



ASSESSMENT OF HEAVY METAL CONTAMINATION IN IRRIGATION WATER, SOIL AND VEGETABLES AT FARIN GADA FARMLANDS, JOS NORTH, PLATEAU STATE, NIGERIA.

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ABSTRACT

Urban irrigation farming contributes significantly to food supply in Nigerian cities but may pose environmental and public health risks due to the use of contaminated surface waters. This study evaluated the levels of selected heavy metals in irrigation water, soil, and vegetables from two irrigation farmlands, Before First Bank (BFB) and Before Permanent Site (BPS), in Farin Gada, Jos North, Plateau State, Nigeria. Samples of irrigation water, soil, and commonly cultivated vegetables were collected in February and analysed for Arsenic, Lead, Cadmium, Chromium, Copper, and Nickel using Atomic Absorption Spectrophotometry following aqua regia wet acid digestion. Irrigation water from BPS recorded higher concentrations of As (0.726 mg/L), Cd (0.394 mg/L), and Cu (0.254 mg/L) compared with BFB, with As and Cd exceeding FAO permissible limits at both sites. Heavy metal concentrations in irrigated soils were significantly elevated relative to control soils collected approximately 200 m away, indicating strong anthropogenic enrichment. BPS soils contained particularly high levels of Ni (27.44 mg/kg), Cu (70.95 mg/kg), As (49.00 mg/kg), Cd (20.58 mg/kg), and Cr (20.19 mg/kg). Pollution indices revealed severe contamination: Contamination Factor and Enrichment Factor values indicated pronounced anthropogenic impact; the Geo-accumulation Index classified soils as moderately to strongly polluted, while Pollution Load Index values were 39.61 (BFB) and 7.69 (BPS), indicating severe soil pollution at both sites. Vegetables analysed (*Brassica oleracea* var. *capitata*, *Daucus carota*, *Lycopersicon esculentum*, and *Spinacia oleracea*) showed variable heavy metal accumulation, with leafy and root crops recording higher Cd and As levels, often exceeding recommended food safety limits. These findings demonstrate a clear contamination pathway from irrigation water to soil and edible vegetables, highlighting potential health risks associated with urban irrigation farming in Farin Gada.

Keywords: Farin Gada, heavy metals, pollution indices, soil contamination, urban irrigation, vegetables

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INTRODUCTION

Irrigation farming has become an essential component of food production systems in many developing countries, particularly in sub-Saharan Africa. Rapid population growth, urban expansion and increasing demand for fresh vegetables have led to the widespread cultivation of crops along river banks, streams and drainage channels within cities [1]. While this practice contributes significantly to food security and livelihoods, it also raises serious environmental and public health concerns due to the frequent use of untreated and contaminated surface water for irrigation [2].

Heavy metals are among the most critical pollutants associated with urban irrigation farming. Unlike organic contaminants, heavy metals are non-biodegradable, persistent in the environment and capable of accumulating in soils and living organisms over time [3]. Once introduced into agricultural systems, they can remain in soils for decades, gradually increasing in concentration through repeated irrigation, atmospheric deposition and anthropogenic inputs [4]. This persistence makes

heavy metal contamination particularly problematic in intensively cultivated urban farmlands.

Irrigation water is a major pathway through which heavy metals enter agricultural soils. Surface waters flowing through urban centres often receive untreated domestic wastewater, industrial effluents, market refuse, automobile workshop wastes and storm runoff [5]. These inputs introduce metals such as lead (Pb), cadmium (Cd), arsenic (As), chromium (Cr), copper (Cu) and nickel (Ni) into the water bodies. When such waters are used continuously for irrigation, heavy metals are deposited onto agricultural soils, where they may bind to soil particles or remain in bioavailable forms [6].

