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Assessment of Heavy Metal Levels in Vegetables Grown on Abandoned Refuse Dumpsite Soil and Associated Health Risks in Mubi Metropolis, Adamawa State, Nigeria

Babayo A. Umar, Kawuwa B, Abubakar U. Dewa, Suwaiba L. Muhammad, Rebecca S. Aminu

Department of Chemical Sciences, Federal University of Kashere, Gombe,
P.M.B 0182 Gombe State, Nigeria.

Corresponding author: babayoaumar023@gmail.com

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Abstract

Heavy metal contamination in agricultural soils and vegetables near dumpsites poses significant health and ecological risks. This study assessed the concentration levels of cadmium (Cd), lead (Pb), nickel (Ni), arsenic (As), chromium (Cr), and cobalt (Co) in soil and vegetable samples collected from refuse dumpsites in (Yelwa Abattoir and Kolere) Mubi, Adamawa State, Nigeria, using Microwave Plasma-Atomic Emission Spectroscopy (MP-AES).The concentrations found in leaves for arsenic reached 13.02 ± 3.55 mg/kg, while lead was recorded at 1.54 ± 0.04 mg/kg. Bioconcentration Factor (BCF) values for arsenic in leaves were notably high at 4.24195, indicating significant uptake, while the Translocation Factor (TF) from roots to leaves for cadmium was 3.714939, suggesting efficient movement within the plant. Health risk indices revealed an Estimated Daily Intake (EDI) for adults of 1.26032E-08 mg/kg/day for arsenic, with a Hazard Quotient (HQ) of 4.20106E-05, indicating potential non-carcinogenic risks. The Hazard Index (HI) for multiple metals in leaves was 4.43956E-05, suggesting cumulative exposure risks for consumers. Results highlighted that arsenic levels in soil and vegetables exceeded FAO/WHO limits, indicating a potential carcinogenic risk. This study underscores the need for regular environmental monitoring, public awareness campaigns, and sustainable agricultural practices to mitigate the risks of heavy metal contamination.

Keywords: Heavy Metals, Contamination, Vegetables, Soil, Health risks, and Bioaccumulation

Introduction

Improper waste disposal remains a major environmental challenge in Mubi and many other Nigerian cities. The indiscriminate dumping of waste materials, coupled with inadequate waste management practices, has led to serious environmental and public health concerns. One of the most pressing issues arising from improper waste disposal is the contamination of soil and vegetation with heavy metals. Leachates from refuse dumps infiltrate the soil, where heavy metals accumulate and are subsequently absorbed by plants, introducing these hazardous elements into the food chain (Obaliagbon and Olowojoba, 2006). The continuous disposal of solid waste in open dumps, burning of refuse, and the use of decomposed waste as manure further exacerbate the problem, posing significant risks to both the environment and human health.

Heavy metal pollution from waste disposal is a growing concern due to its ability to persist in the environment and bioaccumulate in living organisms. Rainwater dissolves these metals, allowing them to leach into the soil and be absorbed by plants, which are then consumed by humans and animals. Additionally, poor waste management contributes to groundwater contamination through runoff, further polluting the ecosystem and making it difficult to control the spread of toxic substances. As a result, individuals who consume vegetables grew on contaminated soil face potential health risks, including neurological disorders, kidney damage, and carcinogenic effects (Njojju and Ayoka, 2006). The contamination of soil by heavy metals from dumpsites is particularly alarming, as it can compromise food safety and agricultural sustainability in urban and peri-urban areas.

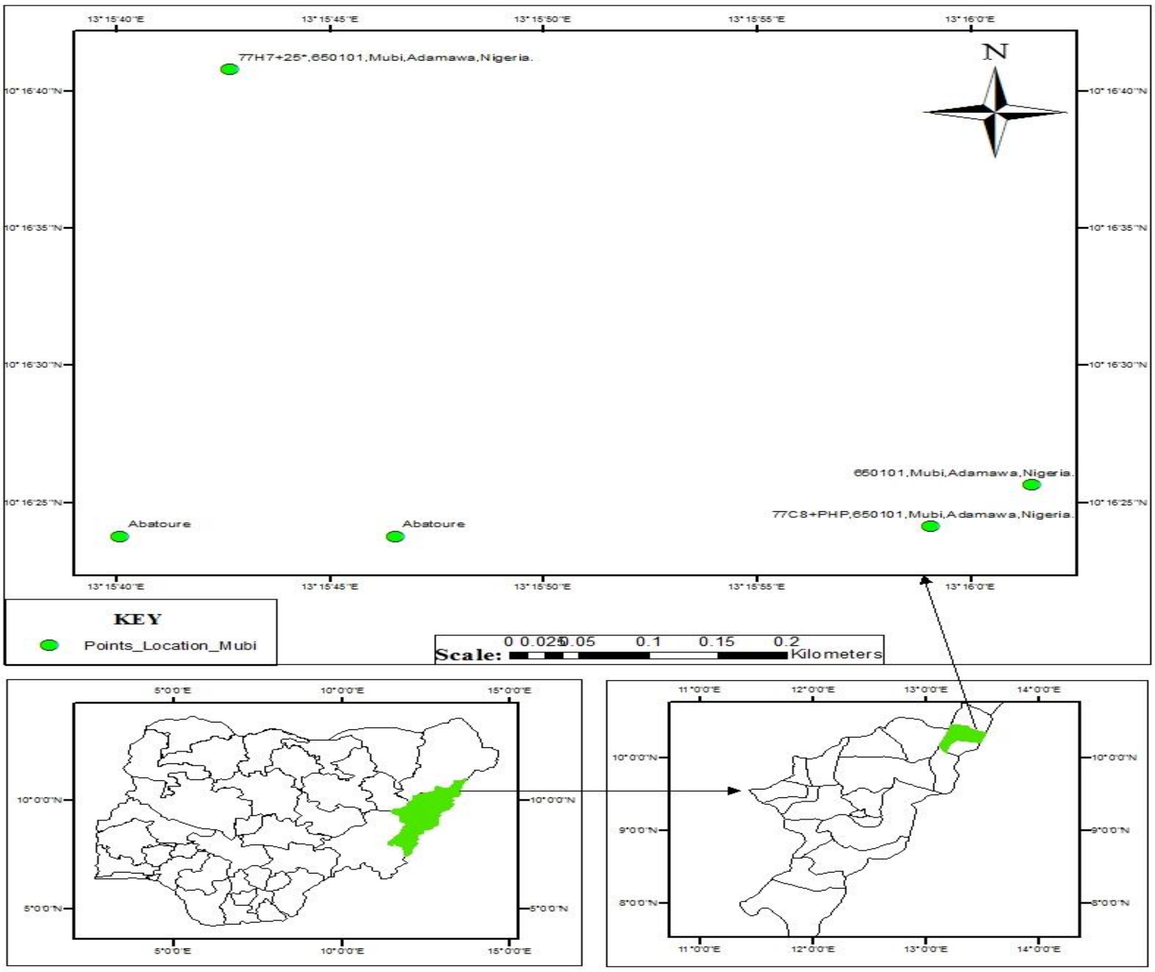
Several studies have documented the impact of waste disposal on heavy metal accumulation in agricultural soils and crops. Research by Adekunle *et al.,* (2003) revealed that dumpsites contribute significantly to heavy metal contamination in the soil, which in turn affects plant uptake and human health. The extent of heavy metal absorption by plants is influenced by various factors, including the type of metal, plant species, growth stage, and the specific plant parts being analyzed. Uzoho and Oti (2006) further reported that in many Nigerian cities, including Mubi, refuse dumpsites are often repurposed as farmland, where vegetables are cultivated using decomposed waste as manure. This practice enhances soil fertility but also increases the risk of heavy metal bio accumulation in edible crops.

