

RISK OF HEAVY METAL INTAKE VIA CONSUMPTION OF SPINACH AND ROSELLE IRRIGATED WITH URBAN WASTEWATER IN YOLA AND KANO, NIGERIA

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Abstract

The level of Cadmium (Cd), Lead (Pb), Copper (Cu) and Chromium (Cr) in Spinach (*Amaranthus candatus* L) and Roselle (*Hibiscus subtaritta* L) irrigated with urban wastewater in Fagge - Kano and Shinko - Yola were investigated. The heavy metal concentrations in the wastewater used for irrigation at both sites were analyzed including the daily intake of heavy metal through consumption of the two vegetables. Atomic Absorption Spectrophotometer was used for the analysis of both water and plant samples. The concentrations of Cd, Pb, Cu and Cr in almost all the vegetables exceeded the maximum permissible limit of 1.5 mg kg⁻¹, 2.5 mg kg⁻¹, 73 mg kg⁻¹ and 30 mg kg⁻¹ respectively as set by the World Health Organization and Food Agricultural Organization (WHO/FAO). The estimated daily intake rate of Cd, Pb and Cu as a result of consumption of Spinach and Roselle leaves ranged from 23.10 – 37.65 mg/day, 4.13 – 24.75 mg/day and 6.60 – 14.03 mg/day which were far above the maximum tolerable daily intake limits of 0.06 mg/day, 0.21 mg/day and 1.2 mg/day respectively. This alarming intake rate of the heavy metals in the study areas could lead to bioaccumulation and toxicity resulting in serious health risks such as kidney damage, bronchitis, bone marrow cancer and mental retardation.

Key Words: Vegetable, Irrigation, Urban Wastewater, Heavy metals, Daily intake

1.0 Introduction

Vegetables are rich sources of fibers, minerals and vitamins as well as having beneficial anti-oxidative effects [1]. In addition, vegetables contain both essential and toxic elements which comprises of heavy metals at different concentrations. Heavy metals include elements such as Cadmium, Chromium, Copper, Iron, Lead, Mercury and Zinc. They can be hazardous to the environment and could be exceptionally toxic [2].

World Health Organization,[3] and Jarup [4] explained that prolonged intake of unacceptable concentration of heavy metals in foodstuffs may lead to chronic accumulation of heavy metals in the kidney and liver of human beings causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases.

Furthermore, heavy metals may be added to vegetable due to irrigation with contaminated water, addition of fertilizers and pesticides, sewage discharge, emission of heavy metals from vehicles deposited on the vegetable surface during their production, transportation, storage and marketing [5, 6].

Heavy metals are regarded as cumulative toxins which through biomagnifications in plants affect human health. Also due to the significance of vegetables as a source of food, it is necessary to assess the levels of vegetable contamination with heavy metals grown in Urban Area like Fagge Irrigation Site Kano, Kano State (FIS) and Shinko Irrigation Site Yola,

Adamawa State (SIS) which may be polluted as a result of using urban wastewater for irrigation.

This research is aimed at determining the level of heavy metals which include Cadmium (Cd), Chromium (Cr), Copper (Cu) and Lead (Pb) in vegetables (Spinach and Roselle) and waste water for irrigation as well as estimating the daily intake of heavy metals through consumption of the vegetables.

2.0 Materials and Method

2.1 Vegetables

Vegetable samples were randomly harvested from the study areas Fagge and Shinko irrigation sites in Kano and Yola respectively. The Roselle (*Hibiscus subtaritta L*) and Spinach (*Amaranthus candatus L*) samples were collected in different polythene bags and were transported to Chemical Engineering Laboratory of Modibbo Adama University of Technology Yola. The samples were thoroughly washed with tap water to remove sand, dirt and possible parasites as practiced by the consumers. The samples were sorted into leaves and stems after which they were dried at 60°C in an oven to constant weight. The samples were weighed into a porcelain crucible and heated in a muffle furnace at a temperature of 450°C for one hour. The ash samples were grounded with porcelain mortar and piston after which it was passed through 2 mm sieve and stored in plastic containers. 0.2 g of each of the ash samples were dissolved in one molar hydrochloric (1M HCl) acid. The resulting solution was filtered with Whatman No 1 filter paper and the heavy metals were analyzed using Atomic Absorption Spectrophotometer (AAS).

