readings were meticulously corrected using reagent blank samples, with lead and cadmium concentrations determined through triplicate analyses. Quantification of these metals was conducted using an Atomic Absorption Spectrophotometer (AAS), with careful selection and adjustment of slit, frame, and lamps for each metal. Absorbance values were recorded for digested samples, and calibration curves were plotted to determine actual metal concentrations. Lead and cadmium were measured at wavelengths of 217.0 nm and 288.8 nm, respectively. The analysis was carried out at the Chemistry Advanced Research Centre, a subsidiary of Sheda Science and Technology Complex (SHESTCO) in Abuja.

Risk Assessment

The study evaluated the possible health effects of consuming lead and cadmium-contaminated maize over an extended period. The following formulas were used to calculate the Average Daily Intake (ADI), Hazard Quotient (HQ), Hazard Index (HI), and Incremental Lifetime Cancer Risk (ILCR).

Average Daily Dose

$$ADI = \frac{Cm \times EF \times IR \times ED \times CF}{AT \times BW} x\ 0.001 \quad \text{-- Equation (1)}$$

In the provided equations, Cm represents the concentration of heavy metals (mg kg^{-1}), IR denotes the ingestion rate of metals from consuming roasted corn (100g for adults and 200g for children), EF signifies the exposure frequency (365 days per year), ED represents the exposure duration (62.6 years for adults and 6 years for children), CF stands for the conversion factor (0.001), BW indicates the body weight (70 kg for adults and 15 kg for children), and AT signifies the average exposure time for non-carcinogenic effects (ED multiplied by 365 days; 22,995 days for adults and 2,190 days for children) (Emergency & Response 1989a).

Hazard Quotient

The hazard quotient (HQ) determined the non-carcinogenic health risk of Pb and Cd in the maize. Therefore, HQ was calculated as the ratio of the Average daily intake (ADI) and a reference dose (RfD) as given by the equation below.

$$HQ = \frac{ADI}{RfD} \quad \text{---------------------------- Equation (2)}$$

Where RfD represents the reference dose of Pb and Cd through oral ingestion. The RfD_{ing} values for Pb and Cd are 0.00035 and 0.001, respectively (USEPA, 2015).

Hazard Index

The assessment of human health risks associated with exposure to multiple heavy metals (HMs) involves the utilization of the hazard index (HI), as proposed by Emergency & Response (1989a). This index is computed as the aggregate hazard quotients for individual heavy metals in maize. An HI value less than 1 indicates a lack of potential for adverse non-carcinogenic health impacts, whereas an HI exceeding 1 signifies a likelihood of chronic health risks due to metal exposure. The HI was determined for each metal investigated by applying Equation 3 as outlined in Emergency & Response (1989b).

$$HI = HQ_{Pb} + HQ_{Cd} \quad \text{----------------- Equation (3)}$$

Carcinogenic risk

The Carcinogenic Risk Model assesses the likelihood of an individual developing cancer over their lifetime due to chemical exposure. Its application is essential in determining the potential carcinogenic risk faced by consumers of roadside roasted corn from Bwari Area Council, particularly concerning lead (Pb) and cadmium (Cd) exposure. The Incremental Lifetime Cancer Risk (ILCR), as expressed in Equation 4, provides a quantitative measure of this risk.

ILCR = ADI x CSF------------------- Equation (4)

CSF is the cancer slope factor, 6.1 for Cd and 1.5 for Pb (USEPA, 2007), and ADI is the chronic daily intake of carcinogens (mg kg^{-1} d^{-1}).

RESULTS

Heavy metals in the roasted corn

The concentrations of Pb ranged from 0.08±0.00 mg kg^{-1} - 0.287±0.00 mg Kg^{-1} (Table 2). Lead levels were respectively higher and lower at Market Square and Ade Femi Street during the sampling period. The mean concentration of Pb in the roasted corn samples was in the order Market Square > SCC Road > Abiola Road > Primary School > Ade Femi Street, and the variations in the lead content across the sampling locations were significant ($p < 0.05$) (Figure 2A).

Cadmium was below the detectable limit at Abiola Street and Primary School. The highest cadmium levels (0.09±00 mg Kg^{-1}) were recorded in roasted corn obtained from Market Square. The trend in the Cd content of the samples was slightly different from that of Pb (Table 2, Figure 2B).

