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ORIGINAL RESEARCH ARTICLE

HEALTH RISKS ASSOCIATED WITH CONSUMPTION OF VEGETABLES GROWN USING DOMESTIC WASTEWATER IN MINNA, NIGER STATE, NIGERIA

P. A. Adeoye[1*], Z. Saidu[1], A. I. Kuti[1], I. Jibril[1,2] and B. A. Adabembe[3]

([1]Department of Agricultural and Bioresources Engineering, Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria.
[2]Niger State College of Agriculture, P.M.B. 109, Mokwa, Niger State, Nigeria.
[3]Department of Water Resources Management Agro- Meteorology, Federal University, Oye Ekiti, Ekiti State,Nigeria)
** Corresponding author's email address: peter.adeoye@futminna.edu.ng*

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ABSTRACT

Most vegetables consumed in the cities of developing countries are grown using wastewater discharged through township drainage network. This paper, therefore, investigates the risk involved in the consumption of such vegetables. The human daily intake rate (DIR) and Health Risk Index (HRI) of heavy metals were calculated using established formulae and the values of DIR ranged from 0.10 mg/kg/day to 0.71 mg/kg/day in wastewater plots in dry season for adults and 0.10 mg/kg/day to 0.14 mg/kg/day for children. Health risk index (HRI) values ranges from 0.40 mg/kg/day to 0.75 mg/kg/day in wastewater plots for adults in dry season and 0.20 mg/kg/day to 0.95 mg/kg/day for children. In wet season wastewater plots, the HRI ranges from 0.40 mg/kg/day to 0.95 mg/kg/day for children. The values of Hazard index (HI) ranged between 1.00 mg/kg/day and 1.21 mg/kg/day for all the seasons. Statistical analysis showed that there is a significant difference between the wet and dry season values for all the parameters assessed. Finally, uptake of heavy metals from the soil by all the vegetable crops under investigation was established. Therefore proper monitoring needs to be carried out to regulate consumption of vegetables produced from the experimental sites as continuous application of the industrial wastewater may lead to further accumulation of these heavy metals.

1.0 Introduction

A plant that is contaminated with high concentrations of heavy metals does not have visible changes in their appearance or yield but exceed animal and human tolerance or element consumption level. During the last twenty years, environmental problems have started to be a part of daily life in several countries. Their impact is clearly on the Manifest on the terrestrial and aquatic flora fauna and keeps on increasing (Osma et al., 2012). Knowledge of metal-plant interaction is essential for the safety of the environment and for reducing the risk of introduction of trace metals into the food chain.

The anthropogenic sources of environmental pollution by heavy metals include traffic emissions (vehicle exhaust particles, tire wear particles, weathered street surface particles, brake lining wear particles), industrial emissions (power plants, coal combustion, metallurgical industry, auto repair shops and chemical plants) domestic emissions, and weathering of building and pavement surfaces (Ahaneku and Sadiq, 2014). Human activities in most cases have introduced potentially hazardous metals to the environment. Human activities as a result of the industrial revolution, and urban development are promoting a significant threat to ecology and human well-being (Mahmood and Malik 2013; Aljaboobi et al., 2014). Contaminated air, soil, and water by human activities are associated with disease burden, and this could be reasons for the current shorter life expectancy in developing countries when compared with developed nations. Heavy metal toxicity adversely disrupts growth and other physiological processes of the plant, explicitly leading to significant economic and ecological trauma. If heavy metals move too rapidly in a particular soil, they can pollute ground and surface water supplies while it has generally assumed that these metals retained in agricultural soils (Bichi and Bello, 2013).

Singh et al. (2012), assessed heavy metals accumulation and distribution pattern in different vegetable crops grown on heavy metal contaminated soil showed marked differences in metal accumulation, their uptake and distribution pattern. Furthermore, from their studies, it was discovered that vegetable crop plants have a high ability to accumulate metals from the environment, which may pose risks to human health when consumed.

Despite all the glaring adverse effects domestic and industrial wastewater causes to human health when used for irrigation, the trend of using wastewater for irrigation is at increase as most people lack adequate knowledge of the health risk that is involved. This study therefore, seeks to investigate the heavy metals uptake and accumulation in some selected vegetable leaves, stems and roots in Minna; as well as bringing forth useful recommendations for the farmers, the consumers and the policymakers.