2.2 Water

The concentrations of the heavy metal in irrigation water were evaluated using standard method for examination of water and wastewater [7]. 50 mL of each water sample was transferred to an evaporating dish and evaporated on a steam bath to about 20 mL. 10 mL of 8M Nitric acid (HNO₃) was added and evaporated on a hot plate to near dryness. The residue was quantitatively transferred using two aliquots of 10 and 15 mL of concentrated nitric acid into a 250 mL flask. 20 mL of perchloric acid (HClO₄) was added and boiled until the solution became clear and white fumes of perchloric acid appeared. It was then cooled and de-ionized water was added and the solution filtered. The filtrate was quantitatively transferred to a 100 mL volumetric flask with two portion of 5 ml de-ionized water. The solution was made to mark and mixed thoroughly. The heavy metals were analyzed using Atomic Absorption Spectrophotometer.

2.3 Daily Heavy Metal Intake

The daily intake of heavy metals through the consumption of vegetable was obtained according to the expression [8] in equation 1.

$$\text{Daily intake of heavy metals (mg /day)} = [\text{Daily Vegetable consumption}] \times [\text{Heavy metal concentration}] \text{-----(1)}$$

3.0 Results and Discussion

The results of heavy metal concentrations in the vegetable leaves and stems from Fagge irrigation site (FIS) – Kano and Shinko irrigation site (SIS) - Yola are presented in Figures 1 – 4. The highest concentration of Cd was found in spinach leaves from SIS – Yola as seen in Figure 1. This may be a reflection of the high concentration of Cd in the irrigation wastewater as shown in Table 3. Although Cd was not detected from the irrigation water from FIS – Kano, the high concentrations in the vegetables may be from aerial deposition, soil or use of pesticides

which was not studied. With exceptions of Roselle stems from FIS –Kano in which Cd was not detected, concentrations of Cd in all parts of vegetables under study exceeded the Maximum set standard of 1.5 mg Kg⁻¹ for prevention of food adulteration [9].

Although Lead (Pb) was not detected in Spinach at FIS – Kano and in Roselle at SIS – Yola, higher concentrations of Lead (Pb) were observed in Spinach leaves from SIS – Yola and Roselle stem from FIS – Kano. All the concentrations of Lead (Pb) found in the vegetables from both sites were above the maximum permissible limit of 2.5 mg Kg⁻¹ for prevention of food adulteration [9] as shown in Figure 2. Exposure to high concentration of Pb affects the body building system, more especially children whose major organs such as brain are still under developed making them more vulnerable compared with adults [10, 11].

