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Review paper

Determination of selected Heavy Metals in Vegetables Grown on Dakasoye Farmlands, Kano State, Nigeria

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Abstract

Consumption of vegetables contaminated with heavy metals can cause serious health problems, including kidney damage, cancer, high blood pressure, and impaired brain development. This study analyzed levels of Zn, Fe, Mn, Cd, Cr, and Pb in 10 vegetables from the Kura-Dakasoye agricultural area in Kano State using Atomic Absorption Spectrophotometry after wet digestion. Metal concentrations were generally within safe limits, except for lead. ANOVA showed no significant differences among the vegetables ($P > 0.05$). Estimated Daily Intakes (EDIs) for all the analyzed metals were found to be below their respective oral reference doses, and Hazard Quotients (HQs) were all less than one, indicating no significant non-carcinogenic health risk. The findings suggest minimal health risk to consumers, aside from possible lead exposure.

Keywords: *Contamination; Estimated daily intake; Hazard quotients; Heavy metals; Spectrometry; Vegetables.*

1. Introduction

Vegetables, the edible leafy or fleshy parts of plants, are widely consumed globally as essential components of diets, serving as side dishes, supplements, herbal remedies, and soup condiments [1]. Nutritionally, they are rich sources of vitamins, minerals, dietary fiber, and bioactive compounds critical for maintaining optimal health, providing immediate energy, and supporting various physiological functions [2]. The antioxidants in vegetables play a vital role in disease prevention and digestive health by protecting the body against oxidative stress and aiding in regular bowel movements [3].

Despite these benefits, the contamination of vegetables with heavy metals has emerged as a significant global environmental and public health concern. Heavy metals, naturally occurring elements in the Earth's crust, are characterized by their persistence and inability to biodegrade or break down in the environment [4]. Their accumulation in the food chain can lead to toxic effects on both ecological systems and human health [5]. While some heavy metals such as manganese and zinc are essential micronutrients in trace amounts, many others—including lead, cadmium, and mercury are toxic even at low concentrations, with potential to bioaccumulate and cause adverse health outcomes [6].

Globally, anthropogenic activities—especially improper disposal of industrial and household wastes, sewage, and sludge—have exacerbated heavy metal contamination in soils and water bodies [7]. Vegetables readily absorb these metals through various environmental pathways[8]. Uptake occurs primarily via root systems from contaminated soils[9], while atmospheric deposition from vehicle emissions, fossil fuel combustion, and industrial dust can contaminate foliage and soil surfaces [10]. Additionally, irrigation with polluted water and the use of chemical fertilizers, pesticides, and herbicides containing trace heavy metals further contribute to vegetable contamination [11]. Even organic fertilizers such as compost and manure, though generally safer, may contain heavy metals including cadmium, lead, chromium, mercury, and nickel, depending on their source and composition [12].

This widespread contamination poses a serious challenge for food safety worldwide, with many studies reporting elevated heavy metal levels in vegetables from both developed and developing countries, raising concerns about chronic exposure risks to consumers. Consequently, there is a critical need to monitor and assess the concentrations of these metals in vegetables to ensure food safety and public health.

In line with this global imperative, the present study aims to assess the concentrations of selected heavy metals, manganese (Mn), chromium (Cr), zinc (Zn), iron (Fe), lead (Pb), and cadmium (Cd) in vegetables cultivated in Dakasoye village. The study also evaluates the potential health risks associated with the consumption of these vegetables, providing essential data to inform local food safety regulations and risk mitigation strategies. to consumers. Consequently, there is a critical need to monitor and assess the concentrations of these metals in vegetables to ensure food safety and public health.

In line with this global imperative, the present study aims to assess the concentrations of selected heavy metals, manganese (Mn), chromium (Cr), zinc (Zn), iron (Fe), lead (Pb), and cadmium (Cd) in vegetables cultivated in Dakasoye village. The study also evaluates the potential health risks associated with the consumption of these vegetables, providing essential data to inform local food safety regulations and risk mitigation strategies.

2. Materials and methods

In the preparation of reagents, chemicals of analytical grade purity and deionised a riskwater were used. All glassware was washed with liquid detergent and rinsed with distilled water before drying in an oven at 105⁰C. All weighings were done using an analytical weighing balance model FA, and analysis of metals was done using an Agilent Atomic Absorption spectrophotometer (AAS).

2.1. Sample collection

Ten vegetable samples were collected from the Kura-Dakasore Agricultural area. For heavy metals analysis, Great care was taken during plant sampling. The samples of Vegetables were collected at maturity, i.e. ripening. In case of Onion, the whole plant was uprooted carefully using a wooden stick, so that the tuber does not receive any cuts to avoid contamination due to soil. All the samples were washed with distilled water and rinsed with deionized water, then dried using good-quality tissue paper. Each sample was cut into slices using a stainless steel knife and spread on Polyethylene sheets to sun-dry, taking care of any dust deposition by covering with a light veil. Later, the fruit samples were dried in the oven at 60 ⁰C, and this was repeated until complete drying. The samples were ground and sieved using a 0.5 mm sieve [13].

2.2. Sample digestion

1.0g of the ground plant sample was placed in a 100 cm^3 volumetric flask. 10 cm^3 of HNO_3 was added and kept overnight for pre-digestion. 8 cm^3 of $HClO_4$ was added and swirled gently. The flask was then placed on low heat (at about 100 ⁰C) on hot plate. Then heated at a higher temperature (at about 260 ⁰C) for 1 hour and 35 minutes until the production of red fumes ceases, the content was then further evaporated until the volume is reduced to about 3 cm^3. The completion of the digestion was confirmed when the liquid became colourless. Deionised water was added up to mark after cooling and filtration through Whatman number 1 filter paper [14].