Heavy metals, defined as elements with densities at least five times that of water, include toxic pollutants such as arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), aluminum (Al), and zinc (Zn). These metals, as identified by the European Commission, pose serious health risks due to their stability and ability to bioaccumulate in the food chain. Over the past five decades, industrial activities, agricultural practices, and refuse dumping have significantly increased human exposure to these toxic elements. Jekin (1989) noted that urban residential and commercial areas are particularly vulnerable to heavy metal pollution due to the widespread presence of waste dumps in close proximity to farmlands. Despite existing studies on heavy metal contamination from refuse dumpsites, there remains a need for localized investigations to understand the extent of this issue in specific regions.

This study aims to assess the levels of heavy metals in vegetables grown on abandoned refuse dumpsites in Mubi Metropolis, Adamawa State, and evaluate the potential health risks associated with their consumption. While previous studies have explored heavy metal contamination in soil and water sources, limited research has focused on the direct impact on food crops cultivated in urban dumpsites. The novelty of this study lies in its localized approach to assessing heavy metal accumulation in commonly consumed vegetables, providing essential data for policymakers and stakeholders to implement effective waste management strategies and safeguard public health.

Materials and Methods

Area of study



The Abattoir dumpsite is situated at approximately 10°16'21.24" N latitude and 13°15'37.75" E longitude, around 1 km from Kwanan Yelwa and AA Duhu filling station. Similarly, the Kolere dumpsite is located at 10°16'40.75" N latitude and 13°15'42.62" E longitude, approximately 2 km from Mubi's main market and Wuro-Gude Bridge. Mubi is a town located in the northeastern part of Adamawa State, Nigeria, positioned at latitude of 10° 16' 23.46" N and a longitude of 13° 15' 50.26" E. The climate in Mubi is tropical, characterized by two distinct seasons: a dry season and a rainy season. The rainy season is typically oppressive and overcast, whereas the dry season is partly cloudy and hot. Throughout the year, temperatures generally range from 60°F to 110°F, rarely falling below 55°F or exceeding 107°F. With an estimated population of around 475,540, Mubi is densely populated, primarily by the Fulani, Fali, and Gude ethnic groups. The Fali and Gude communities are predominantly engaged in farming, while the Fulani are primarily cattle herders. This population generates a significant volume of waste, which is deposited at designated dumpsites (Google Maps Gazette, 2015). Local farmers also cultivate vegetable plants in close proximity to these dumpsites.

Plate 2.1 Kolere dumpsite

Plate 2.2 Abattoir dumpsite

Materials

All glassware and vessels that were used were soaked in 10 % (V/V) HNO_3 for 24 hrs and were rinsed with distilled water. There were further rinsed with 0.5 % (W/V) $KMnO_4$, and there rinsed finally with distilled water, after which there were air-dried before use.

All reagents used for the determination of heavy metals were of analytical grade (BDH Chemicals Ltd, Poole, England). Working standards of $CdCl_2.2.5H_2O$, $Pb(NO_3)_2$, and $K_2Cr_2O_7$ for Cd, Pb, and Cr respectively were prepared by diluting stock solutions (Merck, Germany) 1000 mg/l in distilled water for the preparation of all solutions. Blank solutions were also prepared alongside and were bulked together for use as dilutant. The working solutions were freshly prepared by diluting an appropriate aliquot of the stock solution through intermediate solution

Sample Collection and Preparation

The vegetable samples of spinach (*Spinacia oleracea*) were randomly collected 100 m away from the dumpsites during the month of June, stored in labelled ziploc polythene bags and transported to the laboratory from areas of known dumpsites in (Yelwa Abattoir and Kolere) in Mubi respectively. The vegetable samples were washed thoroughly under clean tap water followed by distilled water to remove soil and air-born pollutants. Samples (leaves, stems and roots) were cut into small pieces, air dried at room temperature. The dried samples were ground and passed through a sieve of 2 mm size, stored in labelled ziploc bags and kept at room temperature for further analysis.