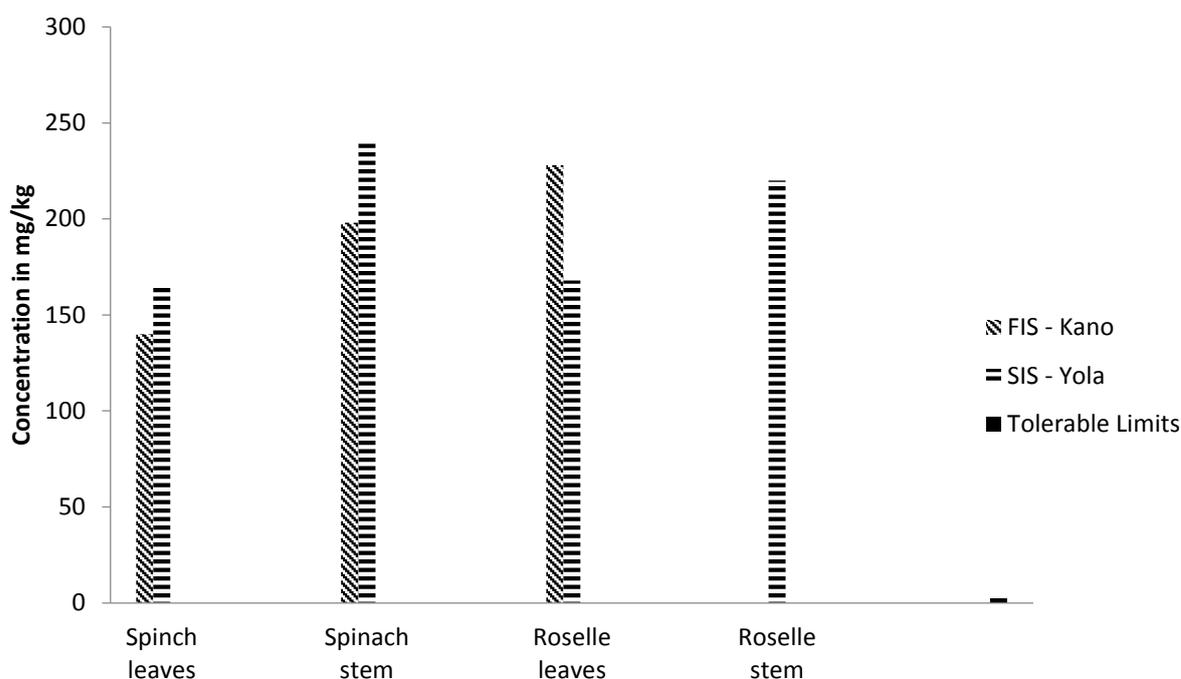


Figure 1: Variation of Cd in FIS - Kano and SIS - Yola Vegetables

The variations of Copper (Cu) concentration in Spinach and Roselle are shown in Figure 3. With the exceptions of Spinach leaves and stem from SIS – Yola, concentrations of Cu in all vegetables were below the maximum permissible limits set by WHO [12]. This shows that Spinach and Roselle from FIS – Kano and Roselle from SIS – Yola are safe for consumption, but because of the large amount of the vegetable consumption by Nigerians, the estimated range of daily intake rate of Cu is still above the limits set by WHO [12] as shown in Tables 1 and 2.

The variations of the concentrations of Cr were shown in Figure 4. With the exceptions of Spinach and Roselle leaves from FIS – Kano, all concentrations of Cr in vegetables were above the maximum limits of WHO [12]. Irrespective of the high concentrations of Cr in the vegetables, the estimated range of Cu intake rate in the vegetables is still below the maximum level set by Agency of Toxic Substances and Disease Registry (ASTD) [13] as seen in Tables 1 and 2.