2.3. Description of the study area

Dakasoye is a village located near the boundary between Kura and Garun Malam local governments in Kano state, Nigeria. Geographically, Dakasoye village is located on a latitude of 11.7071° ° north of the equator and longitude 8.4406° East of the Greenwich meridian with an elevation of about 473m above sea level(Figure 1). The village is situated close to localities such as Turedasu, Takanawa, Shifawa, and Yadakwari [15]. The area is well known for Rice farming and vegetable cultivation.

2.4. Sampling location

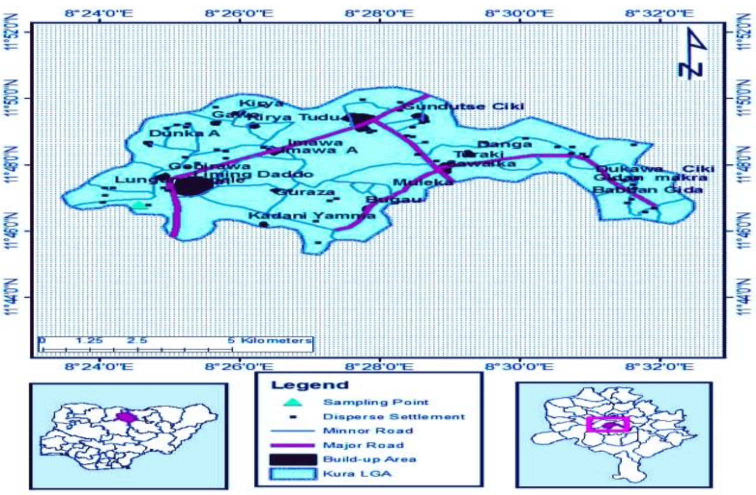

Fig. 1: Map of Kura-Dakasoye Indicating the Sampling Sites.

Source: GIS Unit, Department of Geography, Bayero University Kano

2.6. Instrumentation

Heavy metals (Cd, Cr, Mn, Pb, and Zn) were determined by an Agilent Atomic Absorption spectrophotometer (AAS), after appropriate digestion of samples to extract the metals. Standard solutions with known concentrations and blanks are prepared. A calibration curve is created from the standards. The absorbance of the vegetable samples is measured and compared to the calibration curve to determine the concentration of the heavy metals. A blank is used to correct for background interference[16].
Where Cm is the measured element concentration in the sample and RL is the recommended limit taken from USEPA.

2.7 Elements correlation matrix in the samples

Correlation analysis has been widely used in analytical and environmental studies. Information regarding relationships between multiple elements in a sample matrix is depicted by correlation analysis. Such analysis enables understanding of how environmental factors affect chemical components in a matrix and how some of the elements influence their concentrations [17]. When the matrix coefficient is positive between elements in a sample, it suggests similar contamination or pollution sources, e.g., soil, water, or air, while when it is negative, it suggests dissimilar contamination or pollution sources. The strength of correlation is based on the coefficient values.

2.8. Estimated daily intake (EDI)

The estimated daily intake (EDI) of microelements was calculated as described by [18]. The chemometric model for calculating EDI is presented in equation (3.4)
Estimated daily intake (EDI) =
Where EDI is estimated daily intake of microelements per person per day (mg/person/day). C (mg/kg, dry weight basis): average metal concentration in the tested leafy vegetables; Cf (0.085): conversion factor used to convert the fresh to dry weight of the tested leafy vegetables, IngR (kg/person/day): daily average intake of the samples, the average daily consumption of the samples was considered as 0.20 kg/person/day for adults, whereas 0.133 kg/person/day for children [19]. BW: average body weight of the target population, for adults, 70 kg, and for children, 32.7 kg [20].

2.9. Target hazard quotient (THQ)

The non-carcinogenic risks to human health via the consumption of metal-contaminated Fruits and Vegetables were estimated based on the hazard quotient (HQ), which is defined as the health risk due to exposure to a pollutant concerning the estimated daily intake (EDI). If the hazard quotient of a particular contaminant is less than one (<1), there would be no obvious adverse effects expected on the exposed population. The HQ was calculated by dividing the estimated daily intake (mg/kg/day) of the contaminant through fruit or Vegetable ingestion by the reference oral dose, as follows (Equation 3.5)
The reference oral dose (RfD, mg/kg/day) is an estimated value of tolerable daily ingestion of pollutants (maximum permissible risk) by human beings during a lifetime. 0.7, 0.3, 0.05, 0.003, 0.001, and 0.004 for Fe, Zn, Mn, Cr, Cd, and Pb, respectively[21].

3. Statistical analysis of heavy metal concentrations in vegetables from Dakasoye farmlands

The mean concentrations of selected heavy metals—Iron (Fe), Zinc (Zn), Cadmium (Cd), Chromium (Cr), Lead (Pb), and Manganese (Mn)—in vegetable samples collected from Dakasoye farmlands were statistically analyzed using IBM SPSS Statistics version 23.0.To determine whether there were statistically significant differences in heavy metal concentrations among the vegetable samples, Analysis of Variance (ANOVA) was performed. Additionally, Pearson correlation analysis was conducted to assess the relationships between the concentrations of the different heavy metals. The results of the ANOVA and correlation analyses are presented in Tables 2 and 3, respectively.

3.1. Results

The results of Vegetables from the Kura-Dakasoye Agricultural area are presented in Table 1below.