Soils act as both sinks and sources of heavy metals within agro-ecosystems. The accumulation of metals in soils is influenced by factors such as soil pH, organic matter content, texture, cation exchange capacity and redox conditions [7]. Under favourable conditions, accumulated metals may become mobile and available for plant uptake. Prolonged irrigation with contaminated water therefore results in progressive enrichment of soils, often exceeding

natural background levels and posing long-term ecological risks [8].

Vegetables grown on contaminated soils are particularly vulnerable to heavy metal accumulation. Many vegetable species possess high metal uptake capacities due to their shallow root systems, rapid growth rates and high transpiration demands [9]. Leafy vegetables, in particular, tend to accumulate higher metal concentrations because metals can be absorbed both through roots and deposited directly onto leaf surfaces from irrigation water and atmospheric fallout [10]. Root vegetables may also accumulate substantial metal loads due to direct contact with contaminated soils.

The consumption of vegetables contaminated with heavy metals represents a major route of human exposure. Chronic intake of metals such as Cd, Pb, As and Hg has been linked to a range of adverse health effects, including kidney dysfunction, neurological disorders, cardiovascular diseases and carcinogenic outcomes [11]. Because vegetables are often consumed fresh or lightly cooked, the potential for dietary exposure is especially high in communities relying on urban irrigation produce [12].

In Nigeria, several studies have reported elevated levels of heavy metals in irrigation water, soils and vegetables from urban farming areas [13-15]. Factors commonly identified include indiscriminate waste disposal, poor wastewater management, industrial activities and informal automobile repair operations. Despite these findings, urban irrigation farming remains largely unregulated, and contaminated produce continues to enter local markets.

Farin Gada, located in Jos North Local Government Area of Plateau State, is one of the major urban agricultural zones supplying vegetables to residents of Jos metropolis. The area is characterised by intensive year-round irrigation farming supported by surface water bodies that flow through multiple residential, commercial and industrial sections of the city. Along their course, these water bodies receive various wastes, including domestic refuse, sewage discharges and urban runoff. In addition, automobile mechanic workshops are located close to some sections of the irrigation sites, particularly near the Before First Bank (BFB) area, where wastes such as used engine oil, battery residues and metal scraps are often disposed near the water body.

Another important but less documented source of contamination in urban farms is the use of burnt refuse (ash) as manure. Open burning of municipal waste concentrates heavy metals in the residual ash, which is sometimes applied directly to

farmlands as a soil amendment due to its perceived nutrient value [16]. This practice can significantly increase the concentration and bioavailability of heavy metals in soils, thereby enhancing plant uptake.

Although previous studies in Jos and other Nigerian cities have examined heavy metal contamination in individual environmental components, integrated assessments linking irrigation water, soils and vegetables within the same farming system remain limited. Such integrated approaches are essential for understanding contamination pathways and for identifying critical control points for intervention [17].

Furthermore, the application of pollution assessment indices such as Contamination Factor (CF), Enrichment Factor (EF), Geo-accumulation Index (Igeo) and Pollution Load Index (PLI) provides a quantitative basis for evaluating the degree of soil contamination and distinguishing between natural and anthropogenic sources of metals [18]. These indices are increasingly recommended for comprehensive environmental quality assessment and decision-making.

The present study therefore provides an integrated assessment of heavy metal contamination in irrigation water, soil and vegetables from two urban irrigation farmlands in Farin Gada, Jos North, Plateau State. The specific objectives of the study were to: (i) determine the concentrations of selected heavy metals in irrigation water from two distinct sites; (ii) evaluate the levels of heavy metals in irrigated soils relative to control soils; (iii) assess the accumulation of heavy metals in commonly consumed vegetables; and (iv) determine the degree of soil contamination using established pollution assessment indices.

The findings of this study are expected to contribute to environmental monitoring efforts, inform policy decisions on urban irrigation practices and raise awareness of potential food safety risks associated with urban agriculture in Jos metropolis.