2. Materials and Methods

2.1 Description of the Study Area

Niger state is one of the North-central states in the Guinea Savannah Zone of Nigeria. It was at sometimes called the 'food basket' of the nation owing to the abundant potentials for all year-round farming. Geographically, it is located on Longitude 6° 00′ 00′′ E and Latitude 10° 00′ 00′′ N as presented in figure 1. It is characterised by two distinct seasons; rainy and dry seasons. Short grasses and scattered trees in its extreme north and dense forest towards the south are features of its vegetation with mean maximum and minimum temperatures of 37 °C and 20 °C respectively.

Corresponding author's e-mail address: peter.adeoye@futminna.edu.ng

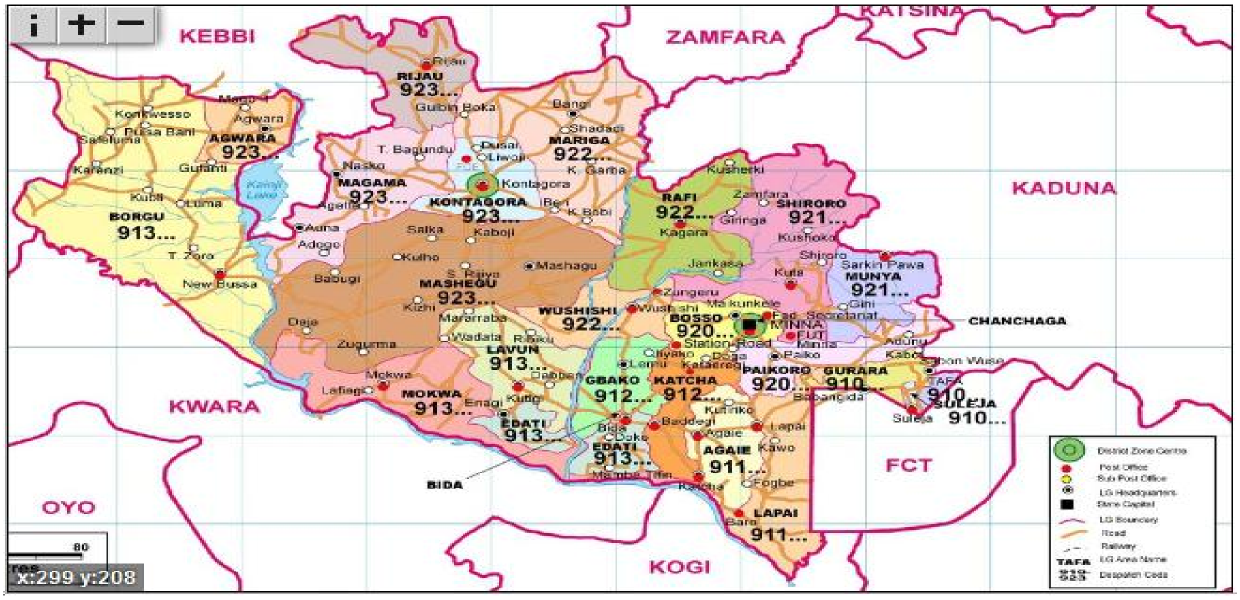

Figure 1: Map of Niger State showing its boundary with other states of Nigeria

2.2 Experimental Set-up

A piece of land measuring 9m x 9m situated at Dutsen Kura along Minna western by-pass in Minna, Niger State was selected as a plot area. Wastewater from an urban drain (industrial/municipal) passing through Keterin-Gwari area was used as a source of irrigation water at the wastewater irrigation plot, while water from a closed well at Dutsen-Kuran Gwari, down Police Secondary School Avenue, was used for irrigation at control plot. The entire experimental is as presented in Figure 2.

Control Plot

Pepper	Okro	Jutemallow	Roselle	Spinach
Spinach	Roselle	Okro	Pepper	Jutemallo
Jutemallow	Spinarch	Roselle	Okro	Pepper
Roselle	Jutemallo	Pepper	Spinach	Okro
Okro	Pepper	Spinach	Jutemallo	Roselle

Figure 2: Experimental Plot Design

2.3 Vegetable Samples Collection

From edible portion of different vegetables grown, 300g each were collected and washed with distilled water to remove soil particles, separated into three parts, chopped into small pieces using a knife and kept air-dried for approximately 70 hours at 105°C. These samples were ground into a fine powder before use for heavy metals extractions by acid digestion. Powdered samples (15g each) were placed in a silica crucible, and few drops of concentrated nitric acid were added. The dry-ashing process was carried out in a muffle furnace (Swastik Scientific Co.Mumbai, P.14, Se.No 1021) by a stepwise increase of the temperature up to 550°C and then left to ash at this temperature for 6 hours. The ash was kept in desiccators and then rinsed with 3N hydrochloric acid.