Table 1: The Mean Concentrations of Micro Elements in the Samples Analysed

Samples (mg/kg)	Fe	Zn	Mn	Cr	Cd	Pb
Spinach- Amaranthus Hybridus (Alaiyahu)	5.878	4.884	1.43	0.212	0.034	0.272
Cabbage- Brassica Oleracea	1.680	4.146	0.796	0.244	0.028	0.28
Sesame Leaves (Karkashi)	6.462	4.722	1.094	0.318	0.034	0.25
Baobab leaves- Adansonia digitata (Kuka)	8.800	3.062	1.450	0.368	0.044	0.022
Lettuce- Lactuca Sativa (Salak)	12.456	4.898	4.542	0.436	0.048	0.748
Onion- Allium Cepa (Albasa)	2.688	3.874	0.590	0.17	0.038	0.548
Kenaf- Hibiscus Cannabinus (Rama)	7.812	5.252	3.242	0.286	0.003	0.216
Senna- Cassia Senna (Tafasa)	10.578	4.976	1.378	0.388	0.046	0.404
FAO	425.0	20.00	5.00	2.300	0.300	0.300
WHO	425.5	99.4	5.00	1.30	0.200	0.300

Table 2: Estimated Daily Intake (EDI, Mg/Person/Day) of Elements Through Consumption of the Samples

Samples	Fe		Zn		Mn		Cr		Cd		Pb	
	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children
Spinach Amaranthus Hybridus (Alaiyahu)	1.4E-2	2.0 E-4	1.2 E-3	1.7 E-3	3.5 E-4	4.9 E-4	5.1 E-5	7.3 E-5	8.3 E-6	1.2 E-5	6.6 E-5	9.4 E-5
Cabbage- Brassica Oleracea	4.1E-2	5.8 E-4	1.0 E-3	1.4 E-3	1.9 E-4	2.8 E-4	5.9 E-5	8.4 E-5	6.8 E-6	9.7 E-5	6.8 E-5	9.7 E-5
Sesame Leaves (Karkashi)	1.6E-3	2.2 E-4	1.1 E-3	1.6 E-3	2.4 E-4	3.9 E-4	7.7 E-5	1.1 E-5	8.3 E-6	1.2 E-5	6.1 E-5	8.6 E-5
Baobab leaves- Adansonia digitata (Kuka)	2.1E-3	3.0 E-4	7.4 E-4	1.1 E-3	3.5 E-4	5.0 E-4	8.9 E-5	1.3 E-5	1.1 E-5	1.5 E-5	5.3 E-6	7.6 E-6
Lettus- Lactuca Sativa (Salak)	3.0E-3	4.3 E-4	1.2 E-4	1.7 E-3	1.1 E-4	1.6 E-3	1.0 E-4	1.5 E-5	1.2 E-5	1.7 E-5	1.8 E-4	2.6 E-4
Onion- Allium Cepa (Albasa)	6.5E-4	9.3 E-4	9.4 E-4	1.3 E-3	1.4 E-4	2.0 E-4	4.1 E-5	5.9 E-5	9.3 E-6	1.3 E-5	1.4 E-6	1.9 E-4
Kenaf- Hibiscus Cannabinus (Rama)	2.0E-3	2.7 E-4	1.3 E-3	1.8 E-3	7.9 E-4	1.1 E-4	6.9 E-5	9.9 E-5	7.3 E-7	1.0 E-6	5.2 E-5	7.5 E-5
Bitterleaf-Vernonia Amygdalina (Shuwaka)	1.2E-3	1.7 E-4	9.5 E-4	1.4 E-3	3.5 E-4	5.0 E-4	6.6 E-5	9.4 E-5	5.8 E-6	8.2 E-6	4.8 E-5	6.8 E-5
Senna- Cassia Senna (Tafasa)	2.6E-3	3.6 E-4	1.2 E-3	1.7 E-3	3.3 E-4	4.8 E-4	9.4 E-5	1.0 E-5	1.1 E-5	1.6 E-5	9.8 E-5	1.4 E-4
Reference oral dose (RFD)	7.0× $\mathbf{10^{-1}}$		3.0× $\mathbf{10^{-1}}$		5.0× $\mathbf{10^{-2}}$		3.0× $\mathbf{10^{-3}}$		1.0× $\mathbf{10^{-3}}$		4.0× $\mathbf{10^{-3}}$	

Table 3: Target Hazard Quotient (THQ) of the Various Samples

Samples	Fe		Zn		Mn		Cr		Cd		Pb	
	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children
Spinach Amaranthus Hybridus (Alaiyahu)	2.0E-03	2.9E-03	4.0E-03	5.6E-03	6.9E-03	9.9E-03	1.7E-02	2.4E-02	8.3E-03	1.2E-02	1.7E-02	2.4E-02
Cabbage- Brassica Oleracea	5.8E-04	8.3E-04	3.4E-03	4.8E-03	3.9E-03	5.5E-03	2.0E-02	2.8E-02	6.8E-03	9.7E-03	1.7E-02	2.4E-02
Sesame Leaves (Karkashi)	2.2E-03	3.2E-03	3.8E-03	5.4E-03	5.3E-03	7.5E-03	2.6E-02	3.6E-02	8.3E-03	1.2E-02	1.5E-02	2.2E-02
Baobab leaves- Adansonia digitata (Kuka)	3.1E-03	4.3E-03	2.5E-03	3.5E-03	7.0E-03	1.0E-02	3.0E-02	4.2E-02	1.1E-02	1.5E-02	1.3E-03	1.9E-03
Lettuce- Lactuca Sativa (Salak)	4.3E-03	6.2E-03	4.0E-03	5.6E-03	2.2E-02	3.1E-02	3.5E-02	4.9E-02	1.2E-02	1.7E-02	4.5E-02	6.5E-02
Onion- Allium Cepa (Albasa)	9.3E-04	1.3E-03	3.1E-03	4.5E-03	2.9E-03	4.1E-03	1.4E-02	1.9E-02	9.2E-03	1.3E-02	3.3E-02	4.7E-02
Kenaf- Hibiscus Cannabinus (Rama)	2.7E-03	3.9E-03	4.3E-03	6.1E-03	1.6E-02	2.2E-02	2.3E-02	3.2E-02	7.3E-04	1.0E-03	1.3E-02	1.9E-02
Bitterleaf-Vernonia Amygdalina (Shuwaka)	1.7E-03	2.4E-03	3.2E-03	4.5E-03	7.0E-03	9.9E-03	2.2E-02	3.1E-02	5.8E-03	8.3E-03	1.2E-02	1.7E-02
Senna- Cassia Senna (Tafasa)	3.7E-03	5.2E-03	4.0E-03	5.7E-03	6.7E-03	9.5E-03	3.1E-02	4.4E-02	1.1E-02	1.6E-02	2.5E-02	3.5E-02