The calculation of the hazard quotients and hazard indexes of lead and cadmium are presented in Table 2. The present study showed a significant (p < 0.05) variation in the calculated ADIs and Incremental Lifetime Cancer Risk for both lead and cadmium. The range of ADIs of lead for adults and children is 1.07×10^{-7} mg kg^{-1} d^{-1} – 4.07×10^{-7} mg kg^{-1} d^{-1} and 1.00×10^{-6} mg kg^{-1} d^{-1} – 3.82×10^{-6} mg kg^{-1} d^{-1} respectively (Table 2). The risk assessment indices of lead for adults and children had the same trend. The values of HQ and ILCR for Cd are shown in Table 2. The HI and ILCR for the locations were in the order of Market Square > Ade Femi Street > Abiola Road, SCC Road, and Primary School (Table 1). Meanwhile, Pb was ordered Market Square > SCC Road > Abiola Road > Primary School > Ade Femi Street. Our study showed that the ILCR value of lead for all age groups was observed to be within 1×10^{-1} - 1×10^{-6} (Table 3).

Table 2: Average daily intake (ADI), hazard quotient (HQ) and hazard index (HI) values from metals exposure in the investigated roasted maize samples

Locations	HMs	C (mg Kg^{-1})	Adult ADI (mg kg^{-1} d^{-1})	Rfo (mg kg^{-1} d^{-1})	HQ	HI	Children ADI (mg kg^{-1} d^{-1})	Rfo (mg kg^{-1} d^{-1})	HQ	HI
Market Square	Pb	0.287±0.00	4.07×10^{-7}	0.0035	1.1×10^{-5}	2.2×10^{-5}	3.82×10^{-6}	0.0035	1.10×10^{-4}	2.2×10^{-4}
	Cd	0.09±0.00	1.18×10^{-7}	0.001	1.1×10^{-5}		1.11×10^{-6}	0.001	1.1×10^{-4}	
Ade Femi Street	Pb	0.08±0.00	1.07×10^{-7}	0.0035	3.04×10^{-5}	7.3×10^{-5}	1.00×10^{-6}	0.0035	2.80×10^{-5}	6.8×10^{-5}
	Cd	0.03±0.00	4.31×10^{-8}	0.001	4.3×10^{-5}		4.05×10^{-7}	0.001	4.0×10^{-5}	
Abiola Road	Pb	0.153±0.00	2.18×10^{-7}	0.0035	6.2×10^{-5}	6.2×10^{-5}	2.04×10^{-6}	0.0035	5.80×10^{-5}	5.8×10^{-5}
	Cd	ND	0.00	0.001	0.00		0.00	0.001	0.00	
SCC Road	Pb	0.195±0.00	2.77×10^{-7}	0.0035	7.91×10^{-5}	8.7×10^{-6}	2.60×10^{-6}	0.0035	7.40×10^{-5}	1.5×10^{-5}
	Cd	0.006±0.00	8.66×10^{-9}	0.001	8.65×10^{-6}		8.13×10^{-8}	0.001	8.13×10^{-5}	
Primary School	Pb	0.147±0.00	2.09×10^{-7}	0.0035	5.96×10^{-5}	5.9×10^{-5}	1.96×10^{-6}	0.0035	5.60×10^{-5}	5.6×10^{-5}
	Cd	ND	0.00	0.001	0.00		0.00	0.001	0.00	

Where HMs = Heavy metals, C = Concentration of metals, Pb = Lead, Cd = Cadmium, Rfo = Reference oral dose, HQ = Hazard quotient, HI = Hazard index