Soil samples were also collected simultaneously from the same sampling points as the vegetable samples from the same dumpsites. Soil samples of about 1 kg were collected from topsoil at a depth of (0-15 cm and 15-20 cm respectively) using soil auger and stored in labelled ziploc polythene bags. These bags were then transported to the laboratory. Approximately 20 g was taken from each sample, air dried at room temperature, crushed and sieved using 2 mm mesh and finally stored in clean polythene bags which were used for the analysis.

Digestion of Vegetable and Soil Samples for Heavy Metals Analysis

The samples were prepared as programmed by the equipment; briefly: 200 mg of solid samples and 50 mL for liquid samples were weighed and transferred into 90 ml microwave digestion vessels. Approximately 10 mL mixture of 15.9 N trace metal grade Nitric acid, hydrogen peroxide and perchloric acid (7:2:1) was added to each vessel. After standing for one hour, the samples were processed by microwave digestion system as follows: ramp temperature from ambient to 200 ºC over 20 min, then held at 200 ºC for 20 min, after digesting. They were cooled to approximately 50 ºC or lower before handling. The digest was transferred to 50 ml volumetric flask. The solution volume was adjusted to 50 ml with deionized water and filtered for instrumental analysis.

Heavy Metals Analysis

A microwave plasma-Atomic Emission Spectrometer (model: Agilent 4210 MP-AES), was used for the analysis of cadmium, nickel, arsenic, cobalt, lead and chromium concentrations in both the vegetable and soil samples. Results were reported in mg/kg dry weight of sample.

Statistical Analysis

The concentration of heavy metals in the vegetable and soil samples were analyzed using descriptive statistics such as mean, standard deviation using Microsoft Excel 2013 version. The mean concentration of the heavy metals in vegetable and soil were compared to the standard criteria for heavy metal contamination in vegetables and soil established by FAO/WHO standards. Two-way analysis of variance (ANOVA) was used in this study to determine the significant variation of the heavy metals concentration in the vegetable (leaves, stems and roots) between the two locations at ($P<0.05$).

Bioconcentration Factor (BCF) of the Heavy Metals

BCF of heavy metals from soils to vegetables was assessed by computing the ratio of the concentration of each heavy metal in vegetable's edible parts and the concentration of corresponding heavy metals in the respective soil. If BCF is less than 1, it suggests less movement of heavy metals from soil to vegetables. Conversely, BCF of more than one indicate the higher uptake of heavy metals by tested vegetable from soil (Chang *et al*., 2014).

It was assessed by following Equation 1.

$$BCF = C_{vegetable}/C_{soil} \qquad 1$$

$C_{vegetable}$ is the concentration of heavy metals contained in the vegetable (roots, stems or leaves) (mg/kg), and C_{soil} is the concentration of heavy metals in the soil (mg/kg) (Chang *et al*., 2014). If the BCF value less than one or equal to one, it shows the plant can only absorb but not accumulate heavy metals. If BCF is more than one, it indicates that the plant can absorb and accumulate metals (Liu *et al.,* 2009).

Translocation Factor (TF)

The transfer of metals between the roots and the leaves of vegetable can be estimated by the translocation factor (TF) [reference number] Translocation factor from the roots to the leaves was assessed using Equation 2.

$$TF = C_{vegetable}/C_{root} \qquad (2)$$

C_{leaves} is the concentration of heavy metals contained in the leaves of the vegetable (mg/kg), and C_{root} is the concentration of heavy metals in the roots (mg/kg) (USEPA, 2021). High TF value indicates high mobilization of metal elements from roots to the leaves.

Health Risk Assessment

Human health risk assessment involves the estimation of the probability of adverse health effects in humans who are exposed to metals in contaminated environments. Generally, the health risk assessment process comprises four main components: identification, exposure assessment, toxicity assessment (dose-response) and risk calculation (Wongsasuluk *et al.,* 2014). Based on the assessment of risk level, it can be categorized into carcinogenic and non-carcinogenic risks (Kamunda *et al.,* 2016). Carcinogenic risk assessment is a method of estimating the incremental probability of developing cancer over an individual's lifetime due to exposure to a potential carcinogenic metal (Wongsasuluk *et al.,* 2014)..

Exposure Assessment

Estimated daily intake (EDI) was used to estimate human exposure to heavy metals through direct ingestion according to equation 3 adopted from USEPA methods (USEPA, 2021). Estimations were made for two groups: children (as a sensitive group) and adults (as the general population).

$$EDI = C \times IR \times EF \times ED / BW \times AT \qquad 3$$

were EDI (mg/kg/day) is the estimated daily dose intake through ingestion, C is the concentration of metal (mg/kg) in the food, IR is the ingestion rate (kg/day), EF is the Exposure frequency, ED is the exposure duration, BW (kg) is the Standard body weight and AT is the time duration of human exposure. The parameters for calculating the estimated daily intake are presented in Table 1 adopted from (USEPA, 2021).

Table:1 parameters for assessment of Estimated Daily Intake (EDI).

Parameters	**Value**
Ingestion Rate (IR)	0.0002 kg/day for children and 0.0001 kg/day for adults
Exposure Frequency (EF)	365 days/year
Exposure Duration (ED)	6years for children and 24 years for adults
Body Weight (BW)	70 kg for adults and 15 kg for children
Average Time (AT)	365 ×ED

Source; USEPA, 2021

Non-Carcinogenic Risk

Non-carcinogenic health risk involves estimating the likelihood that a given amount of a substance will have adverse health effects over a specified time period. Non-carcinogenic health risk was conducted using Hazard quotient and Hazard index.