3. MATERIALS AND METHODS

Study area and sites

The study was carried out in Farin Gada, located within Jos North Local Government Area of Plateau State, Nigeria. Farin Gada is an urban agricultural zone characterized by intensive dry-season irrigation farming that supports the cultivation of vegetables throughout the year. The area lies within the Jos Plateau, which experiences a temperate climate relative to other parts of Nigeria, with distinct wet and dry seasons.

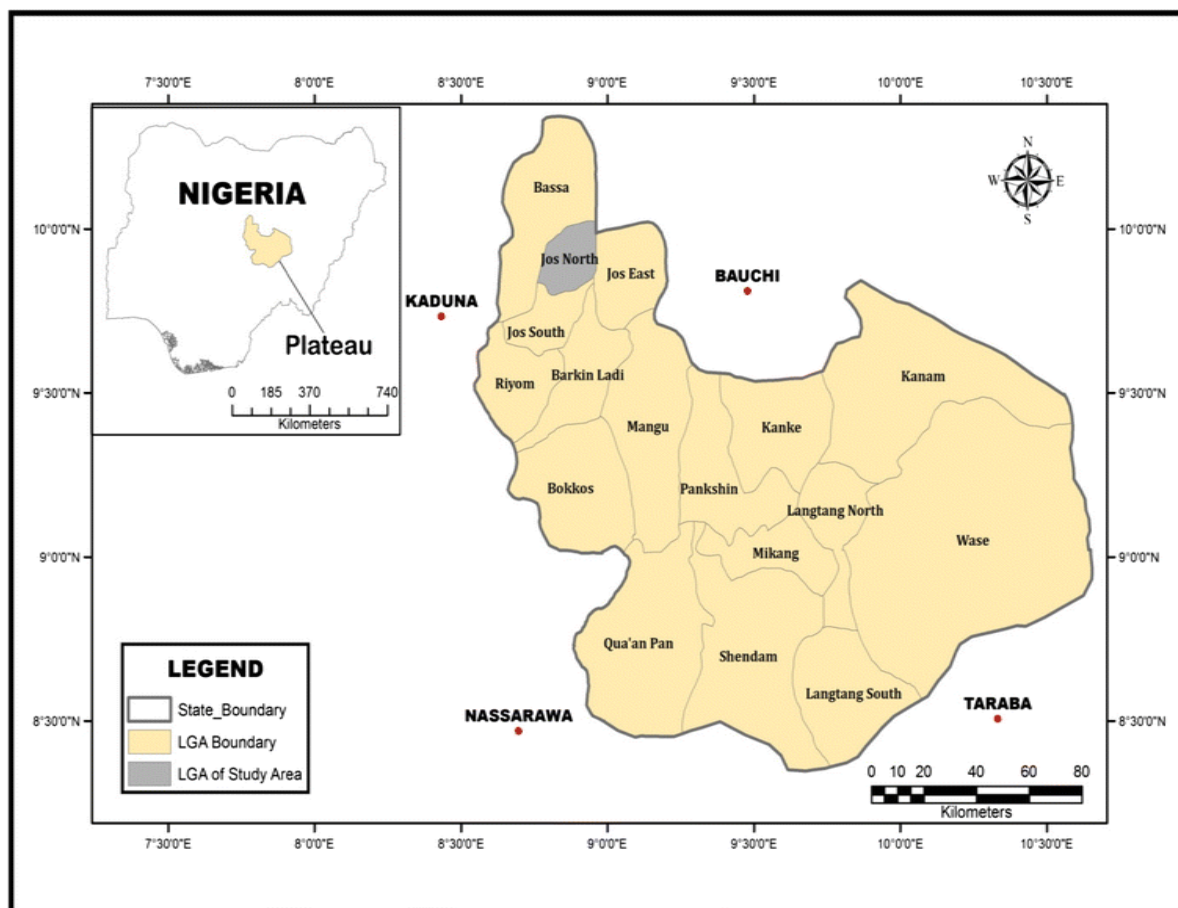


Figure 1: Map of Plateau State Showing Jos North LGA (Jos metropolis IRSIS Maps)

Two irrigation farmlands were selected for this study based on differences in location, surrounding land use activities and irrigation water sources. These sites were identified as Before First Bank (BFB) and Before Permanent Site (BPS). Both farms depend on running surface water bodies that flow through several residential, commercial and industrial areas of Jos metropolis before reaching the farmlands. Along their flow paths, these water bodies are exposed to indiscriminate disposal of domestic waste, sewage effluents and urban runoff.