Table 4: Pearson Correlation Coefficients for Micro Elements

	Pb	Cd	Cr	Mn	Zn	Fe
Pb	1					
Cd	0.456417	1				
Cr	0.218515	0.291104	1			
Mn	0.46387	0.011428	0.559758	1		
Zn	0.153032	-0.19518	0.341599	0.219546	1	
Fe	0.250731	0.239275	0.904565	0.695508	0.289909	1

Table 5: ANOVA Result

Groups	Count	Sum	Average	Variance		
Fe	12	68.38	5.698333	12.97162		
Zn	12	50.522	4.210167	0.935201		
Mn	12	19.034	1.586167	1.354267		
Cr	12	3.688	0.307333	0.017492		
Cd	12	0.413	0.034417	0.000159		
Pb	12	3.83	0.319167	0.035189		
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	339.4028	5	67.88057	26.59561	1.29E-14	2.353809
Within Groups	168.4532	66	2.552322			
Total	507.8561	71				

3.2. Discussion

From Table 1, Lettuce (Lactuca sativa) recorded the highest concentration of iro(12.456 mg/kg) among the samples analyzed, while Cabbage (Brassica oleracea) exhibited the lowest concentration (1.680 mg/kg). Analysis of variance (ANOVA) indicated a significant difference in iron concentrations among the samples ($p <0.05$)(Table 5). Iron was moderately correlated with lead (Pb), cadmium (Cd), and zinc (Zn), and strongly correlated with chromium (Cr) and manganese (Mn) (Table 4), suggesting common sources such as soil composition, irrigation water, and atmospheric deposition from industrial and agricultural activities. The iron concentrations were below the recommended permissible limit of 425.0 mg/kg [22], indicating minimal risk to consumers.

The iron levels observed were lower than those reported in Ficus sycomorus (75.05 mg/kg) [19], Vernonia amygdalina (126.88 mg/kg) [23], Allium cepa leaf (27.46 mg/kg) [23], and Sesamum indicum leaf (23.33 mg/kg) [23], as well as Cordia dichotoma (24.15 mg/kg) [23] and Grewia tiliifolia (34.13 mg/kg) [23]. Similarly, iron concentrations in spinach from northeastern Iran were 4.74 mg/kg [24]. Higher iron contents were reported in Moringa (133.7 mg/kg) and Amaranthus (129.96 mg/kg) from Ghana [25], whereas lower levels were found in Foetid Cassia (0.242 mg/kg) [26], Kenaf (0.252 mg/kg) [27], spinach (0.071 mg/kg) [27], and lettuce (0.27 mg/kg) [27]. These variations reflect differences in soil mineral content, anthropogenic contamination, and agricultural practices.

For zinc, Kenaf (Hibiscus cannabinus) recorded the highest concentration (5.252 mg/kg) and Baobab (Adansonia digitata) the lowest (3.062 mg/kg) (Table 1). Significant differences in zinc concentrations were observed across samples ($p < 0.05$)(Table 5). Zinc showed weak correlation with iron (Table 4), suggesting differing sources, potentially including soil parent material and use of zinc-containing fertilizers or pesticides. zinc concentrations were below the permissible limit of 20.0 mg/kg [22], implying no immediate health risks.

These zinc concentrations agree with those reported by [28], who found 5.4 mg/kg in Grewia tiliifolia, 3.85 mg/kg in Cordia dichotoma, 2.13 mg/kg in Flacourtia indica, and 1.46 mg/kg in Glycosmis pentaphylla. Higher zinc levels in Spondia cytherea (58.77 mg/kg) [29], Syzygium malaccense (42.90 mg/kg) [29], and Cola pachycarpa (117.30 mg/kg) [29], as well as vegetable samples from allotment gardens in Poland (13.0–254.0 mg/kg) [30], reflect localized contamination from industrial emissions and intensive fertilizer use. Lower zinc concentrations were also reported in Foetid Cassia (0.227 mg/kg) [31], Kenaf (0.250 mg/kg) [31], Tossa jute (0.221 mg/kg) [31], and Wild jute (0.375 mg/kg) [31], as well as in leafy vegetables from China (<10 mg/kg) [32].

Manganese concentrations were highest in Lettuce (4.542 mg/kg) and lowest in Onion (Allium cepa) (0.590 mg/kg) (Table 1), with significant differences detected ($p < 0.05$)(Table 5). Manganese was moderately correlated with zinc and iron (Table 4), indicating a similar source, likely natural soil geochemistry, as well as anthropogenic inputs such as agrochemicals [46]. Manganese concentrations were below the permissible limit of 5 mg/kg [22], suggesting low health risks.

The manganese levels reported were higher than in Ficus racemosa (0.95 mg/kg) [28] and Meyna laxiflora (0.94 mg/kg) [28], and cabbage (0.417 mg/kg) and lettuce (0.160 mg/kg) in Malaysia [34]. However, they were substantially lower than elevated levels in Basella alba (1852 mg/kg), Spinacia oleracea (13,222 mg/kg), Lactuca sativa (59,861 mg/kg), and Brassica oleracea (9,018 mg/kg) [35], which may result from heavy industrial pollution. Similar ranges were reported in Ficus sycomorus (17.021 mg/kg) [23] and US leafy vegetables (5.388–216.6 mg/kg) [36].