Hazard Quotient

The HQ was calculated according to equation 4. A hazard quotient is the ratio of the potential exposure to a substance and the level at which no adverse effects are expected USEPA, (2012). The individual reference dose (RD) for the various heavy metals are presented in table 2 adopted from USEPA, (2021)

$$HQ = EDI/RfD \qquad 4.$$

Table 2. Reference dose and Cancer slope factor (CSF) of the heavy metals

Heavy Metals	**REF Dose (RD) (mg/kg/day)**	**Cancer Slope Factor (CSF) (mg/kg/day)**
Cd	0.001	0.0061
Ni	0.02	0.00084
As	0.0003	3.66
Co	0.02	0.01
Pb	0.04	0.0085
Cr	1.5	0.041

Source: USEPA, 2021 Reference dose and CSF values

Hazard Index

Hazard Index technique was used to evaluate the overall potential for non-carcinogenic health risk posed by many contaminants USEPA, (2012). The hazard index for a mixture of pollutants is determined using equation 5 USEPA, (2012)

$$HI = \Sigma HQ \qquad 5.$$

If the HI value is less than one, the exposed population is unlikely to experience obvious adverse health effects. If the HI value exceeds one, then adverse health effects may occur USEPA, (2021)

Carcinogenic Risk Assessment

Carcinogenic risks are estimated by calculating the probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. The carcinogenic health risk is calculated using a cancer slope factor as shown in equation 6. The cancer slope factor is an estimate of the probability that an individual will develop cancer if exposed to a chemical substance for a lifetime of 70 years.

$$LCR = EDI \times CSF \qquad 6.$$

Where, LCR is the lifetime cancer risk and CSF is the cancer slope factor (mg/kg/day). LCR above 1×10^{-4} is viewed as unacceptable, risks below 1×10^{-6} are not considered to have significant health effects, and risk lying between 1×10^{-4} and 1×10^{-6} is considered an acceptable range Titilawo *et al.,* 2018. The individual cancer slope factors as adopted from the USEPA, (2021) are presented in Table 2**.**

Results and Discussion

Cadmium Contamination in spinach (*Spinacia oleracea*) and Soil

Cadmium (Cd) levels in spinach (*Spinacia oleracea*) from the Yelwa Abattoir study area varied between 0.087 mg/kg (roots) and 0.232 mg/kg (stems of YAM**)**, indicating moderate bioaccumulation. Soil samples contained Cd concentrations ranging from 0.086 mg/kg to 0.219 mg/kg, well below the WHO/FAO 2011 limit of 3.0 mg/kg for soils, suggesting that while contamination is present, it does not pose an immediate environmental risk. In contrast, the Kolere Mubi study area exhibited lower Cd accumulation, with vegetable concentrations ranging from 0.005 mg/kg (roots) to 0.171 mg/kg (stems**)** and soil concentrations between 0.002 mg/kg and 0.019 mg/kg, all significantly below the safety limits. Despite Cd levels in vegetables at both sites being below the FAO/WHO permissible limit of 0.2 mg/kg, some samples from Yelwa Abattoir approached this threshold, highlighting a higher contamination risk compared to Kolere Mubi, which appears to provide a safer agricultural environment.

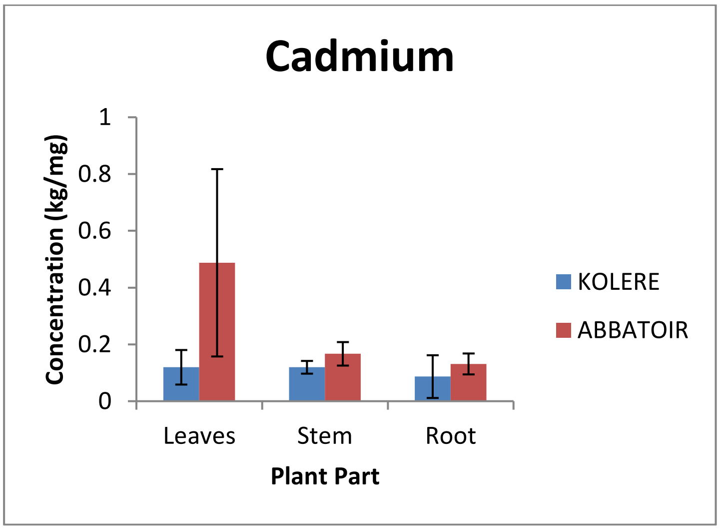


Fig. 1: Concentration in *Spinacia oleracea* samples

Nickel (Ni) Contamination in spinach (*Spinacia oleracea*) and Soil

In the Yelwa Abattoir study area, nickel (Ni) concentrations in spinach (*Spinacia oleracea*) ranged from 0.066 mg/kg (leaves) to 1.218 mg/kg (roots), indicating substantial root uptake. This suggests that Ni availability in the soil and the plant's absorption capacity significantly influence its accumulation. Soil Ni concentrations were higher, ranging from 0.291 mg/kg to 14.203 mg/kg, yet remained well below the FAO/WHO permissible limit of 50 mg/kg, suggesting contamination without exceeding critical agricultural safety thresholds. At the Kolere Mubi site, Ni concentrations in vegetables were slightly lower, ranging from 0.056 mg/kg (leaves) to 2.195 mg/kg (stems). Soil concentrations were also lower, between 0.003 mg/kg and 1.313 mg/kg, all swithin safe limits. This suggests that Kolere Mubi has healthier soil conditions, possibly due to reduced anthropogenic influences compared to Yelwa Abattoir. While Ni levels in vegetables from both locations remained below the FAO/WHO food safety limit of 5.0 mg/kg, higher concentrations in Yelwa Abattoir, particularly in roots and stems, exceeded the reported range of 0.4–0.5 mg/kg by Ali et al. (2019) for industrial areas. This highlights enhanced soil-to-plant transfer in Yelwa, likely driven by localized environmental factors, necessitating further investigation into soil contamination sources and plant uptake mechanisms.