The BFB site is located close to clusters of automobile mechanic workshops, where activities such as vehicle repair, oil changes and battery handling are common. Solid and liquid wastes generated from these activities are often discharged near the water body. The BPS site, although farther from mechanic workshops, is influenced by upstream waste inputs from densely populated areas. These characteristics make both sites suitable for assessing the impact of urban activities on irrigation water quality, soil contamination and vegetable safety.

Sample collection and analysis

Sampling was conducted during the dry season when irrigation activities were at their peak. Three environmental matrices (irrigation water, soil and vegetables) were sampled from each farmland to

allow for an integrated assessment of heavy metal contamination.

Irrigation water sampling

Irrigation water samples were collected from the main water sources used for farming at the BFB and BPS sites. Samples were collected in pre-cleaned polyethene bottles that had been washed with detergent, rinsed with distilled water and soaked in 10% nitric acid prior to use. At each site, the bottles were rinsed with the irrigation water before final collection. Immediately after collection, a few drops of concentrated nitric acid were added to each water sample to reduce microbial activity and prevent metal adsorption onto the container walls. The samples were then transported in an ice box to the laboratory and stored at 4°C until analysis.

Soil sampling

Soil samples were collected from the surface layer (0-20 cm), which represents the most active zone for root growth and metal accumulation. Multiple sub-samples were collected randomly within each study site and composited to obtain representative samples for analysis. Soil samples from the irrigated farmlands were tagged as BFB1 (irrigated soil from Before First Bank) and BPS1 (irrigated soil from Before Permanent Site). To determine background metal levels, control soil samples were collected

approximately 200 m away from each farmland. The control locations were selected based on similar topography and absence of irrigation influence. These control samples were tagged as:

- i. BFB2 - control soil for BFB
- ii. BPS2 - control soil for BPS

All soil samples were placed in clean polythene bags, labelled appropriately and transported to the laboratory.

Vegetables sampling

Four commonly consumed vegetables were selected based on their availability and popularity in the study area:

- i. *Brassica oleracea* var. *capitata* (cabbage)
- ii. *Daucus carota* (carrot)
- iii. *Lycopersicon esculentum* (tomato)
- iv. *Spinacia oleracea* (spinach)

Fresh vegetable samples were harvested directly from the farms at both BFB and BPS sites. Samples were placed in clean polythene bags, labelled and transported to the laboratory for preparation and analysis.

Preparation of water samples

Water samples were filtered using Whatman No. 42 filter paper to remove suspended particles. Aliquots of the filtered samples were used for digestion and subsequent analysis.

Preparation of soil samples

Soil samples were air-dried at room temperature to constant weight, gently crushed using a porcelain mortar and pestle, and passed through a 2-mm sieve to remove stones and debris. The processed samples were stored in clean, labelled containers prior to digestion.

Preparation of vegetable samples

Vegetable samples were thoroughly washed with tap water followed by distilled water to remove surface contaminants. The edible portions were separated, chopped into small pieces and air-dried, after which they were oven-dried at 60 °C to constant weight. The dried samples were ground into fine powder and stored in airtight containers for digestion.