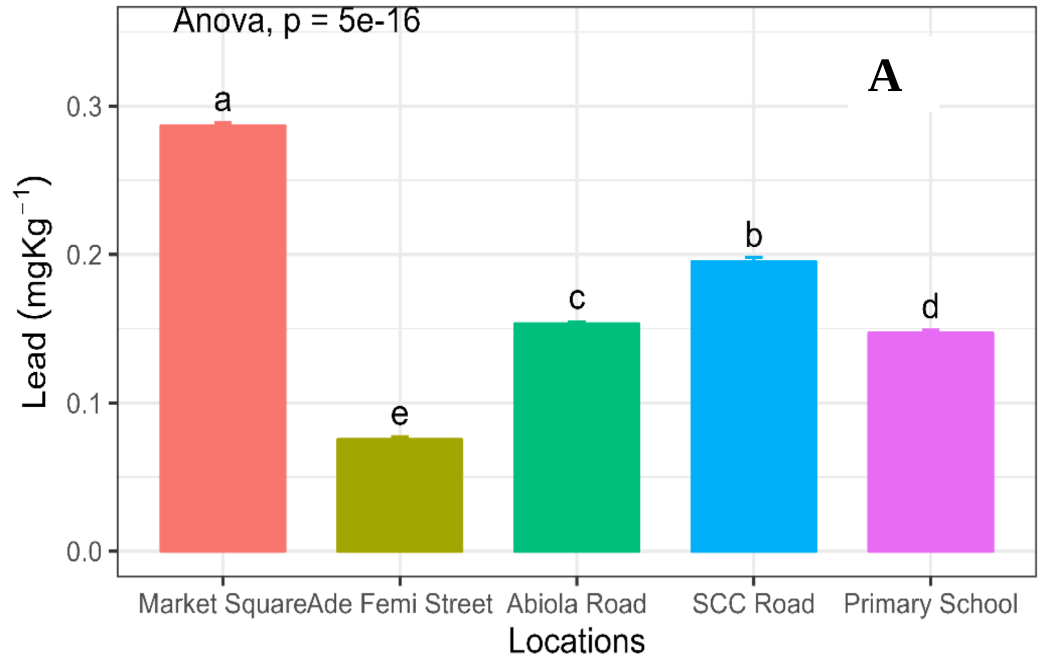

Figure 2A: Variation in the mean of lead across the study locations

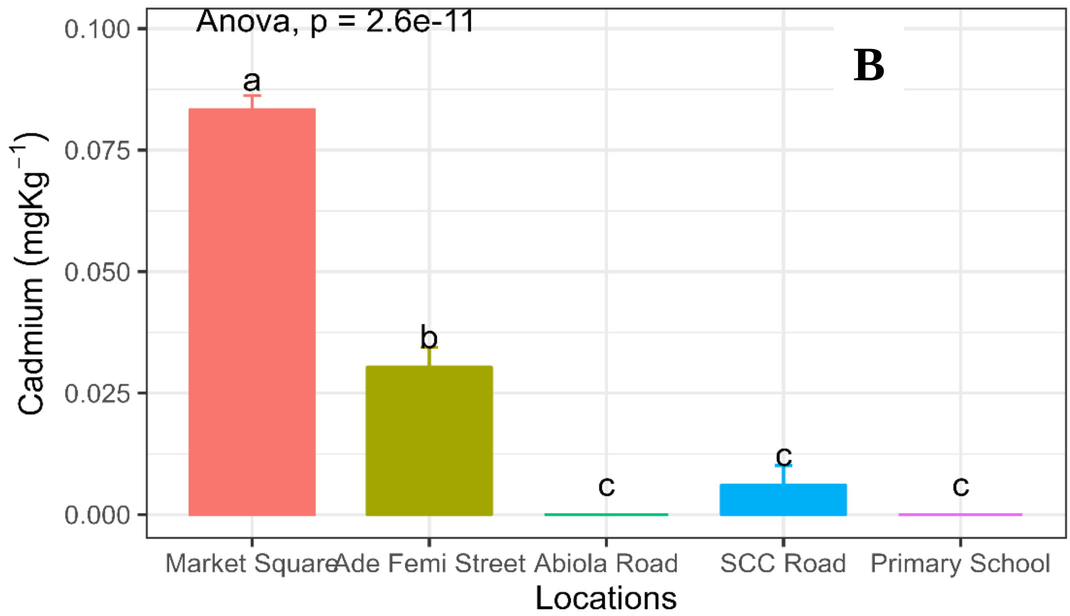

Figure 2B: Variation in the mean of cadmium across the study locations

The first and second components of the principal component analysis accounted for 93.20% of the total variation in the dataset. A strong positive association was observed between the metals. Elevation of the study locations had a strong negative relationship with the heavy metal content of the maize (Figure 3A). A cluster dendrogram was developed to show the study locations' Pb and Cd content similarity (Figure 3B).