2.4 Sample Digestion and Heavy Metal Determination

Concentrations of heavy metals in the acidic solution were estimated using Atomic Absorption Spectrophotometer (Spectrometer Ice 3000 AA 02134 Dell, Thermo Scientific Pvt. Ltd., India). Soil to plant metal transfer was carried out as transfer factor using equation 1:

$$TF = \frac{C_{plant}}{C_{soil}} \quad (1)$$

Where, C_{plant} is the concentration of heavy metals in plants and C_{Soil} is the concentration of heavy metal in the soil (Mahmood and Malik, 2013). Daily intake rate was determined as stated in equation 2.

$$DIM = C_{metal}\ x\ C_{factor}\ x\ \frac{D_{food\ intake}}{B_{average\ weight}} \quad (2)$$

Where, Cmetal, Cfactor, Dfood intake and Baverage weight represent the heavy metal concentrations in plants (mg kg-1), a Conversion factor (0.085), daily intake of vegetables and average body weight (kg/person/day) respectively. Health risk index and a Hazard index of heavy metals were calculated by knowing the exposure levels of these metals on humans.

2.5 Data Analysis

The heavy metals determined in the laboratory were analysed using descriptive statistics and one-way ANOVA to determine the significance of the heavy metals in vegetables.

3. Results and Discussions

3.1 Daily intake rate (DIR), Health Risk Index (HRI) and Hazard Index (HI) at Dry Season

The daily intake rate of metals for adults at wastewater plots ranges from 0.00 mg/kg/day to 0.11mg/kg/day for all the metals analysed. The highest element consumed by adults is iron with a value of 0.11mg/kg/day. The values of all metals are below the daily tolerable intake limits specified by (FAO, 2013) as presented in table 1. For adults except for okra leaves, pepper leaves, spinach stem, and roselle stem with chromium values of 0.03 mg/kg/day, 0.03 mg/kg/day and 0.03 mg/kg/day respectively. Daily intake for children at the wastewater plot also ranges from 0.00 mg/kg/day to 0.14 mg/kg/day for all the metals with iron having the highest value of 0.14 mg/kg/day. Chromium and copper are present in some non-edible parts that are of no threat to the children. Iron has the highest value which perhaps, might be due to the presence of iron in the soil at its original state.

Table 1: Upper Tolerable Daily Intake Limit for Both Adults and Children

Heavy metals	Upper tolerable daily intake (mg/day)
Cr	0.0105
Fe	45
Cu	10
Cd	0.0640

Source: integrated risk Information System FAO (2013)

The result also confirmed 0.03 mg/kg/day of iron in Roselle leaves and 0.01mg/kg/day of copper. On the other hand, the concentration of the heavy metals in the vegetables grown on the control plots during the dry season is negligible for both adults and children, which is in line with Cui et al. (2014).

The result of the health risk index showed that, for the dry season at wastewater plots, the Health Risk Index (HRI) value for adult consumer ranges from 0.00 mg/kg/day to 0.16 mg/kg/day. Chromium was 0.01mg/kg/day in okra leaves and 0.03 mg/kg/day in roselle stems. However, the values of 0.75 mg/kg/day of copper in okra leaves and 0.075 mg/kg/day in jute mallow leaves are of no threat to the adult's consumer. HRI values for children consumers of the edible parts of okra fruits was 0.00mg/kg/day, Roselle leaves 0.06 mg/kg/day and spinach leaves 0.25 mg/kg/day. All values obtained are below the standard reference doses pegged by USEPA as presented in table 2.