Sample digestion procedure

- i. For soil and vegetable samples, a known weight (1.0 g) of the dried and ground sample was transferred into a digestion flask. A mixture of concentrated hydrochloric acid and nitric acid in a ratio of 3:1 (aqua regia) was added, and the mixture was heated gently on a hot plate until a clear solution was obtained. The digest was allowed to cool,

filtered, and diluted to 100 cm³ with deionised water.

- ii. For water samples, 50 cm³ of water sample was measured and 5 cm³ concentrated nitric acid was added and heated gently until about half of the solution has evaporated. The solution was then cooled and filtered. The filtrate was then transferred into a volumetric flask and diluted to 50 cm³ using deionised water. All digested samples were stored in acid-washed bottles until AAS analysis. The digestion of water releases metals bound to suspended particles and converts metals into soluble nitrate salts suitable for AAS analysis.

Heavy metal analysis

Concentrations of arsenic As, Pb, Cd, Cr, Cu, and Ni were determined using AAS (AA320N Model, Graphite Furnace). The instrument was calibrated using standard solutions prepared from certified stock standards. Quality assurance procedures included the analysis of reagent blanks and replicate samples to ensure accuracy and precision.

Quality assurance and quality control

Quality control measures included analysis of reagent blanks and triplicate instrumental measurements. Calibration of the instrument was carried out using standard solutions prepared from certified stock standards.

Pollution assessment indices

To evaluate the degree of heavy metal contamination in soils, four (4) pollution indices described in different literature were employed [18-20].

1. *Enrichment Factor (EF)*: The enrichment factor (EF) was employed to evaluate the extent of anthropogenic contribution to heavy metal concentrations in roadside soils. EF was calculated using iron (Fe) as the reference element, following Equation (1):

$$EF = \frac{C_n/C_{ref}}{B_n/B_{ref}} - 1$$

where (C_n) is the concentration of the metal in the roadside soil, (C_{ref}) is the concentration of Fe in the sample, (B_n) is the background concentration of the metal, and (B_{ref}) is the background concentration of Fe.

EF values were classified as no enrichment (EF < 1), minimal enrichment (1 ≤ EF < 5), significant enrichment (5 ≤ EF < 20), very high enrichment (20 ≤ EF < 40), and extremely high enrichment (EF ≥ 40).

2. *Contamination Factor (CF)*: The contamination factor (CF) was calculated to assess the level of contamination of individual heavy metals relative to

background concentrations. CF was computed using Equation (2):

$$CF = \frac{C_n}{B_n} \quad (2)$$

CF values were interpreted as low contamination ($CF < 1$), moderate contamination ($1 \leq CF < 3$), considerable contamination ($3 \leq CF \leq 6$), and very high contamination ($CF > 6$). The mean contamination factor (mCF) can be used to evaluate the overall degree of contamination at each sampling location.

3. **Pollution Load Index (PLI):** The pollution load index (PLI) was used to assess the overall level of heavy metal pollution at each sampling site. PLI was calculated as the geometric mean of the contamination factors using Equation (3):

$$PLI = (CF_1 \times CF_2 \times CF_n)^{1/n} \quad (3)$$

where (n) is the number of metals analysed. PLI values less than 1 indicate no pollution, PLI equal to 1 indicates baseline levels, and PLI greater than 1 indicates deterioration of site quality.

4. **Geo-accumulation Index (I_{geo}):** The geo-accumulation index was applied to determine the degree of heavy metal accumulation in roadside soils relative to background values. I_{geo} was calculated using Equation (4):

$$I_{geo} = \log \left(\frac{C_m}{1.5 \times B_m} \right) \quad (4)$$

where (C_n) is the metal concentration in roadside soil and (B_n) is the background concentration. The constant 1.5 accounts for possible lithogenic variations. I_{geo} values are classified into seven categories ranging from uncontaminated to extremely contaminated.

RESULTS AND DISCUSSION

Heavy metal concentrations in irrigation water

The concentrations of heavy metals detected in irrigation water from the two study sites, Before First Bank (BFB) and Before Permanent Site (BPS), are presented in Table 1. The results indicate the presence of all analysed metals in both water bodies, although their concentrations varied between the two locations.