Table 3: Incremental Lifetime Cancer Risk (ILCR) of the heavy metals in the maize samples

Locations	HMs	ILCR_Adult	ILCR_Children
Market square	Pb	3.55×10^{-6}	6.01×10^{-6}
	Cd	6.63×10^{-6}	1.12×10^{-5}
Ade Femi Street	Pb	4.35×10^{-6}	7.34×10^{-6}
	Cd	4.31×10^{-6}	7.28×10^{-6}
Abiola Road	Pb	4.52×10^{-6}	7.65×10^{-6}
	Cd	3.92×10^{-6}	6.64×10^{-6}
SCC Road	Pb	4.65×10^{-6}	7.86×10^{-6}
	Cd	3.54×10^{-6}	5.97×10^{-6}
Primary School	Pb	3.09×10^{-6}	5.22×10^{-6}
	Cd	3.37×10^{-6}	5.70×10^{-6}

Where Pb = lead, Cd = Cadmium, HMs = heavy metals, ILCR = Incremental life time cancer risk

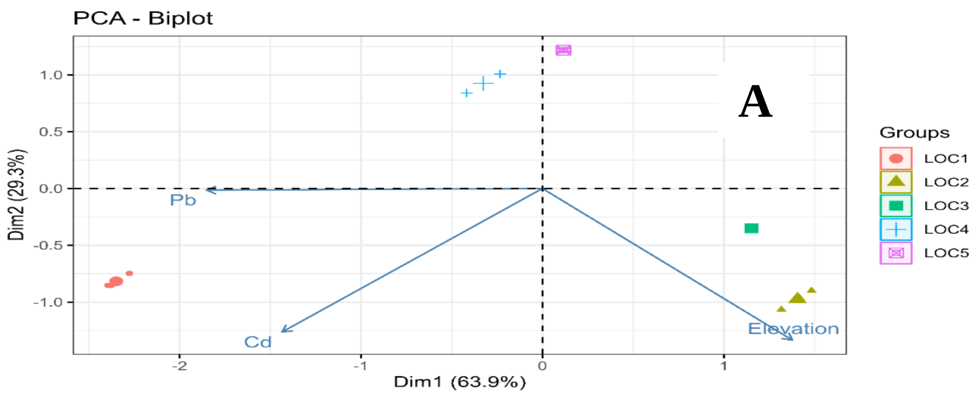

Figure 3A: Principal Component Analysis showing the relationship between heavy metals and locations

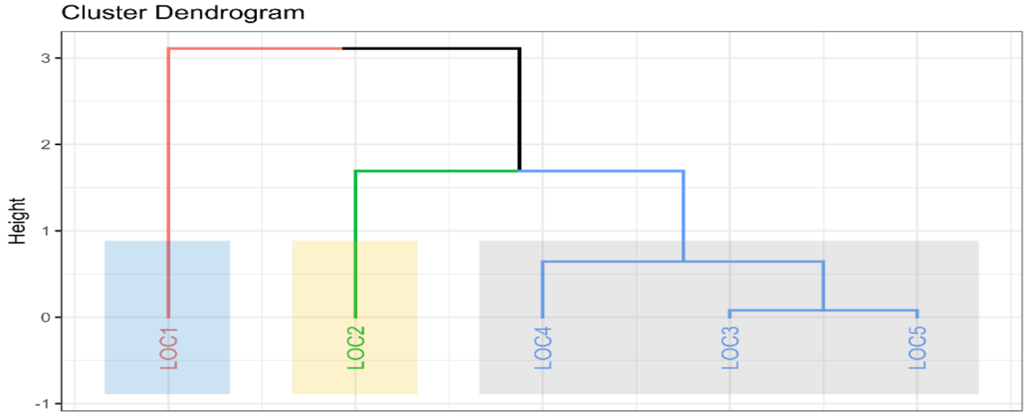

Figure 3B: Cluster dendrogram showing levels of similarity between study locations
Where LOC1 = Market square, LOC2 = Ade Femi Street, LOC3 = Abiola Road, LOC4 = SCC Road.

DISCUSSION

Lead levels were respectively higher and lower at Market Square and Ade Femi Street during the sampling period. The high lead content in the roasted corn obtained from the Market Square is associated with the high vehicular emissions at this location. The traffic burden at this sampling point was higher than observed for the other four sampling locations. It is also possible that the corn roasted at this location was grown in heavy metal-contaminated soil. Studies conducted in Zaria and Lagos, Nigeria, showed significantly higher values of lead (92.75±14.80 mg Kg^{-1}; 5.75-8.14 ± 0.41 mg Kg^{-1}) in roadside roasted corn (Onipede & Rahman, 2017; Bello *et al.*, 2022). The result of these findings is similar to that reported by El-Hassanin *et al.* (2020) and Guo *et al.* (2019) for Pb levels (0.009 mg Kg^{-1} - 0.3 mg Kg^{-1}) in maize samples obtained from Egypt. Primary Schools had lower vehicular activities or emissions compared to the other locations. However, our results show that Ade Femi Street had the least Pb content in the roasted corn. This suggests that the heavy metal content of roasted corn in this study may have originated from vehicular and industrial emissions and contaminated farms.