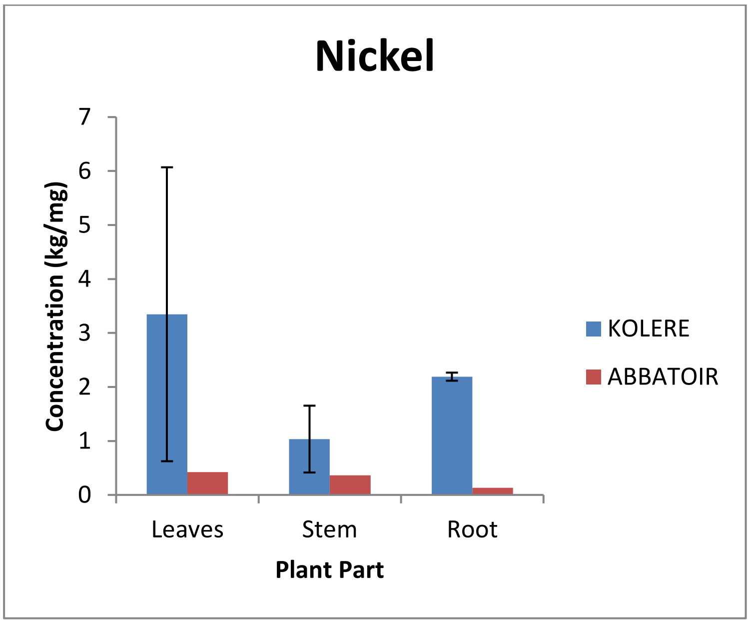


Fig. 2: Concentration in *Spinacia oleracea* samples

Arsenic (As) Contamination in spinach (*Spinacia oleracea*) and Soil

Arsenic (As) concentrations in spinach (*Spinacia oleracea*) from Yelwa Abattoir were alarmingly high, ranging from 0.52 mg/kg (leaves) to 49.0 mg/kg (roots) significantly exceeding the FAO/WHO permissible food safety limit of 0.2 mg/kg. Soil concentrations in this area were lower, varying between 0.29 mg/kg and 13.50 mg/kg, remaining within the FAO/WHO limit of 20 mg/kg. However, the extreme levels of arsenic in plant roots highlight a strong soil-to-plant transfer, raising concerns over potential health risks from consuming contaminated vegetables. A similar trend was observed in Kolere Mubi, where arsenic levels in vegetables ranged from 0.92 mg/kg (roots) to 35.92 mg/kg (roots). These values also exceeded permissible food safety limits, despite lower soil concentrations (0.23 mg/kg to 1.55 mg/kg) compared to Yelwa. This suggests that even moderate soil arsenic contamination can lead to significant bioaccumulation in plants, making them unsafe for consumption. These findings align with Okorie et al. (2020), who reported arsenic concentrations between 0.7 mg/kg and 1.9 mg/kg in vegetables from landfill sites, reinforcing concerns about arsenic mobility and uptake in contaminated environments.

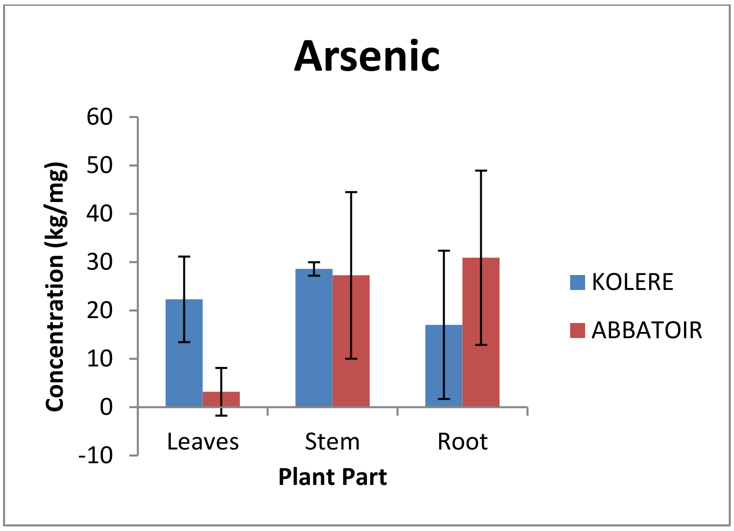


Fig. 3: Concentration in *Spinacia oleracea* samples

Cobalt (Co) Contamination in Spinach (*Spinacia oleracea*) and Soil

In the Yelwa Abattoir area, cobalt (Co) concentrations in spinach (*Spinacia oleracea*) ranged from 0.02 mg/kg (stems) to 0.49 mg/kg (roots), indicating significant bioaccumulation in plant tissues. Soil concentrations in Yelwa ranged between 1.61 mg/kg and 6.62 mg/kg, well below the FAO/WHO permissible limit of 50 mg/kg for soil, suggesting moderate contamination. At the Kolere Mubi site, Co concentrations in vegetables were slightly lower, ranging from 0.05 mg/kg (roots) to 6.61 mg/kg (leave). However, soil Co concentrations in Kolere were significantly lower than in Yelwa, ranging between 0.05 mg/kg and 0.34 mg/kg, highlighting lower environmental contamination. Importantly, Co concentrations in vegetables from Yelwa exceeded the FAO/WHO food safety limit of 0.1 mg/kg, raising concerns about potential health risks. These findings align with Bello et al. (2017), who reported Co levels of 0.12–0.13 mg/kg in vegetables from moderately contaminated sites. The elevated Co levels in Yelwa suggest enhanced soil-to-plant transfer, possibly linked to local industrial activities or environmental pollution. This underscores the urgent need for continuous monitoring and assessment of Co contamination in soil and crops to ensure food safety and mitigate health risks