Table 2: Oral Reference Doses R_fD_O(mg/kg/day)

Heavy metals	R_fD_O(mg/kg/day)
Cr	1.5
Fe	0.7
Cu	0.04
Cd	0.001

Source: USEPA (2013)

The Hazard Index (HI) was computed by the summation of all metals investigated in accordance with Wang et al. (2005), and Mahmood and Malik (2013). The results of dry season wastewater plots for adults and children are within the acceptable limit of 5, above which is hazardous for both consumers. The highest value of HI was found to be 0.092 mg/kg/day in okra leaves for adults and 1.21 mg/kg/day in okra leaves for children. Figures 3, 4, 5 and 6 give clear pictorial views of the analysis of heavy metal concentration for all vegetables irrigated with wastewater.

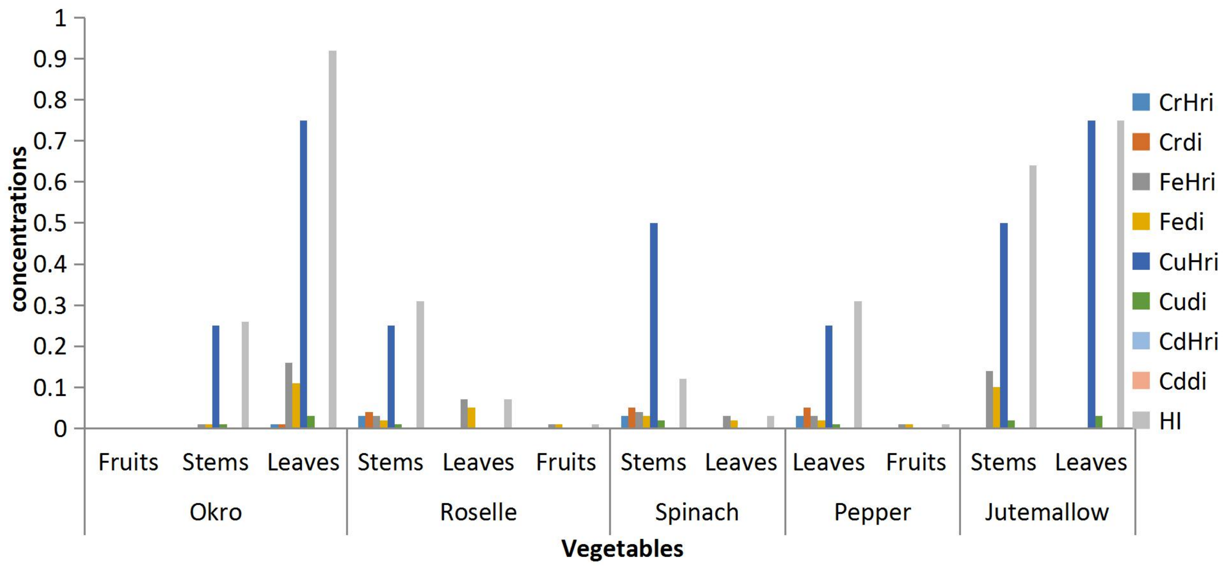

Figure 3: Dry Season Indices in Adults for Wastewater Plots

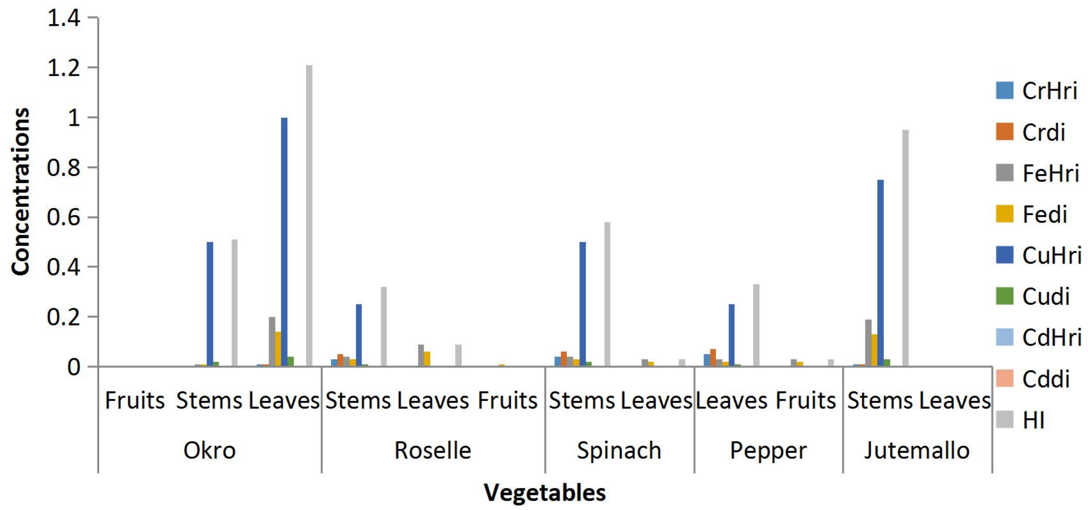

Figure 4: Dry Season Indices in Children for Wastewater Plots

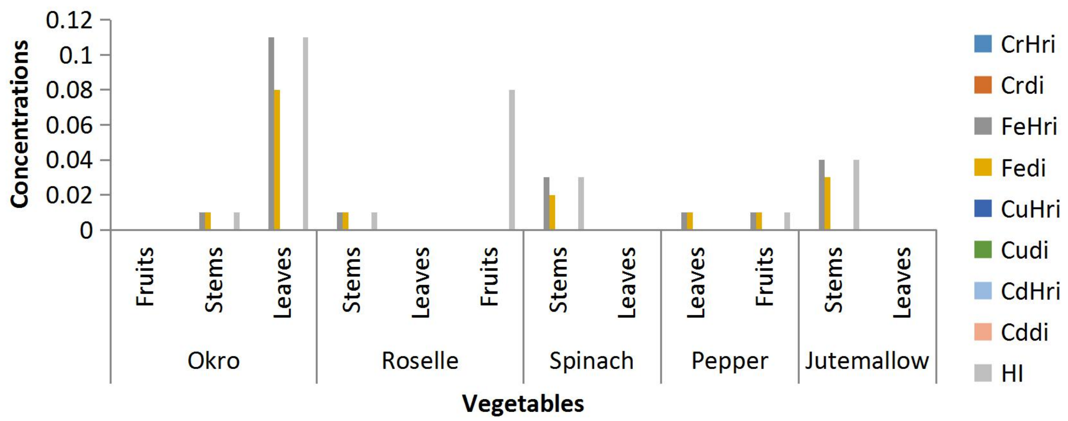

Figure 5: Dry Seasons Indices in Adults for Clearwater Plots (Control plots)

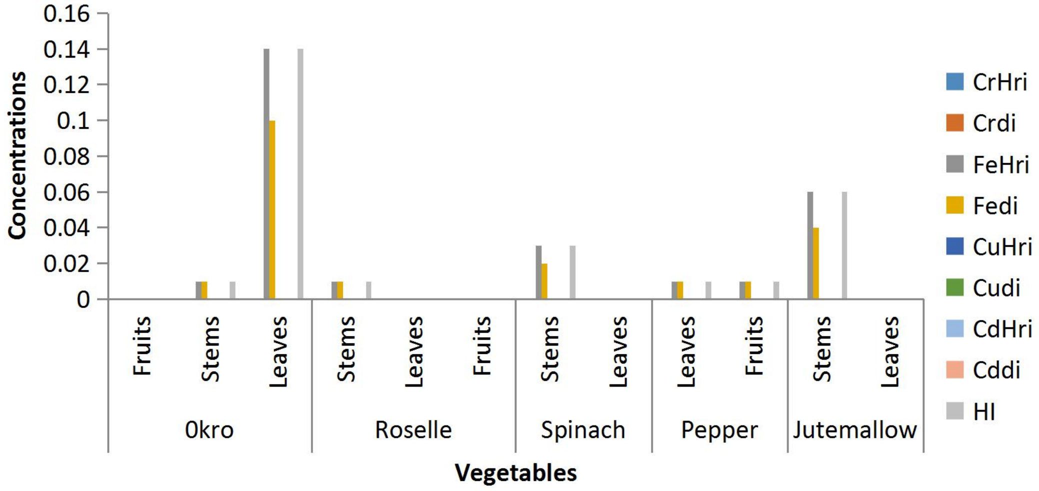

Figure 6: Dry season Indices in Children for Clearwater Plots (Control plots)