The concentration of Pb in only roasted corn obtained from Market Square exceeded the FAO/WHO recommended limit of 0.2 mg Kg^{-1}. Continuous exposure to lead can trigger several irreversible harmful medical conditions. For instance, chronic exposure to lead and mercury can result in disorders such as haematological and neurological disorders. Common diseases associated with lead and mercury poisoning are selenosis, arsenicosis, Parkinson's disease, acrodynia, and Alzheimer’s disease (Fu & Xi, 2020; Obasi & Akudinobi, 2020; Renu *et al.*, 2021; Sonone *et al.*, 2020).

In this study cadmium levels (ND - 0.09±00 mg Kg-1) were lower than those reported in other studies. For instance, Cd levels of 0– 0.06 mg kg^{-1} were reported for roasted corn from Alimosho Local Government Area of Lagos State, Nigeria (Oyelola *et al.*, 2013) and 0.32 – 1.10±0.05 mg Kg^{-1} (Onipede & Rahman, 2017).

Average Daily Intake (ADI) calculation is critical for determining the non-carcinogenic influence of any substance or pollutant. To evaluate the risk to human health linked to exposure to more than one heavy metal (HM), the hazard index (HI) has been developed (Emergency & Response, 1989b). This study's Pb and Cd hazard index was <1, indicating a non-potential for adverse non-carcinogenic health effects. Other studies have reported a hazard index of < 1 for both heavy metals in maize (El-Hassanin *et al.*, 2020; Larsen *et al.*, 2020). Similar to what was observed for Pb, there is no risk connected to cadmium exposure from the study locations based on the current exposure and model. Heavy metals such as Pb, Cd, Cu, and Ni have no known bio-importance in human biochemistry and physiology, hence consumption, even at very low concentrations, can be toxic (Arise *et al.*, 2015). Heavy metals can trigger the growth and proliferation of cancerous cells in humans. Many types of cancers are highly related to chronic exposures to low concentrations of toxic heavy metals. Consequently, estimating incremental lifetime cancer risk is critical to heavy metal studies. Therefore, it can be concluded that both groups are not at risk of developing cancer. These results are similar to El-Hassanin *et al.* (2020) & Farrag *et al.* (2016) for HI and ILCR of Pb and Cd in Maize and wheat.

The positive relationship observed between Cd and Pb indicates the similarity of contamination. The PC also revealed a strong influence of Market Square on the Pb and Cd content in roasted corn throughout the study period. It is commonly reported that metals with positive relationships are likely to have originated from the same contaminated source (Nduka et al., 2023).

At an H index of 2, two clusters were formed, with the Market square being relatively distinct from the others. Generally, Abiola Road and Primary School were more closely related to each other than with other locations. This may be related to these locations' comparably low vehicular activities or emissions.

CONCLUSION

This study measured the concentration of lead and cadmium in roadside roasted corn (Zea mays), and the associated risk of these metals in maize grains was assessed. The findings showed that the lead levels in Market Square were higher than those recommended by the Food and Agriculture Organization and the World Health Organization (FAO/WHO). On the other hand, based on the cadmium content of the maize, they were evaluated to be safe for ingestion by adults and children, with an Incremental Lifetime Cancer Risk (ILCR) between 1 × 10^{-4} and 1 × 10^{-6} and a Hazard Index (HI) less than one.

ACKNOWLEDGEMENT

The authors acknowledge Mr. Boniface Ogbu for the technical assistance given in the laboratory.

FUNDING

No governmental, private, or nonprofit grant was given for this research.

REFERENCES

Abrar, S., Javed, S., Kiran, S., & Awan, H. (2022). Analysis of lead, cadmium, and arsenic in colored cosmetics marketed in Pakistan. *Journal of Public Health Policy*, 1-11.

Afonne, O. J., & Ifediba, E. C. (2020). Heavy metals risks in plant foods-need to step up precautionary measures. *Current Opinion in Toxicology*, 22, 1-6.