Chromium concentrations ranged from 0.17 to 0.436 mg/kg, with Lettuce highest and Onion lowest (Table 1). significant differences were observed ($p < 0.05$)(table 5). Chromium was strongly correlated with manganese, zinc, and iron (Table 4), supporting a common origin from soil, industrial emissions, and agricultural practices [46]. All chromium values were below the permissible limit of 0.3 mg/kg [22].

Comparative studies in Nigeria found chromium concentrations between 0.014 and 0.012 mg/kg in various vegetables [37], while vegetable samples from Algeria reported chromium below 1.5 mg/kg [38], both higher than the current study. Elevated chromium levels in Spondias cytherea (14.83 mg/kg) [31], Cola pachycarpa (30.25 mg/kg) [31], and Syzygium malaccense (25.00 mg/kg) [31], as well as in onions from Algeria (16.33 mg/kg) [39] and vegetables near tannery-affected areas in Australia (4.3–10.2 mg/kg) [40], highlight the impact of industrial pollution on chromium contamination.

Cadmium concentrations ranged from 0.024 to 0.048 mg/kg, with Lettuce having the lowest and Bitter-leaf (Vernonia amygdalina) the highest (Table 1). significant differences were detected ($p < 0.05$)(table 5). Cadmium correlated positively with chromium, manganese, and iron but negatively with zinc (Table 4), indicating different contamination sources for cadmium and zinc. Likely cadmium sources include phosphate fertilizers, sewage sludge, and atmospheric deposition from industrial activities[46]. Most samples were below permissible limits except for Sesame leaves (0.318 mg/kg), Baobab leaves (0.368 mg/kg), Lettuce (0.436 mg/kg), Cassia Senna (0.388 mg/kg), and Moringa (0.624 mg/kg), which exceeded recommended limits.

Higher cadmium levels than observed here were reported in Garden egg (0.845 mg/kg) [33], Bitter leaf (0.70 mg/kg) [42], and leafy vegetables from Ethiopia (0.23–6.24 mg/kg) [43]. Conversely, similar levels were reported in Telfairia occidentalis (0.006 mg/kg), Pterocarpus mildbraedii (0.007 mg/kg), Gongronema latifolium (0.009 mg/kg), and Vernonia amygdalina (0.007 mg/kg) [44], and in South Korean leafy vegetables (0.03–0.08 mg/kg) [45].

Lead concentrations (Table 1) were highest in Lettuce (0.748 mg/kg) and Onion (0.548 mg/kg), with Baobab leaves showing the lowest level (0.022 mg/kg). Except for Cassia Senna (0.404 mg/kg), all samples were below the permissible limit of 0.30 mg/kg [22]. Elevated lead levels may result from pesticide and manure application, contaminated irrigation water, automobile exhaust, and waste disposal near cultivation sites [46]. ANOVA showed significant differences in lead among samples ($p<0.05$)(Table 5). Lead showed strong correlations with iron, zinc, chromium, manganese, and cadmium (Table 4), suggesting common contamination sources likely associated with agricultural activities, such as the use of phosphate fertilizers, pesticides, and irrigation with contaminated water."

Lead concentrations were lower than those reported in Sesamum indicum leaf (1.55 mg/kg) [23], Lactuca capensis (4.59 mg/kg) [23], Amaranthus hybridus (2.54 mg/kg) [23], Adansonia digitata (3.70 mg/kg) [23], Brassica oleracea (1.00 mg/kg) [23], Allium cepa leaf (5.50 mg/kg) [23], and Vernonia amygdalina (22.2 mg/kg) [23]. High lead concentrations were also noted in Amaranthus (4.3 mg/kg) [47], tomatoes (3.90 mg/kg) [47], cabbage (12.9 mg/kg) [47], and eggplant (12.0 mg/kg) [47]. Lower lead levels than those found here were reported in Foetid Cassia (0.118 mg/kg) [28], Kenaf (0.095 mg/kg) [28], Tossa jute (0.071 mg/kg) [28], and Wild jute (0.095 mg/kg) [28], as well as in Telfairia occidentalis (0.009 mg/kg) [47], Pterocarpus mildbraedii (0.012 mg/kg) [47], Gongronema latifolium (0.005 mg/kg) [47], and Vernonia amygdalina (0.011 mg/kg) [47]. Concentrations ranging from 2.526 to 9.143 mg/kg were reported in Amaranthus blitum, Ipomoea batata, and Curcubita maxima along the Msimbazi River in Tanzania [48], and lower levels (0.1–1.3 mg/kg) were found in red spinach, bathua, and coriander from Kolkata, India [49]. Similarly, [50] reported a lead concentration range of 0.00–0.0086 mg/kg in cabbage, lettuce, and Moringa oleifera leaves grown around Gwaigwaye Dam in Katsina State, indicating geographic variation likely influenced by differences in pollution sources.

Table 2 summarizes the results of the Estimated Daily Intake (EDI) of heavy metals. The EDI values for Iron across all analyzed samples were found to be below the oral reference dose of 0.7 mg/kg/day, as established by the United States Environmental Protection Agency (US EPA). This indicates that exposure to Iron through the consumption of these vegetable samples is unlikely to pose adverse health effects to the consumer population. Furthermore, the Target Hazard Quotient (THQ) values for Iron, calculated for both adults and children, were below the threshold value of one (Table These findings suggest that the consumption of the studied vegetables does not present a significant health risk in terms of Iron exposure.

The Estimated Daily Intake (EDI) values for zinc in all analyzed samples were below the oral reference dose of 0.3 mg/kg/day, as established by the United States Environmental Protection Agency (US EPA). This indicates that exposure to zinc through the consumption of the studied samples is unlikely to result in adverse health effects among the consumer population. Additionally, the Target Hazard Quotient (THQ) values for zinc in both adults and children were found to be less than one, as shown in Table 3. A THQ value below one suggests that there is no significant non-carcinogenic health risk associated with zinc intake from these samples. Therefore, the consumption of the analyzed samples does not pose a potential health risk concerning zinc exposure.