3.2 Daily intake rate (DIR), Health Risk Index (HRI) and Hazard Index (HI) During Rainy Season

During the wet season, results were a little different even in the same wastewater plots. Intake rate of 0.01mg/kg/day of chromium in the leaves of okra, 0.01mg/kg/day of copper and 0.13 mg/kg/day of iron was recorded, though was confirmed safe for children and adults as values are within the FAO/USEPA acceptable limit as marked by Chanhan and Chanhan (2014). On Health Risk Index (HRI), computation of result for both plots were done and compared with the oral reference doses RfDo (Mg/Kg/day). Values obtained for all vegetables in all plots were negligible. Hazard Index (HI) according to the result obtained for vegetables grown on wastewater plots during the wet season had its highest value to be 0.45 mg/kg/day in roselle leaves for adult consumers and 0.14 mg/kg/day for children consumers. Highest amounts of 0.07 mg/kg/day were recorded for okra leaves for adult consumers and 0.09 mg/kg/day for children consumers. For clear water (well water) or the control Plots, the highest values were found to be 0.07 mg/kg/day in okra leaves for adults and 0.09 mg/kg/day in okra leaves for children consumers. These analyses are as presented in Figures 7, 8, 9 and 10. From all results, it is clear that concentrations of heavy metals in vegetables grown on all plots during the wet season are negligible and therefore are safe for consumption for both adults and children.