Afridi, H. I., Bhatti, M., Talpur, F. N., Kazi, T. G., Baig, J. A., Chanihoon, G. Q., & Rahoojo, A. (2022). Cadmium Concentration in Different Brands of Cosmetic and their Effect on the Skin of Female Dermatitis Cosmetic Users. *Journal of the Chemical Society of Pakistan*, *44*(5).

Arise, R.O., Idowu, O.A., Farohunbi, S.T. & Abubakar, F.A. (2015). Levels of Some Metals and Earthworm Phosphatase Activities in the Soil around Odo-Efo River, Ilorin, Kwara State. Centre Point Journal (Science Edition) 21(1): 88-105.

Armienta, M. A., Beltrán, M., Martínez, S., & Labastida, I. (2020). Heavy metal assimilation in maize (Zea mays L.) plants growing near mine tailings. *Environmental Geochemistry and Health*, *42*, 2361-2375.

Arshad, H., Mehmood, M. Z., Shah, M. H., & Abbasi, A. M. (2020). Evaluation of heavy metals in cosmetic products and their health risk assessment. *Saudi Pharmaceutical Journal*, *28*(7), 779-790.

Bello, F., Wada, Y. A., Halilu, F. W., Abolude, D. S., & Abdullahi, S. A. (2022). *Roadside roasted plantain and maize in Zaria and environs: nutritional composition and heavy metal evaluation*.

Chauhan, G., & Chauhan, U. K. (2014). Human health risk assessment of heavy metals via dietary intake of vegetables grown in wastewater irrigated area of Rewa, India. *International journal of scientific and research publications*, *4*(9), 1-9.

Collin, M. S., Venkatraman, S. K., Vijayakumar, N., Kanimozhi, V., Arbaaz, S. M., Stacey, R. G. S., Anusha, J., Choudhary, R., Lvov, V., & Tovar, G. I. (2022). Bioaccumulation of lead (Pb) and its effects on human: A review. *Journal of Hazardous Materials Advances*, *7*, 100094.

Dinake, P., Motswetla, O., Kereeditse, T. T., & Kelebemang, R. (2023). Assessment of level of heavy metals in cosmetics. *Toxicology Research and Application*, *7*, 23978473231156620.

El-Hassanin, A. S., Samak, M. R., Abdel-Rahman, G. N., Abu-Sree, Y. H., & Saleh, E. M. (2020). Risk assessment of human exposure to lead and cadmium in maize grains cultivated in soils irrigated either with low-quality water or freshwater. *Toxicology Reports*, *7*, 10-15.

Emergency, U. States. E. P. Agency. O. of, & Response, R. (1989a). *Risk Assessment Guidance for Superfund: pt. A. Human health evaluation manual* (Vol. 1). Office of Emergency and Remedial Response, US Environmental Protection Agency.

Emergency, U. States. E. P. Agency. O. of, & Response, R. (1989b). *Risk Assessment Guidance for Superfund: pt. A. Human health evaluation manual* (Vol. 1). Office of Emergency and Remedial Response, US Environmental Protection Agency.

Farrag, K., Elbastamy, E., & Ramadan, A. (2016). Health risk assessment of heavy metals in irrigated agricultural crops, EL-Saff wastewater canal, Egypt. *CLEAN-Soil, Air, Water*, *44*(9), 1174-1183.

Fatima, G., Raza, A. M., Hadi, N., Nigam, N., & Mahdi, A. A. (2019). Cadmium in human diseases: It's more than just a mere metal. *Indian Journal of Clinical Biochemistry*, *34*, 371-378.

Fu, Z., & Xi, S. (2020). The effects of heavy metals on human metabolism. *Toxicology Mechanisms and Methods*, *30*(3), 167-176.

Gadzama, I. M. K., Yisa, A. G., & Thliza, I. A. (2014). Heavy metal concentrations in whole soft tissues of Anodonta implicate (class: Bivalvia) from Makera industrial discharge point of Kaduna river, Nigeria. *Zoologist (The)*, *12*, 16-22.

Gu, Q., Yu, T., Yang, Z., Ji, J., Hou, Q., Wang, L., Wei, X., & Zhang, Q. (2019). Prediction and risk assessment of five heavy metals in maize and peanut: A case study of Guangxi, China. *Environmental Toxicology and Pharmacology*, *70*, 103199.