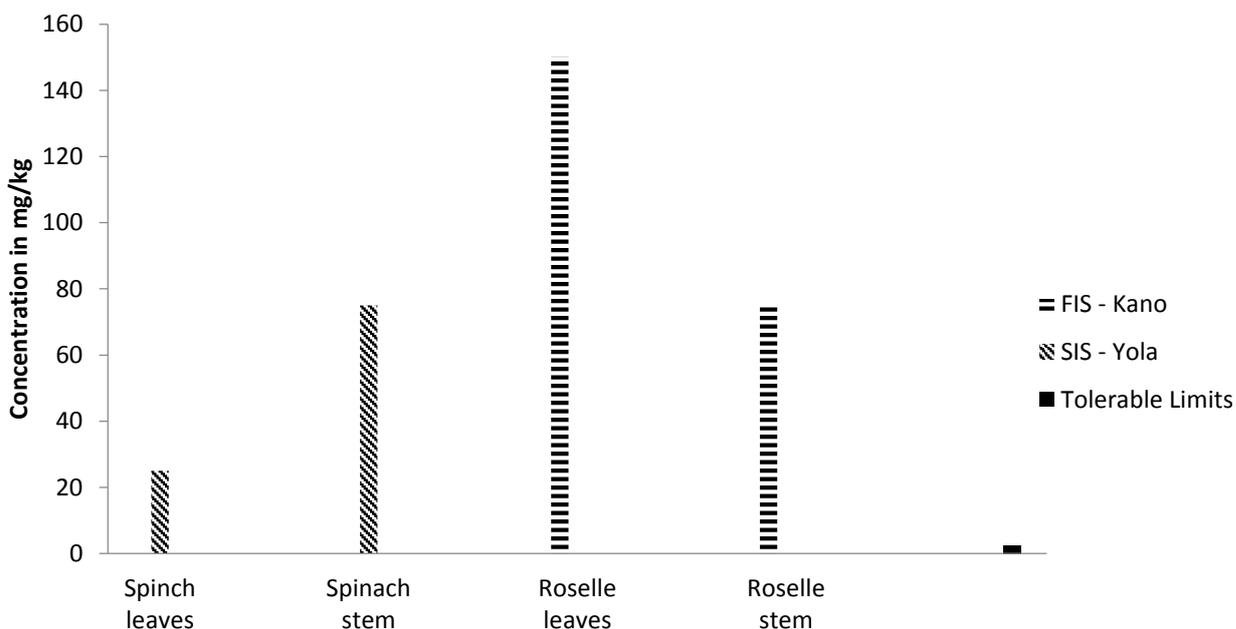


Figure 2: Variation of Pb in FIS - Kano and SIS - Yola

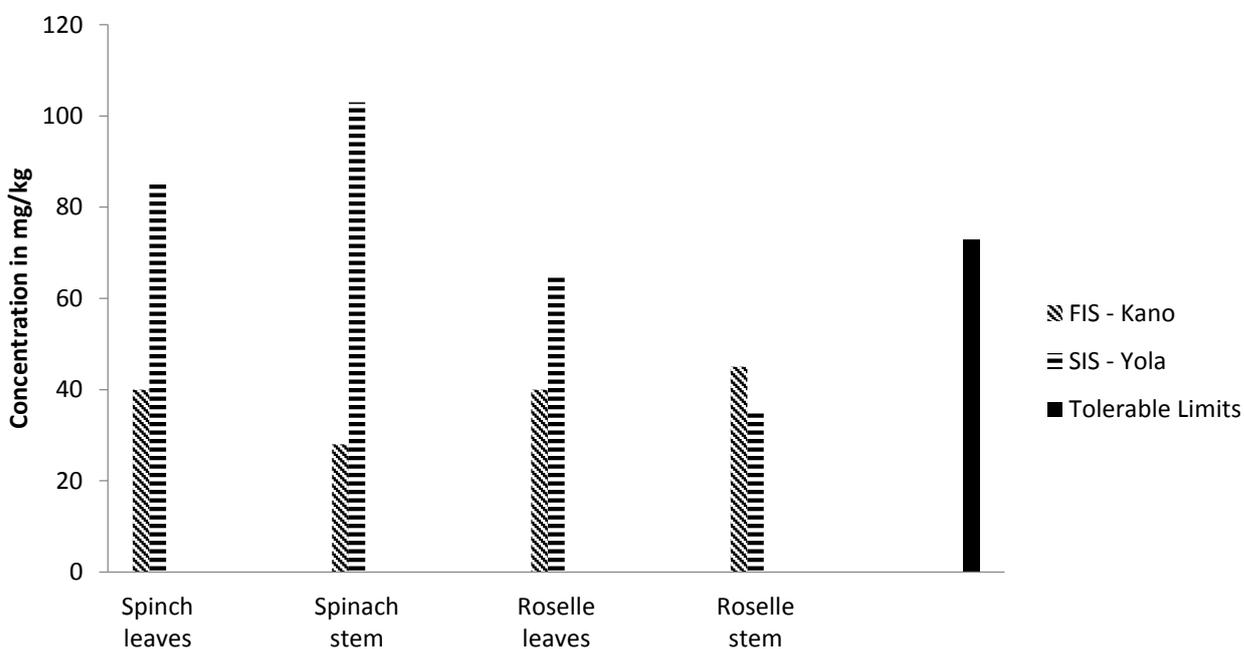


Figure 3: Variation of Cu in FIS - Kano and SIS - Yola

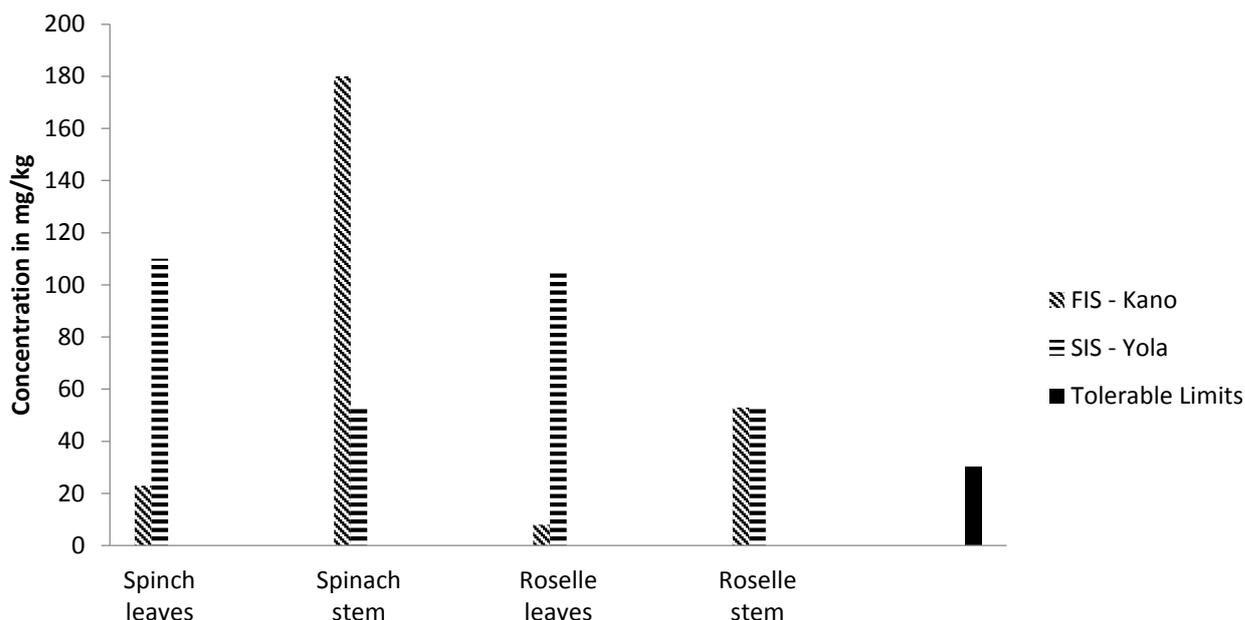


Figure 4: Variation of Cr in FIS - Kano and SIS - Yola Vegetables

Most of the Northern parts of Nigeria use the vegetable leaves of Spinach and Roselle for making delicacies. Therefore the daily intake of the heavy metals (mg/day) can be calculated from equation 1. Thus the concentrations of the heavy metal in the leaves of the vegetables are used for the estimation of the daily metal intake.

The National Nutrition and Food Research Institute of Iran estimated the average consumption of edible vegetable as 218g/person/day [14]. Also the Consumer Council of Zimbabwe’s total dietary study estimated a leafy vegetable consumption rate for low income urban dweller to be 183 – 219 g/person/day for adult of 60kg body weight [15]. The estimated average consumption of vegetables in Nigeria is 165 g/person/day for adult with average body weight of 60 kg [16]. The estimated heavy metal intake rate from Yola and Kano are shown in Tables 1 and 2 below:

Table 1: Concentration of Heavy Metals in Spinach leaves (dry weight) and the estimated Heavy Metals Intake Rates by an Adult (of 60kg body wt.) from the FIS-Kano and SIS-Yola

Metal	Concentrations of Heavy Metal in Leaves (mg/g Dry Wt.)		Estimated Range of Heavy Metal Intake Rate (mgday ⁻¹)		Maximum Limit (mgday ⁻¹)
	FIS-Kano	SIS-Yola	FIS-Kano	SIS-Yola	
Cd	0.140	0.165	23.10	27.23	0.06*
Pb	ND	0.025	ND	4.13	0.21*
Cu	0.040	0.085	6.60	14.03	1.2**
Cr	0.023	0.110	3.80	18.15	90**

* [17]; ** [13]. ND = Not detected

Table 2: Concentration of Heavy Metals in Roselle leaves (dry weight) and the estimated range of Heavy Metals Intake Rates by an Adult (of 60kg body wt.) from the FIS-Kano and SIS-Yola