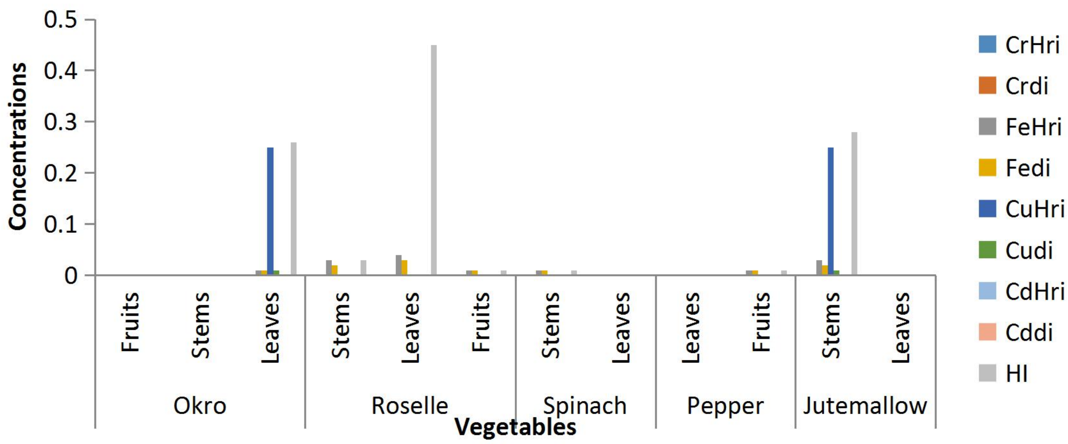

Figure 7: Wet Season Indices in Adults for Wastewater Plots

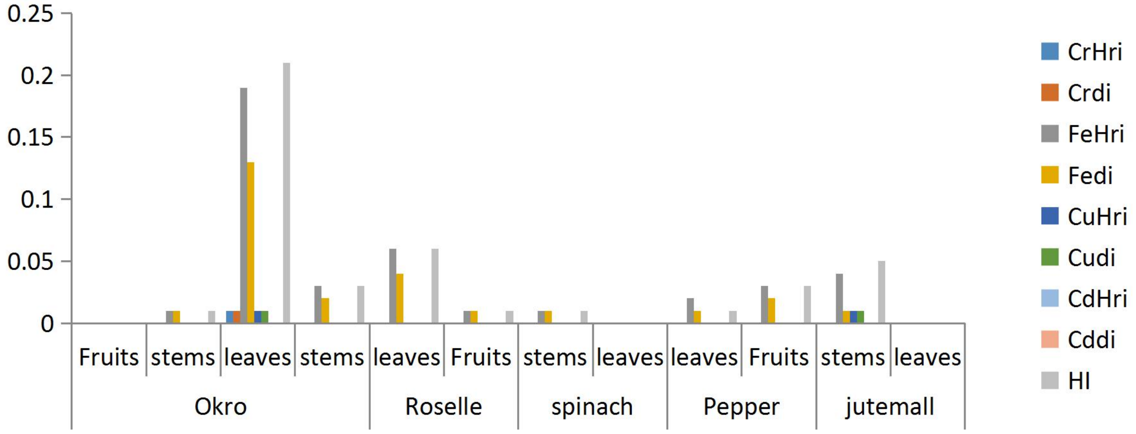

Figure 8: Wet Season Indices in Children for Wastewater Plots

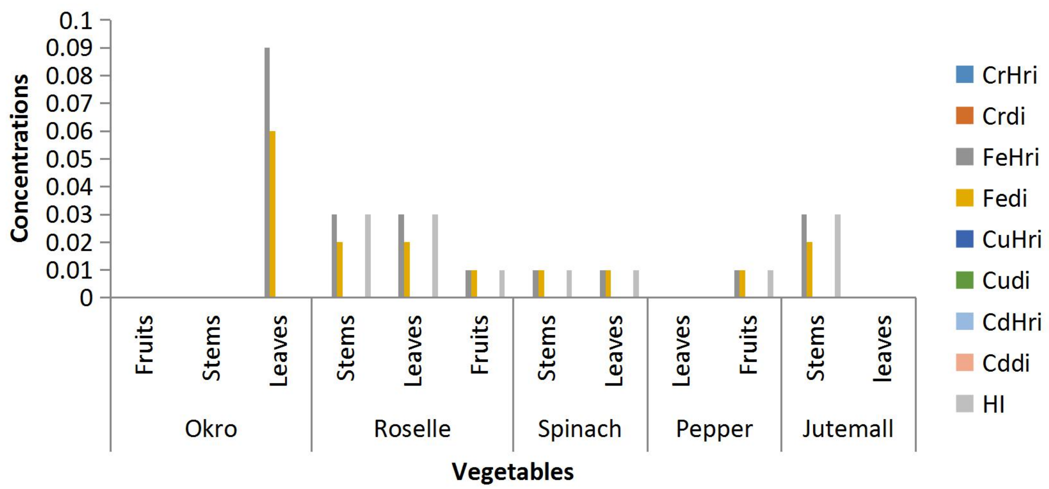

Figure 9: Wet Seasons Indices in Adults for Clearwater Plots (Control plots)

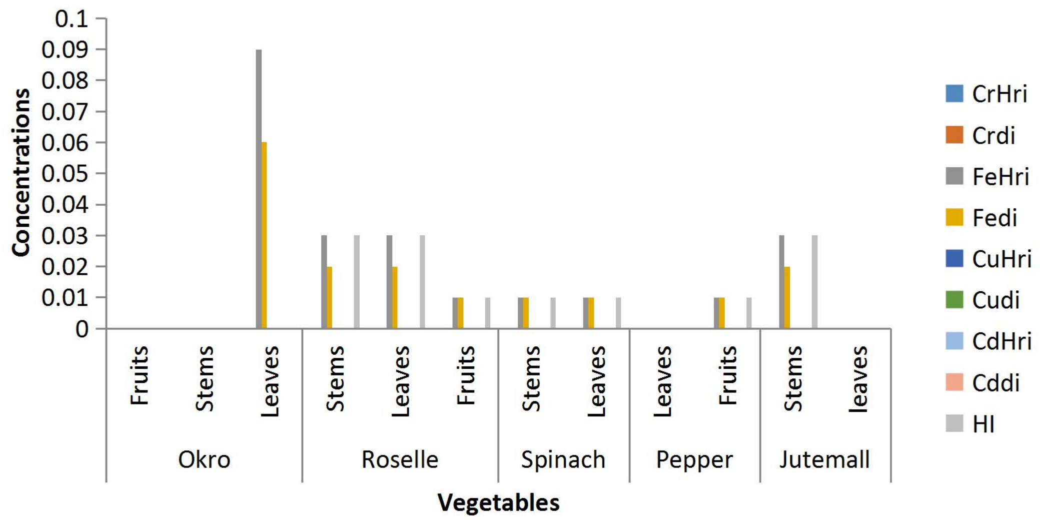

Figure 10: Wet Seasons Indices in Children for Clearwater Plots (Control plots)