Table 1: Concentrations (mg/L) of some heavy metals in irrigation water collected from Farin Gada irrigation sites, Jos North, Plateau State.

Sample	As	Cu	Cr	Ni	Pb	Cd
BFB	0.320	0.034	0.174	0.168	0.012	0.028
BPS	0.726	0.254	0.172	0.036	0.030	0.394
FAO	0.100	0.017	0.55	1.400	0.065	0.010

Arsenic concentrations in irrigation water were 0.320 mg/L at BFB and 0.726 mg/L at BPS. These values exceed the FAO-recommended limit of 0.1 mg/L for irrigation water, indicating significant contamination. Cadmium concentrations were also elevated, particularly at the BPS site (0.394 mg/L), far exceeding the permissible limit of 0.01 mg/L.

Copper concentrations were relatively low at BFB (0.034 mg/L) but increased markedly at BPS (0.254 mg/L), slightly exceeding recommended limits. Chromium, nickel and lead were detected at moderate levels and remained below FAO permissible limits at both sites. The generally higher metal concentrations observed in BPS irrigation water suggest greater exposure to upstream anthropogenic activities.

Both irrigation water bodies are flowing surface waters that traverse several residential, commercial and industrial areas of Jos metropolis. Along their flow paths, these waters receive domestic

sewage, market wastes, storm runoff and other urban effluents. Such continuous waste inputs contribute to the accumulation of heavy metals in the water bodies despite their flowing nature. In addition, the proximity of automobile mechanic workshops to the BFB water body provides a direct source of metal-rich wastes such as used engine oil, battery residues and metal scraps, which are often disposed of indiscriminately near the stream. These observations explain the presence of elevated levels of toxic metals such as Cd and As in the irrigation waters [21, 22].

Heavy metal concentrations in soil

The concentrations of heavy metals in irrigated soils (BFB1 and BPS1) and their corresponding control soils (BFB2 and BPS2) are presented in Table 2. Across both sites, irrigated soils recorded substantially higher metal concentrations than control soils, indicating significant anthropogenic enrichment.

Table 2: Concentrations (mg/kg) of some heavy metals in irrigated and control soil samples from Farin Gada Farmlands in Jos North, Plateau State.

Location	Soil samples	Heavy metals					
		Pb	Ni	Cu	As	Cd	Cr
Before First Bank	Irrigated Soil	0.288	0.192	3.552	0.768	2.016	2.880
	Control	0.021	0.005	0.356	0.041	0.037	0.004
Before Permanent Site	Irrigated Soil	2.740	27.440	70.950	49.000	20.580	20.190
	Control	0.890	3.470	11.190	7.130	2.480	0.400

At the BFB site, irrigated soils contained Pb (0.288 mg/kg), Ni (0.192 mg/kg), Cu (3.552 mg/kg), As (0.768 mg/kg), Cd (2.016 mg/kg), and Cr (2.880 mg/kg), whereas the control soil recorded much lower concentrations. Similarly, at the BPS site, irrigated soils exhibited very high concentrations of Ni (27.44 mg/kg), Cu (70.95 mg/kg), As (49.00 mg/kg), Cd (20.58 mg/kg), and Cr (20.19 mg/kg), compared to significantly lower levels in the control soil.

The pronounced differences between irrigated and control soils confirm that irrigation practices and on-farm activities are the major contributors to soil contamination rather than natural geological sources. Continuous application of contaminated irrigation water results in the gradual

accumulation of heavy metals in surface soils, where they bind to soil particles and organic matter. In addition, the use of burnt refuse (ash) as manure by some farmers introduces concentrated metal residues into the soil, further increasing metal loads. Similar trends have been reported for urban irrigation soils in other Nigerian cities [23, 24].