The results of estimated daily intake (EDI) for Manganese in all the samples analysed, as shown in Table 2, were below the reference oral dose (0.05 mg/kg/day set by the USEPA. Indicating that exposure to these elements through the consumption of the samples is unlikely to produce detrimental effects on the consumer population. The results of the target hazard quotient for Manganese in both adults and children are less than one, as presented in Table 3, Hence, there is no potential health risk through the consumption of the studied samples in terms of Manganese.

The Estimated Daily Intake (EDI) values for cadmium in all analyzed samples, as presented in Table 2, were below the oral reference dose of 0.001 mg/kg/day established by the United States Environmental Protection Agency (US EPA). This indicates that exposure to chromium through the consumption of the studied samples is unlikely to cause adverse health effects in the consumer population. Furthermore, the Target Hazard Quotient (THQ) values for chromium in both adults and children were less than one, as shown in Table 3A. A THQ value below one suggests an absence of significant non-carcinogenic health risk. Therefore, based on both EDI and THQ assessments, the consumption of the analyzed samples does not pose a potential health risk concerning chromium exposure.

The results of estimated daily intake (EDI) for Chromium in all the samples analysed, as shown in Table 2, were below the reference oral dose (0.003 mg/kg/dayset by the USEPA. Thereby, indicating no harm in the consumption of the samples to the population. The results of the target hazard quotient for Cadmium in both adults and children are less than one, as presented in Table 3. Hence, there is no potential health risk through the consumption of the studied samples in terms of Cadmium.

The results of estimated daily intake (EDI) for Lead in all the samples analysed, as shown in Table 2, were below the reference oral dose (0.004 mg/kg/day) set by the U EPA. Indicating that exposure to this element through the consumption of the samples is unlikely to produce adverse effects on the consumer population. The results of the target hazard quotient for Lead in both adults and children were also less than one as presented in Table 3. Hence, there is no potential health risk through the consumption of the studied samples in terms of Lead.

4. Conclusion and recommendations

4.1. Conclusion

This study revealed that the analyzed vegetables from Dakasoye farmlands generally contain acceptable levels of essential and non-essential heavy metals, including iron, zinc, Manganese, chromium, cadmium, and lead. However, lead levels in some vegetable samples exceeded the safety limit and, therefore, might pose significant health risks

Although the results show that most vegetables from Dakasoye farmlands contained metals within permissible limits, with localized lead contamination detected in some samples, these findings should be interpreted with caution. The study's relatively small sample size may not adequately capture the full range of vegetable types and farming practices in the area. Furthermore, the lack of multi-season sampling restricts the ability to evaluate seasonal changes in metal accumulation, which could be influenced by variations in irrigation sources, rainfall, and atmospheric deposition. As such, the reported concentrations may not fully represent year-round exposure risks."

4.2. Recommendations

The use of contaminated water for irrigation should be avoided to reduce heavy metal uptake by vegetables.

Good Agricultural Practices (GAP), including controlled application of fertilizers and agrochemicals, should be implemented.

Periodic testing of soil and water in Dakasoye farmlands should be carried out to monitor contamination trends.

Potential pollution sources, such as nearby industrial activities and improper waste disposal, should be identified and mitigated.

Awareness of the risks of heavy metal contamination and safe farming practices should be raised among local communities.

A policy-driven monitoring framework for regular surveillance of heavy metals in agricultural areas should be established, ensuring alignment of environmental standards with public health protection.

Future research should be expanded to include other heavy metals and contaminants not analyzed in this study, such as Mercury, Nickel, Cobalt, Arsenic, and Selenium.

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References

[1] H. Rumeza, I. Zafar, I. Mudassa, H. Shaheena, R. Masooma, Uses of Vegetables As Nutritional Food: Role in Human Health. Agric. Bio. Sci. 1(2006),18 – 22.

[2] M.A.Van Duyn, E Pivonka, Overview of the Health Benefits of Fruit and Vegetable Consumption for the Dietetics Professional: Selected Literature. J Am Diet Assoc; 100(2000): 1511-1521. https://doi.org/10.1016/S0002-8223(00)00420-X.

[3] A. Kozlowska, D. Szostak-Wegierek, Flavonoids: Food Sources and Health Benefits. Roczniki Państwowego Zakładu Higieny; 65 (2014),79-85.

[4] A.K. Gupta, S.K., Verma, K. Khan, R.K. Verma, Phytoremediation using aromatic plants, a sustainable approach for remediation of heavy metal pollutants sites. Environ Sci and technol 47(2013),101115-10116. https://doi.org/10.1021/es403469c.

[5] M. Adnan, B. Xiao, P. Xiao, P. Zhao, R. Li, S. Bibi, Research progress on heavy metals pollution in the soil of smelting sites in China. Toxics 10(2022b), 23. https://doi.org/10.3390/toxics10050231.

[6] R. Barzaga, L. Leston-Sanchez, F. Aguilar-Galindo, O. Estevez-Henandez, S. Diaz-Jendero, Synergy effects in heavy metals ion chelation with aryl and aroyl substituted derivatives. Inorg. Chem 60(2022),11984-12000. https://doi.org/10.1021/acs.inorgchem.1c01068.

[7] K., Fijalkowsi, A., Rotate, A., Grobelak, M.J., Kacprazaj, Presence of contaminations in sewage sludge. The current situation. J. Environ Manage 203(2017),1126-1136. https://doi.org/10.1016/j.jenvman.2017.05.068.