Based on the levenes degree of significance, that is < 1 is not significance and 1 is significance the one-way ANOVA test shows that concentrations of heavy metal are significant in some vegetables while some are not concerning season's interactions. The differences in the concentration of heavy metals in plant parts may be due to their physiology and ability to take up or remove metals from the soil and or store the metals in their various tissues as reported by (Aora et al., 2008; Kalaskar, 2012 and Akan et al., 2013). The analysis also indicated that the concentrations of Fe, Cu, Cr and Cd varies with the plant parts, though values are below the tolerable limit as contained in FAO/WHO, 2007, 2010 and USEPA, 2010 standards. The concentration of and iron, chromium and cupper are significantly difference in stems and leaves of Okra while only iron and cupper concentrations are significant in the fruits. Also, concentrations of Cr, Fe, and Cu are significantly different in stems, roots and leaves of Roselle with Cd is not significant in any of the parts. In stems of spinach, only Cr, Fe, and Cu concentrations are significant while Cd is not. While in the leaves, Fe and Cd concentrations show significance. In the leaves and fruits of pepper, it's only Cd concentration that is not significant. The same applies to stems of Jute mallow except for the leaves where concentrations of Cr and Cd are not significantly difference. These are as presented in Table 3.

Table 3: Mean of Metals (mg/kg) in Vegetables in Dry Season for Wastewater Plots

VEGETABLES		Cr	Fe	Cu	Cd
Okra	Fruits	0.50*	3.25**	2.75**	0.08*
	Stems	7.07**	14.24**	25.24**	0.07*
	Leaves	13.75**	227.74**	57.10**	0.10*
Roselle	Stems	82.50**	48.75**	24.06**	0.22*
	Leaves	3.75**	97.06**	5.06**	0.24*
	Fruits	5.1**	22.07**	4.00**	0.12*
Spinach	Stems	94.25**	52.74**	36.50**	0.03*
	Leaves	0.50*	37.74**	0.10*	1.10**
Pepper	Leaves	111.75**	39.51**	18.75**	0.21*
	Fruits	6.74**	28.25**	2.75**	0.10*
Jute/mallow	Stems	9.06**	211.10**	42.51**	0.31*
	Leaves	0.10*	6.10**	6.07**	0.14*

Results are mean difference *Not significant < 1 **significant within the columns at 99% confidence level.

Rainy season's heavy metals accumulation in plant parts were the list compared to the dry season based on the ANOVA test. This might be because excess rainwater or irrigation washes heavy metals and other elements present in the soil below the root zone of plants as also reported in (Bichi and Bello, 2013). Table 4 is the ANOVA result of heavy metals accumulation in parts of plants under study. In okra leaves, Cu and Fe concentrations are significantly difference, while Cr, Cu and Fe concentrations are significantly difference in its stems and leaves. The concentrations of Fe and Cu in Roselle leaves and stems are significantly difference, while and Fe concentrations is significant in the fruits. In spinach stems, Fe and Cu concentrations are significantly difference, while only Fe concentrations is significant in other parts. Fe concentration is confirmed to be significant in leaves and fruit of pepper. However, the concentrations of Fe and Cu are also found to be significantly difference in stems and leaves of Jute mallow.

Table 4: Mean of Metals (mg/kg) in Vegetables in Wet Season for Wastewater Plots

VEGETABLES		Crm	Fem	Cum	Cdm
Okra	Fruits	0.10*	3.07**	1.24**	0.08*
	Stems	5.51**	10.25**	4.24**	0.02*
	Leaves	11.10*	215.74*	26.75*	0.03*
Roselle	Stems	0.00*	35.75**	9.06**	0.00*
	Leaves	0.00*	61.07**	1.50**	0.00*
	Fruits	0.00*	22.02**	0.10**	0.00*
Spinach	Stems	0.00*	20.24**	5.50**	0.00*
	Leaves	0.15*	4.51*	0.04*	0.00*
Pepper	Leaves	0.00*	8.75**	0.51**	0.00*
	Fruits	0.00*	25.54**	0.50*	0.00*
Jutemallow	Stems	0.00*	47.40**	12.06**	0.00*
	Leaves	0.04*	3.50**	4.74**	0.00*

Results are mean difference *Not significant < 1**significant = 1.

4. **Conclusion**

The study investigated intake rate, health risk index and hazard index from consumption of vegetables irrigated with wastewater. The result showed that heavy metal concentrations in some of the vegetable tissues are within the tolerable range, most especially those raised during the wet season. The heavy metal concentration in vegetables grown (dry season) is also within the acceptable limit. However, it is advised that only those grown during wet season be consumed because of heavy metals build-up.

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