Soil pollution assessment using contamination indices

The results of the soil pollution assessment indices (CF, EF, Igeo and PLI) are presented in Table 3. These indices provide a quantitative evaluation of the degree, source and intensity of heavy metal contamination in the irrigated soils.

Table 3: Heavy Metals Pollution Assessment of the Irrigated Soil Samples

	CF		EF		Igeo		PLI	
	BFB	BPS	BFB	BPS	BFB	BPS	BFB	BPS
Pb	13.714	3.079	12.722	2.705	0.961	0.312	39.608	7.689
Ni	38.400	7.908	35.622	6.949	1.408	0.722		
Cu	9.978	6.340	9.256	5.572	0.823	0.626		
As	18.732	6.872	17.376	6.039	1.096	0.661		
Cd	54.486	8.298	50.544	7.292	1.560	0.743		
Cr	720.000	23.477	667.904	20.630	2.681	1.195		

The CF values indicated severe contamination for most metals at both sites. Extremely high CF values were recorded for chromium (720.0 at BFB and 23.48 at BPS) indicating excessive accumulation relative to control levels. Cadmium also exhibited very high CF values, reflecting its strong enrichment in irrigated soils. According to standard classification criteria, CF values greater than 6 indicate very high contamination, suggesting that the soils are heavily impacted by anthropogenic inputs [25].

The EF values for all analyzed metals were greater than unity, with most exceeding 5. This indicates significant enrichment from non-crustal sources and confirms that the metals are predominantly derived from anthropogenic activities. High EF values observed for Cd and Cr are consistent with contributions from urban waste disposal,

automobile workshop activities and ash application. These findings further support the conclusion that irrigation practices and surrounding land-use activities play a dominant role in soil contamination at the study sites [26].

The Igeo values classified the soils as moderately to strongly polluted, particularly with respect to chromium and cadmium. At both sites, Igeo values greater than 2 indicate substantial contamination above background levels. The higher Igeo values observed at the BFB site suggest more intense localised pollution, likely due to the proximity of mechanic workshops and direct waste discharge into the water body used for irrigation.

The PLI values calculated for the irrigated soils were 39.61 for BFB and 7.69 for BPS. Since PLI values greater than 1 indicate pollution, the extremely

high values obtained confirm that both sites are heavily polluted. The higher PLI value at BFB reflects the cumulative impact of multiple contamination sources acting simultaneously. These results demonstrate severe degradation of soil quality and potential long-term risks to agricultural sustainability [27].

Heavy metal accumulation in vegetables

The concentrations of heavy metals in vegetables harvested from the BFB and BPS farms are presented in Table 4. The results reveal considerable variation in metal accumulation among vegetable species and between sites.

Table 4: Concentrations (mg/kg) of heavy metals in vegetables from irrigation farms

Heavy Metals	<i>Brassica oleracea</i> var. <i>capitata</i>		<i>Daucus carota</i>		<i>Lycopersicon esculentum</i>		<i>Spinacia oleracea</i>	
	BFB	BPS	BFB	BPS	BFB	BPS	BFB	BPS
Pb	0.188	0.59	0.49	0.38	0.27	0.76	0.11	0.98
Ni	0.94	5.35	0.19	2.59	0.18	0.38	0.19	0.69
Cu	3.196	0.99	2.33	4.99	3.27	3.42	3.36	3.72
As	0.94	4.46	1.65	1.44	0.91	8.84	2.88	3.72
Cd	1.222	5.45	0.19	0.67	0.55	1.05	0.38	2.55
Cr	1.034	2.18	1.16	3.36	1.73	0.19	0.77	0.88

At both farms, leafy vegetables such as *Spinacia oleracea* accumulated higher concentrations of heavy metals compared to fruit vegetables. For instance, spinach samples recorded elevated levels of Pb, As, and Cd, particularly at the BPS site. Root vegetables such as *Daucus carota* also exhibited substantial metal accumulation, reflecting direct contact with contaminated soils.