Metal	Concentrations of Heavy Metal in Leaves (mg/g Dry Wt.)		Estimated Range of Heavy Metal Intake Rate (mgday ⁻¹)		Maximum Limit (mgday ⁻¹)
	FIS-Kano	SIS-Yola	FIS-Kano	SIS-Yola	
Cd	0.228	0.168	37.65	27.72	0.06*
Pb	0.150	ND	24.75	ND	0.21*
Cu	0.040	0.065	6.60	10.73	1.2**
Cr	0.008	0.105	1.32	17.33	90**

From Tables 1 and 2 the estimated intake rate of Cd, Pb and Cu for both Spinach and Roselle leaves consumption which ranges from 23.10 – 37.65 mg/day, 4.13 – 24.75 mg/day and 6.60 – 14.03 mg/day were far above the Provisional Tolerance Daily Intake (PTDI) [17] maximum limits of 0.06 mg/day, 0.21 mg/day and 1.2 mg/day respectively. This alarming intake rate of the heavy metals in the study areas can lead to bioaccumulation and toxicity resulting in kidney damage, bronchitis, bone marrow cancer and mental retardation. The estimated daily intake rate of Cr 1.32 – 18.15 mg/day is below the maximum limits of 90 mg/day [13].

Cadmium and Lead daily intake rate in vegetable leaves were far above the Maximum set standard of 0.06 mg of Cd day⁻¹ and 0.21 mg of Pb day⁻¹ respectively by Provisional Tolerance Daily Intake (PTDI) [17] at a high alarming rate. While Cu daily intake rate in vegetable leaves from FIS – Kano is 6.60 mg of Cu day⁻¹ and SIS - Yola ranges between 10.73 – 14.03 mg of Cu day⁻¹ which is still above the maximum risk level of 1.2 mg of Cu day⁻¹.

From Tables 1 and 2, it was observed that Cd, Pb, Cu and Cr daily intake rate from consumption of Spinach leaves from SIS – Yola are higher compared to FIS – Kano, while Cd and Pb daily intake from consumption of Roselle leaves from FIS- Kano is higher compared to SIS – Yola.

Table 3: Concentration of Heavy Metals in mg/L dry weight in the irrigation waters

Site	Cd	Pb	Cu	Cr
FIS-Kano	ND	0.01	0.31	0.10
SIS-Yola	0.02	0.09	0.11	0.21
Maximum Limits (FAO,1985)	0.01	0.065	0.017	0.55

ND = Not detected

From Table 3 the concentrations of Cd, Pb in SIS – Yola and Cu in FIS – Kano were above the maximum limits in irrigation waters set by the Food and Agricultural Organization [18]. These might have resulted to the high concentrations of Cd and Pb in the vegetables which were above the WHO/FAO maximum tolerable limits [12] as shown in Figures 1 and 2.

The higher concentration of heavy metals at SIS – Yola may be attributed to the higher vehicular emission due to the location of the site closer to major highway in addition to the

contribution of wastewater used for the irrigation from Shinko drainage which comprises of domestic waste generated from Jimeta – Yola.

The concentration of Chromium detected in irrigation waters for both sites were below the maximum limits by FAO [18]. These did not reflect the high concentration of Chromium in the parts of vegetables in Figure 4. This shows that the contamination might be as a result of aerial deposition or the use of fertilizers and pesticides which was not studied.

4.0 Conclusion

From the above studies the following conclusion could be made:

The concentrations of Cd and Pb in SIS – Yola and Cu in FIS –Kano irrigation waters were above the maximum permissible limits set by WHO/FAO, these resulted in contaminations of vegetables cultivated in these areas.

The Spinach and Roselle from Fagge and Shinko irrigation sites in Kano and Yola respectively contained high Cd, Pb, Cu and Cr concentrations above the safe limits prescribed by WHO.

The Cd, Pb and Cu estimated intake rate for the two vegetables were far above the maximum limits set by WHO/FAO and ATSDR. The alarming rate of the estimated intake of these heavy metals in the study areas could lead to toxicity resulting to serious health problems such as kidney damage, bronchitis, bone marrow cancer and mental retardation.

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