[8] M., Intawongse, J.R., Dean, Uptake of heavy metals by vegetable plants grown on contaminated soil and their bioavailability in the human gastrointestinal tract. Food Addit Contam. 22(2006), 36-48. https://doi.org/10.1080/02652030500387554.

[9] S.Q., Li, J.L., Yang, X.L., Ruan, G.L., Zhang, Atmospheric deposition of heavy metals and their impacts on soil environment in typical urban areas of Nanjing. China Environ. Sci 34(2014),22-29.

[10] M., Muchweti, J.W., Birkett, E., Chinyanga, R., Zvauya, M.D., Scrimshaw, J.N., Lester, Heavy metals contents of vegetables irrigated with mixtures of wastewater and sewage sludge in Zimbabwe: Implications for human health. Agriculture, Ecosystem and Environment 112(2006),41-48. https://doi.org/10.1016/j.agee.2005.04.028.

[11] A.G., Nino-savala, Z., Zhaung, X., Ma, A., Fangmeirer, H., Li, A., Fang, X., Liu, Cadmium pollution from phosphate fertilizers in arable soils and crops : an overview. Frontiers of Agricultural science and Engineering 6(2019),419-430. https://doi.org/10.15302/J-FASE-2019273.

[12] M., Bawwab, A., Qutob, M., Alkhatib, H., Malassa, A., Shawahna, M., Qutob, Evaluation of heavy metal Concentrations in soil and edible vegetables grown in compost manure from unknown sources in Aljiftlik, Palestine. Journal of Environmental protection.13(2022),112-125. https://doi.org/10.4236/jep.2022.131007.

[13] N.T., Faithfull, Acid-digestion, ashing and extraction procedures. Methods in agricultural chemical analysis: a practical handbook, 30-56. 2002. https://doi.org/10.1079/9780851996080.0030.

[14] C.B., Okpanachi, E.B., Agbaji, H.Z., Omenesa, Assessment of selected heavy metal levels in soil and Maize (Zeamays) plants within the vicinity of automechanic workshops in Gwagwalada Abuja, Nigeria. International Journal of plants and soil science 12(2016), 1-11. https://doi.org/10.9734/IJPSS/2016/27506.

[15] A.A., Bichi, M., Abdulkadir, M.B., Hassan, M.S., Kanoma, S.L., Halliru, A.S., Muhammad, Demographic characteristic of rice Farmers and it's effects on Rice production in Kura Local government area of Kano state, Nigeria. African Journal of environment and natural science research6(2023),23-45. https://doi.org/10.52589/AJENSR-TXVNVQSC.

[16] A., Mustapha, G.H. Nataala, R.S.Kura, Determination of some mineral elements in some vegetables cultivated from Dakasoye farmlands Kano state, Nigeria. Journal of Modern science and Scientific methods 1(2025),1-6.

[17] A.W., Verla E.N., Verla N.A., Chigbo, C.L., Kelechi, O.S., Ngozi, C.E., Enyoh, Biomonitoring of heavy metals in blood and urine of African children from owerri Metropolis, Eastern Nigeria. J Chem Health Risks, 9(2019),11-26.

[18] A.A., Ullah, M.A., Maksud, S.R., Khan, L.N., Lutfa, S.B., Quraishi, Dietary intake of heavy metals from eight highly consumed species of cultured fish and possible human health risk implications in Bangladesh. Toxicology Reports, 4(2017),574-579. https://doi.org/10.1016/j.toxrep.2017.10.002.

[19] R.K.,Rattan, S.P., Datta,P.K., Chhonkar, K., Suribabu, A.K., Singh, Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater—a case study. Agriculture, Ecosystems & Environment, 109(2005),310–322. https://doi.org/10.1016/j.agee.2005.02.025.

[20] T., Zhou Q., Kong, J., Huang R., Dai Q., Li, Characterization of Nutritional Components and Utilization of Pumpkin. Food;1(2007),:313-321

[21] A., Sharma, V., Kumar, P., Kaur, G.P.S., Sidhu, A.S., Bali, R., Bhardwaj, A., Cerda, Pollution assessment of heavy metals in soils of India and ecological risk assessment: A state-of the art. Chemosphere, 21(2019), 449-462. https://doi.org/10.1016/j.chemosphere.2018.10.066.

[22] FAO/WHO(2011): Joint FAO/ WHO Food standards programme Codex Committee on contaminants in foods fifth session. Hague, Netherlands March, 2011.

[23] C.B., Kipkemboi, Determination of Essential Elements in Traditional Vegetables, Medicinal Plants, Fruits and Conventionally Grown Vegetables in Koibatek, Kenya, MSC thesis Submitted At Kenyatta University.2011.

[24] A., Khaledian, M.R., Zare, S., Tajamiri,Heavy metal concentrations and health risk assessment in vegetables cultivated near a major highway in northeastern Iran.PLOS ONE, 17(2022):e0269565.

[25] E.B., Asamoah, R., Frimpong, B., Asare, Total and extractable iron concentrations of commonly consumed indigenous leafy vegetables in Ghana.

[26] J., Omale, E., Ugwu, Comparative studies on the protein and mineral composition of some selected Nigerian vegetables. African Journal of Food Science, 5(2011),22-5.

[27] S.R., Valvi, V.S., Rathod, Mineral composition of some wild edible fruits from Kolhapur district. International Journal of applied biology and Pharmaceutical technology, 2(2011), 392-396.

[28] K., Shuaibu, M., Yahaya, U.K., Abdullahi, (2013). Heavy Metal Levels in Selected Green Leafy Vegetables Obtained From Katsina Central Market, Katsina, Northwestern Nigeria. African Journal of Pure and Applied Chemistry. 7(2013), 179-183.

[29] S., Sarkiyayi, F.M., Samaila, Determination of heavy metals in some selected vegetables cultivated in Sabon Tasha Yola, Adamawa State. Direct Research Journal of Agriculture and Food Science, 5(2017),427-432.