Several metals detected in vegetables exceeded recommended food safety limits, particularly Cd, and As. The accumulation of these toxic metals poses significant health risks to consumers, especially given the frequent consumption of vegetables produced from these farms. The differences observed between BFB and BPS vegetables reflect variations in irrigation water quality, soil contamination levels and local farming practices.

Heavy metals transfer pathway and health implications

The results of this study demonstrate a clear contamination pathway from irrigation water to soil and subsequently to vegetables. Elevated metal concentrations in irrigation water provide a continuous source of contamination, which accumulates in soils over time and becomes available for plant uptake. The application of burnt refuse as manure further enhances metal bioavailability in soils, while atmospheric deposition and surface runoff contribute additional inputs.

The presence of toxic metals such as Cd and As in edible vegetables raises serious public health concerns. Chronic exposure to these metals through dietary intake has been associated with kidney damage, neurological disorders and increased cancer risk. Given the reliance of urban populations on vegetables produced from Farin Gada farms, the findings highlight the urgent need for intervention

measures to protect both environmental quality and human health [28, 29].

Study limitation

The study utilised composite samples to obtain representative samples from each irrigation site. Consequently, spatial variability within individual farms could not be assessed. Future studies should incorporate multiple independent sampling points to enable more robust statistical evaluation of heavy metal distribution.

CONCLUSIONS

This study provides a comprehensive and integrated assessment of heavy metal contamination in irrigation water, soils and vegetables from two urban irrigation farmlands located at Farin Gada, Jos North Local Government Area, Plateau State, Nigeria. The results clearly demonstrate that urban irrigation farming in the study area is significantly impacted by anthropogenic activities, resulting in elevated concentrations of toxic heavy metals across multiple environmental media.

Irrigation water from both study sites contained appreciable levels of arsenic and cadmium, with concentrations exceeding recommended permissible limits for agricultural use. The higher metal concentrations observed at the BPS reflect greater exposure to upstream waste inputs along the water course, while the proximity of automobile mechanic workshops further influences contamination at the BFB site. Continuous discharge of domestic, commercial and mechanical wastes along their paths can contribute to sustained metal loading.

Soil analysis revealed that irrigated soils accumulated substantially higher concentrations of heavy metals compared to control soils collected away from irrigation influence. This confirms that prolonged use of contaminated irrigation water, coupled with on-farm practices, is a major driver of

soil pollution [30]. Some farmers used burnt refuse as manure, which was identified as an additional source of heavy metal input, particularly for metals such as cadmium and chromium, which concentrate in ash residues.

The application of pollution assessment indices further highlighted the severe level of soil contamination. Contamination Factor and Enrichment Factor values indicated strong anthropogenic enrichment, while Geo-accumulation Index values classified the soils as moderately to strongly polluted. The extremely high Pollution Load Index values obtained for both sites confirm a high level of overall pollution, with the BFB site showing a greater cumulative pollution burden due to localised waste disposal and mechanical activities.

Vegetable analysis revealed variable but significant accumulation of heavy metals, with leafy and root vegetables exhibiting higher concentrations than fruit vegetables. Several vegetable samples

contained cadmium and arsenic at levels exceeding recommended food safety limits, indicating potential health risks to consumers. The results clearly establish a contamination pathway from irrigation water to soil and subsequently to edible vegetables, underscoring the role of irrigation practices in transferring environmental pollutants into the human food chain.

Overall, the findings of this study highlight the environmental and public health implications of unregulated urban irrigation farming in Farin Gada. There is an urgent need for regular monitoring of irrigation water quality, enforcement of proper waste management practices along urban water bodies and increased awareness among farmers regarding the risks associated with contaminated water and the use of burnt refuse as manure. Implementation of appropriate intervention measures will be essential to safeguard soil quality, ensure food safety and protect public health in Jos metropolis.

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