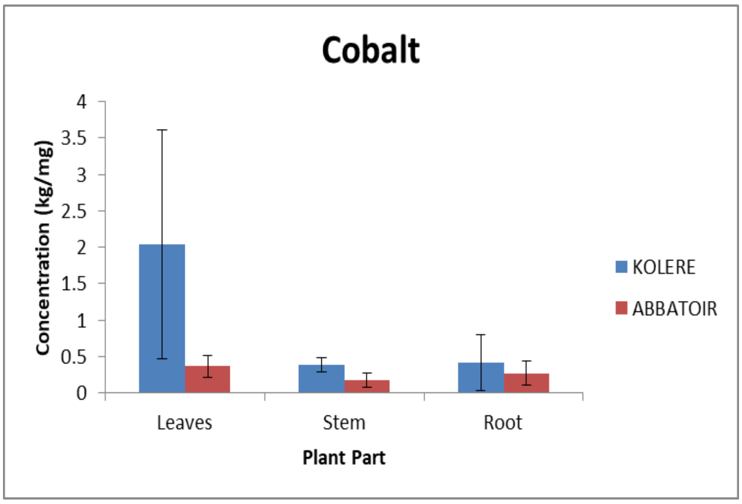


Fig. 4: Concentration in *Spinacia oleracea* samples

Lead (Pb) Contamination in spinach (*Spinacia oleracea*) and Soil

At the Yelwa Abattoir site, lead (Pb) concentrations in spinach (*Spinacia oleracea*) ranged from 0.28 mg/kg (stems) to 7.41 mg/kg (roots), significantly exceeding the FAO/WHO permissible limit of 0.3 mg/kg for food. These findings raise serious concerns about food safety and potential health risks for consumers. The particularly high Pb levels in roots indicate strong bioaccumulation, likely due to environmental contamination from anthropogenic activities. Soil Pb concentrations in Yelwa ranged between 2.08 mg/kg and 20.78 mg/kg. While these values remain below the FAO/WHO limit of 100 mg/kg for soil, they suggest potential contamination, with Pb transfer from soil to plants posing a critical concern. Although soil Pb levels may not present an immediate contamination risk, the high uptake by plants highlights a significant soil-to-plant transfer issue. These findings underscore the need for urgent monitoring and mitigation strategies to limit Pb exposure through food consumption and reduce potential health risks.

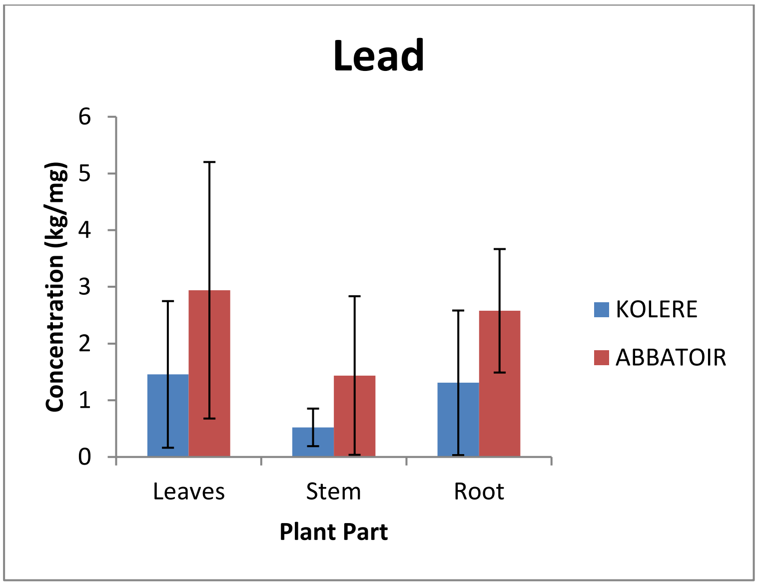


Fig. 5: Concentration of Lead in *Spinacia oleracea* samples

Chromium (Cr) Concentrations in spinach (*Spinacia oleracea*) and Soil

In the Yelwa Abattoir area, chromium (Cr) concentrations in vegetables ranged from 0.06 mg/kg in leaves to 1.48 mg/kg in roots, which are below the FAO/WHO permissible limit of 2.3 mg/kg, indicating a relatively low immediate risk from vegetable consumption. Soil chromium levels in Yelwa were also safe, ranging from 0.41 mg/kg to 10.36 mg/kg, well below the 100 mg/kg limit.Conversely, the Kolere area presents a concerning situation, with chromium concentrations in vegetables ranging from 0.23 mg/kg to 5.41 mg/kg, exceeding permissible limits. This raises potential health risks for consumers, particularly as these levels surpass the 0.15 to 0.2 mg/kg range noted by Akinyele and Shokunbi (2015) for vegetables near industrial sites. The increased chromium concentration in Kolere highlights the need for closer monitoring and assessment of vegetable safety in this region.

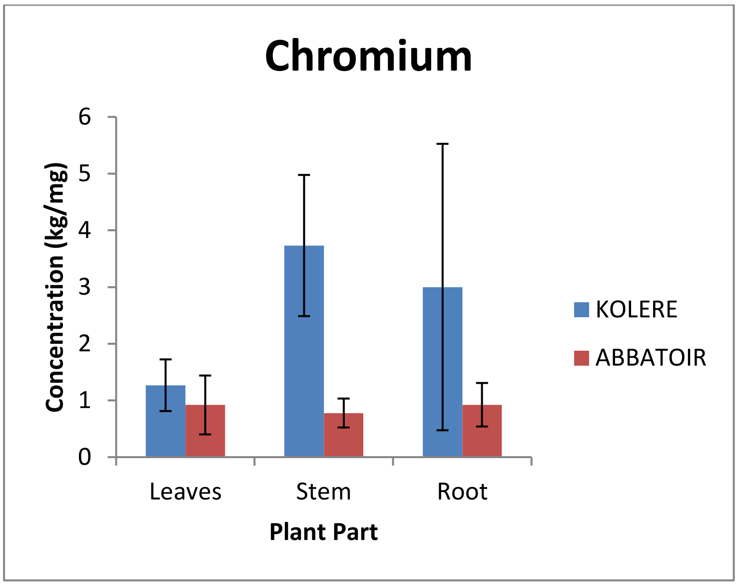


Fig. 6: Concentration in *Spinacia oleracea* samples

Summary of Statistical Analysis

Kolere	**Yelwa Abattoir**
P < 0.05	P-value of 0.0155

When comparing both locations, the results indicated a highly significant difference in heavy metal concentrations, with a P-value of 0.000000, emphasizing the variability in contamination levels between the two sites.