Hocaoğlu-özyiğit, a., & Genç, b. N. (2020). Cadmium in plants, humans and the environment. *Frontiers in Life Sciences and Related Technologies*, *1*(1), 12-21.

Hong, N., Guan, Y., Yang, B., Zhong, J., Zhu, P., Ok, Y. S., Hou, D., Tsang, D. C. W., Guan, Y., & Liu, A. (2020). Quantitative source tracking of heavy metals contained in urban road deposited sediments. *Journal of Hazardous Materials*, *393*, 122362.

F. A. O. (2011). WHO food standards programme codex committee on contaminants in foods. *Fifth Session [Displayed 10 February 2014]. Available at Ftp://Ftp. Fao. Org/Codex/Meetings/CCCF/Cccf5/Cf05_ INF. Pdf*.

Levin, R., Vieira, C. L. Z., Mordarski, D. C., & Rosenbaum, M. H. (2020). Lead seasonality in humans, animals, and the natural environment. *Environmental Research*, *180*, 108797.

Liu, Y.-M., Liu, D.-Y., Zhang, W., Chen, X.-X., Zhao, Q.-Y., Chen, X.-P., & Zou, C.-Q. (2020). Health risk assessment of heavy metals (Zn, Cu, Cd, Pb, As and Cr) in wheat grain receiving repeated Zn fertilizers. *Environmental Pollution*, *257*, 113581.

Miranzadeh Mahabadi, H., Ramroudi, M., Asgharipour, M. R., Rahmani, H. R., & Afyuni, M. (2020). Assessment of heavy metals contamination and the risk of target hazard quotient in some vegetables in Isfahan. *Pollution*, *6*(1), 69-78.

Moghaddam, M., Mehdizadeh, L., & Sharifi, Z. (2020). Macro-and microelement content and health risk assessment of heavy metals in various herbs of Iran. *Environmental Science and Pollution Research*, *27*, 12320-12331.

Nduka, J. K., Umeh, T. C., Kelle, H. I., Mgbemena, M. N., Nnamani, R. A., & Okafor, P. C. (2023). Ecological and health risk assessment of heavy metals in roadside soil, dust and water of three economic zone in Enugu, Nigeria. *Urban Climate*, *51*, 101627.

Obasi, P. N., & Akudinobi, B. B. (2020). Potential health risk and levels of heavy metals in water resources of lead-zinc mining communities of Abakaliki, southeast Nigeria. *Applied Water Science*, *10*(7), 1-23.

Onipede, O. J., & Rahman, N. T. (2017). Metals in some ready-to-eat foods on some highways of Lagos and Ota South-West Nigeria. *J Environ Anal Chem*, *4*(229), 2380-2391.

Oyelola, O. T., Afolabi, M., Ajiboshin, I., Ofodile, N., & Banjoko, I. (2013). *Heavy Metals and Microbial Contents of Roadside Roasted Corn and Plantain*. Wiley Online Library.

Renu, K., Chakraborty, R., Myakala, H., Koti, R., Famurewa, A. C., Madhyastha, H., Vellingiri, B., George, A., & Gopalakrishnan, A. V. (2021). Molecular mechanism of heavy metals (Lead, Chromium, Arsenic, Mercury, Nickel and Cadmium)-induced hepatotoxicity-A review. *Chemosphere*, *271*, 129735.

Sonone, S. S., Jadhav, S., Sankhla, M. S., & Kumar, R. (2020). Water contamination by heavy metals and their toxic effect on aquaculture and human health through food Chain. *Lett. Appl. NanoBioScience*, *10*(2), 2148-2166.

USEPA, United States Environmental Protection Agency. 2007. Slope Factors for Carcinogens from USEPA.http://www.popstoolkit.com/tools/HHRA/SF_USEPA.

USEPA, 2015. Risk-based screening table. http:/www2.epa.gov/risk/risk based screening table generic tables.

Wan, Y., Liu, J., Zhuang, Z., Wang, Q., & Li, H. (2024). Heavy Metals in Agricultural Soils: Sources, Influencing Factors, and Remediation Strategies. *Toxics*, *12*(1), 63.

WHO, G. (2005). *Informal food distribution sector in Africa (street foods): importance and challenges*.

World Health Organisation, 2023. Nigeria data | World Health Organization [WWW Document]. data.who.int. URL https://data.who.int/countries/566