[30] A.T., Oladele, E .A U., Ofodile, B.T., Udi, G. O., Alade, Proximate and mineral elements composition of three forest fruits sold in Port Harcourt, Nigeria. Journal of Applied Sciences and Environmental Management, 24(2020),1899-1908. https://doi.org/10.4314/jasem.v24i11.9.

[31] Barde I.Muhammad, Comparative study on the minerals composition of the flesh of red and yellow fruits of Terminalia catappa L. ChemSearch Journal, 3(2012), 43-46.

[32] Y., Wang, X., Li, J., Zhang, L., Chen, Assessment of heavy metals in food items from markets in Guangzhou, China: Concentrations and health risk evaluation.Environmental Monitoring and Assessment, 196(2024),135. https://doi.org/10.1371/journal.pone.0269565.

[33] A.T.J., Ogunkunle, O.S., Bello, O.S., Ojofeitimi, Determination of heavy metal contamination of street-vended fruits and vegetables in Lagos state, Nigeria. International Food Research Journal, 21(2014), 65-73.

[34] K.L., Lau, Y.C., Ting, Assessment of heavy metal accumulation in vegetables cultivated in Siburan and Beratok farmlands, Kuching, Sarawak, Malaysia.Malaysian Journal of Soil Science, 27(2023), 45–56.

[35] S. M., Fahad, A.F.M., Islam, M., Ahmed, N., Uddin, M., Alam, M., Khalik, M., Abedin, M., Determination of elemental composition of Malabar spinach, lettuce, spinach, hyacinth bean, and cauliflower vegetables using proton induced X-ray emission technique at Savar subdistrict in Bangladesh. BioMed Research International 11(2015),24-30. https://doi.org/10.1155/2015/128256.

[36] X., Bian, Z., Chen, J., Zhang, Y., Liu, Q., Wang, Trace metal content in common vegetables: Implications for dietary intake. Foods, 14(2023), 2264. https://doi.org/10.3390/foods14132264.

[37] M.A., Garba, S., Abdulfattah, A., Haruna, R., Bako, L., Mustapha, M.S., Makama, Muhammad, Quantitative determination of Chromium in some vegetables grown in Tudun wada, Makera, Kaduna state, Nigeria. Journal of Pharmaceutical and Allied sciences 15(2018).

[38] A.,Bouguerra, B., Hamdi, N.,Bouaïcha, Assessment of heavy metal contamination in soils, irrigation water, and vegetables in the Boumerdes region, Algeria.Molecules, 29(2024),4187. https://doi.org/10.3390/molecules29174187.

[39] A., Cherfi, S., Abdoun, O., Gaci, Food Survey: levels and potential health risks of Chromium, Lead, Zinc and Copper in fruits and vegetables consumed in Algeria. Food chem Toxicol. 70(2014,48-53. https://doi.org/10.1016/j.fct.2014.04.044.

[40] A., Patel, R., Kumar, Assessment of chromium contamination in vegetables grown near tannery effluent areas in Australia. Journal of Environmental Monitoring, 2021, Article ID 5531349.

[41] E.O.S., Vincent, B.N.I., Akpogheneta, O., Friday, Occurrence and Concentration of Heavy Metals in Garden Egg, Tomatoes, Cucumber and Watermelon from Two Major Markets in Edo State, Nigeria. Food and Public Health, 10(2020),63-67.

[42] A., Chinazo, S.I., Okonkwo, C., Chibuzor, A.L.C., Onuorah, N.E., Ugwunnadi, Determination of heavy metals in some fruits and vegetables from selected market's in Anambra State. Acta. Scientific Nutritional Health, 4(2020),163-171.

[43] D.,Tewodros, M., Alemayehu, Assessment of heavy metals in soils and commonly consumed vegetables from Mojo area, Ethiopia: Implications for human health. Environmental Science and Pollution Research, 27(2020),29116–29128.

[44] B.O., Isiuku, C.E., Enyoh, Determination and human health risk assessment of heavy metals in floodbasin soils in Owerri, Southeastern Nigeria. Chemistry Africa, 3(2020), 1059-1071. https://doi.org/10.1007/s42250-020-00171-2.

[45] S. H., Lee, S., Kim, H.S., Park, Impact of particulate matter on heavy metal accumulation in leafy vegetables in Gyeongsangnam-do, South Korea. Environmental Science and Pollution Research, 26(2019),26146–26155. https://doi.org/10.1007/s11356-019-05825-4.

[46] S., Khan, Q., Cao, Y.M., Zheng, Y.Z., Huang, Y.G., Zhu, Health risk of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. Environmental pollution, 152(2008),686-692. https://doi.org/10.1016/j.envpol.2007.06.056.

[47] K.I. Kasozi, E.O. Otim, H.I. Ninsiima, G. Zirintunda, A. Tamale, J. Ekou, O. Otim, An analysis of heavy metals contamination and estimating the daily intakes of vegetables from Uganda. Toxicology Research and Application, 5(2021),234-241. https://doi.org/10.1177/2397847320985255.

[48] P.K., Madungu, K.A., Mkongela, O.J., Mwandemele, Heavy metal contamination in soils and vegetable leaves along Msimbazi River, Dar es Salaam, Tanzania.

[49] R., Singh, A., Mukherjee, A.Assessment of heavy metal contamination in commercially grown vegetables using ICP-MS. Environmental Science and Pollution Research, 31(2024),6740–6752. Tanzania Journal of Agricultural Sciences, 22(2023), 45-56.

[50] A., Mustapha, A., Dahiru, Determination of some heavy metals in some vegetables grown around Gwaigwaye dam, Katsina state Nigeria. International Journal of Advanced chemistry 2(2024),67-70. https://doi.org/10.14419/kbwp8v23.