Bioconcentration (BCF) and **Translocation Factor (TF)**

Bioconcentration Factor (BCF)

The Bioconcentration Factor (BCF) indicates the ability of vegetables to accumulate metals from soil into their tissues. A BCF > 1 implies bioaccumulation, while a BCF ≤ 1 suggests minimal accumulation. **Yelwa Abattoir**: **Leaves**: Arsenic (As) exhibited the highest BCF value (4.24195), indicating significant bioaccumulation, followed by Chromium (Cr) (0.173225).Cadmium (Cd) and Lead (Pb) had relatively lower BCF values of 0.4874 and 0.3177, respectively. **Stems**: As recorded the highest BCF (4.531936), surpassing FAO/WHO limits (0.2 mg/kg). Nickel (Ni) and Cobalt (Co) showed minimal accumulation with BCF values of 0.030278 and 0.035206, respectively. **Roots**: As continued to dominate with a BCF of 5.139388, reflecting its strong bioavailability. Other metals like Co (0.053797) and Cr (0.173979) displayed moderate accumulation. **Kolere**: **Leaves**: Cadmium (Cd) showed the highest BCF value (16.8169), followed by Arsenic (As) (18.06807) and Chromium (Cr) (6.469388). This indicates a significant accumulation potential in Kolere's soil for Cd and As. **Stems**: As displayed the highest BCF (23.1637), followed by Cr (19.04082), reflecting a high risk of bioaccumulation in edible parts of vegetables. Roots: Cd and As showed notable BCF values of 12.19718 and 13.79092, respectively, indicating that roots are a primary site for metal accumulation. Both locations exhibited higher accumulation of As in all vegetable parts, with Kolere recording slightly higher BCF values overall. Cd also showed significant bioaccumulation in Kolere.

Translocation Factor (TF)

The TF evaluates the mobility of metals within the plant from roots to leaves. A TF > 1 suggests active translocation of metals. Yelwa Abattoir: Cd (3.714939) and Ni (1.157205) showed significant translocation to leaves, indicating mobility within the plant. As had a low TF value (0.10279), suggesting limited movement from roots to leaves. Kolere: Co demonstrated the highest TF (4.941748), indicating effective translocation to aerial parts. Other metals such as Ni (3.747816) and As (1.310142) also showed high mobility. Kolere displayed higher translocation factors for most metals compared to Yelwa, indicating that plants grown in Kolere soils may have a greater risk of transferring contaminants to edible parts.

Health Risk Assessment.

Health Risks in Yelwa Abattoir, Mubi

Leaves Estimated Daily Intake (EDI): The EDI values for heavy metals in leaves show significant exposure, particularly for Arsenic (1.26032E-08 mg/kg).This level is concerning, given that As is a known carcinogen. Hazard Quotient (HQ): The HQ for Arsenic (4.20106E-05) is notably high, indicating a potential health risk for adults consuming these vegetables regularly. Hazard Index (HI): The HI value of 4.43956E-05 suggests that the cumulative risk from multiple heavy metals in leaves is significant, warranting concern. Lifetime Cancer Risk (LCR): The LCR **Stems** EDI: The EDI values for stems are lower than those for leaves, but Arsenic (1.08119E-07 mg/kg) is still the highest, indicating potential health risks. HQ: The HQ for As (0.000360397) and other metals is concerning, suggesting that regular consumption of these stems could lead to adverse health effects. HI: The HI value is consistent with the risks observed in the leaves, highlighting that consumption of stems also poses a risk. LCR: The LCR for Arsenic (3.95716E-07) suggests a significant cancer risk, reinforcing the urgency for risk mitigation strategies for Arsenic (4.61276E-08) indicates a measurable risk of cancer over a lifetime of consumption, further emphasizing the need for monitoring and intervention. **Roots** EDI: The EDI values for roots are similar to those for stems, with Arsenic (1.22611E-07 mg/kg) again being the most concerning. HQ: The HQ for As (0.000408704) indicates a potential risk from roots, alongside other heavy metals. HI: The HI for roots is slightly elevated, again indicating cumulative risks from multiple metals. LCR: The LCR for Arsenic (4.48757E-07) suggests a notable risk of developing cancer over time, necessitating urgent action

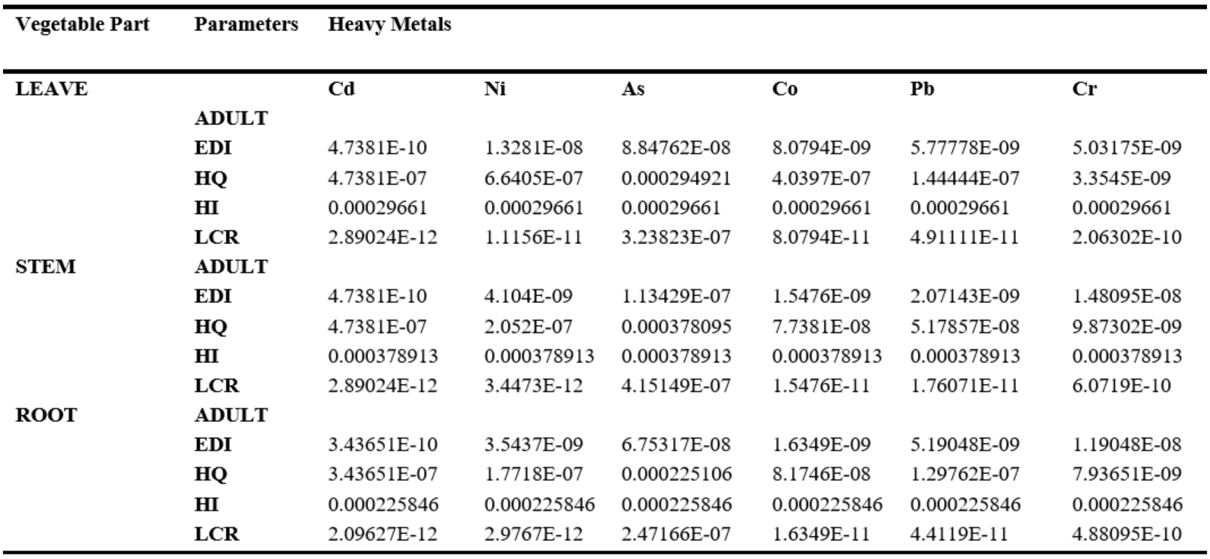
Table 3: Health Risks Assessment from consumption of Spinacia *oleracea* samples in Yelwa Abattoir, Mubi

Vegetable Part	Parameters	Heavy Metals					
LEAVE		Cd	Ni	As	Co	Pb	Cr
	ADULT						
	EDI	1.93413E-09	1.6825E-09	1.26032E-08	1.4524E-09	1.16667E-08	3.65079E-09
	HQ	1.93413E-06	8.4127E-08	4.20106E-05	7.2619E-08	2.91667E-07	2.43386E-09
	HI	4.43956E-05	4.43956E-05	4.43956E-05	4.43956E-05	4.43956E-05	4.43956E-05
	LCR	1.17982E-11	1.4133E-12	4.61276E-08	1.4524E-11	9.91667E-11	1.49683E-10
STEM	ADULT						
	EDI	6.61905E-10	1.4349E-09	1.08119E-07	7.0635E-10	5.69841E-09	3.0873E-09
	HQ	6.61905E-07	7.1746E-08	0.000360397	3.5317E-08	1.4246E-07	2.0582E-09
	HI	0.00036131	0.00036131	0.00036131	0.00036131	0.00036131	0.00036131
	LCR	4.03762E-12	1.2053E-12	3.95716E-07	7.0635E-12	4.84365E-11	1.26579E-10
ROOT	ADULT						
	EDI	5.20635E-10	1.454E-09	1.22611E-07	1.0794E-09	1.02302E-08	3.66667E-09
	HQ	5.20635E-07	7.2698E-08	0.000408704	5.3968E-08	2.55754E-07	2.44444E-09
	HI	0.000409609	0.000409609	0.000409609	0.000409609	0.000409609	0.000409609
	LCR	3.17587E-12	1.2213E-12	4.48757E-07	1.0794E-11	8.69563E-11	1.50333E-10

Health Risks in Kolere Mubi

Leaves: Kolere shows lower EDI values than Yelwa, with Cd (4.7381E-10 mg/kg) and As (8.84762E-08 mg/kg). However, the HQ for As (0.000294921) still indicates a health concern. The HI (0.00029661) suggests a cumulative risk, though lower than in Yelwa. LCR (3.23823E-07) highlights a lifetime cancer risk, necessitating attention. **Stems:** The highest EDI value is for As (1.13429E-07 mg/kg). The HQ (0.000378095) and HI (0.000378913) indicate potential risks, though lower than Yelwa. LCR (4.15149E-07) suggests a significant long-term cancer risk. **Roots:** EDI values are lower in Kolere than in Yelwa, with As (6.75317E-08 mg/kg) being notable. The HQ (0.000225106) and HI indicate potential risks. LCR (2.47166E-07) confirms measurable cancer risk, reinforcing the need for monitoring. Across all vegetable parts, Arsenic is the primary concern, with roots and stems showing the highest cancer risk (LCR) and leaves posing significant cumulative risks (HI) due to higher consumption rates. Immediate intervention is necessary to mitigate these health risks.

Table 4: Health Risks Assessment from consumption of Spinacia *oleracea* samples in Kolere, Mubi



Vegetable Part	Parameters	Heavy Metals					
LEAVE		Cd	Ni	As	Co	Pb	Cr
	ADULT						
	EDI	4.7381E-10	1.3281E-08	8.84762E-08	8.0794E-09	5.77778E-09	5.03175E-09
	HQ	4.7381E-07	6.6405E-07	0.000294921	4.0397E-07	1.44444E-07	3.3545E-09
	HI	0.00029661	0.00029661	0.00029661	0.00029661	0.00029661	0.00029661
	LCR	2.89024E-12	1.1156E-11	3.23823E-07	8.0794E-11	4.91111E-11	2.06302E-10
STEM	ADULT						
	EDI	4.7381E-10	4.104E-09	1.13429E-07	1.5476E-09	2.07143E-09	1.48095E-08
	HQ	4.7381E-07	2.052E-07	0.000378095	7.7381E-08	5.17857E-08	9.87302E-09
	HI	0.000378913	0.000378913	0.000378913	0.000378913	0.000378913	0.000378913
	LCR	2.89024E-12	3.4473E-12	4.15149E-07	1.5476E-11	1.76071E-11	6.0719E-10
ROOT	ADULT						
	EDI	3.43651E-10	3.5437E-09	6.75317E-08	1.6349E-09	5.19048E-09	1.19048E-08
	HQ	3.43651E-07	1.7718E-07	0.000225106	8.1746E-08	1.29762E-07	7.93651E-09
	HI	0.000225846	0.000225846	0.000225846	0.000225846	0.000225846	0.000225846
	LCR	2.09627E-12	2.9767E-12	2.47166E-07	1.6349E-11	4.4119E-11	4.88095E-10

Conclusion and Recommendations

The study confirmed the presence of heavy metals in soil and vegetable samples from dumpsites in Mubi, with arsenic, cadmium, and lead exceeding permissible limits in several cases. The bioaccumulation and translocation of these metals into edible plant parts suggest significant risks of dietary exposure. Health risk assessments revealed that arsenic posed substantial non-carcinogenic and carcinogenic risks, particularly for children consuming contaminated vegetables. The findings underscore the critical need for targeted interventions to mitigate heavy metal contamination and safeguard public health

To minimize heavy metal contamination in urban agriculture, local authorities should enforce proper waste management by ensuring safe disposal and treatment of refuse. Routine monitoring of soil and vegetable samples is essential to maintain compliance with safety standards. Public awareness campaigns should educate farmers and consumers on the risks of contaminated soils and the importance of food safety. Additionally, soil remediation techniques should be implemented to reduce heavy metal concentrations in affected areas. Regulated agricultural policies must be developed to control farming near refuse dumpsites and prevent further contamination. Finally, further research initiatives should explore the health impacts of heavy metal exposure and promote sustainable agricultural practices.

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