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ORIGINAL RESEARCH ARTICLE

ASSESSMENT OF HEAVY METALS UPTAKE BY VEGETABLES CULTIVATED ON SOIL RECEIVING INDUSTRIAL WASTEWATER IN MINNA, NIGERIA

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ABSTRACT
Consumption of vegetable crops grown on soil irrigated with industrial wastewater has been the order of the day in most urban towns and cities of Nigeria, despite reports of its serious health impact. This study assessed the possibility of uptake of heavy metals by crops grown on soil receiving industrial wastewater during rainy and dry seasons. The crops investigated are Spinach, Cayenne Pepper, Jute mallow, roselle and lady's fingers okra. The initial composition of the wastewater was analyzed to contain 0.89 mg/l of chromium, 0.74 mg/l of cadmium, 1.04 mg/l of copper and 2.81 mg/l of iron. Control water used for this experiment contain no trace of any of these heavy metals. The experimental soil was also analyzed and contained 0.10 mg/kg of chromium, 0.06 mg/kg of iron before irrigation in dry season. After irrigation at the wastewater plots, the heavy metal concentrations in soil had increased to 6.24 mg/kg of chromium and 7.50 mg/kg of iron. In wet season, the concentrations of heavy metals in the soil were 0.00 mg/kg of chromium and 2.32 mg/kg of iron before irrigation. After irrigation in wet season, the concentrations increased to 6.01 mg/kg of iron. Mean difference of heavy metal concentrations were significantly high in vegetables in dry season, with values ranging from 0.03 mg/kg to 211mg/kg in wastewater plots, 0.20 mg/kg to 215 mg/kg in wet seasons wastewater plots, 0.00 mg/kg to 157 mg/kg in dry season. It is however recommended that consumption of vegetables irrigated with domestic/industrial wastewater be strongly discouraged because of its serious health implications.

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1. Introduction

Irrigation is the application of water to soil for the purpose of supplying moisture essential for plant growth (Egharevba, 2009). Irrigation depends basically on the availability of water and water rights. Irrigation leads to accumulation of heavy metals in the soil if wastewater and sewage water are use (Queirolo *et al.*, 2000). Using wastewater to irrigate agricultural land is one of the ways to reuse the

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wastewater from urban and industrial areas (Zegi, 2018). Heavy metals implicated as a result of sewage water includes Cu, Cd, Zn, Pb, Ni, Cr, in food items. Even at low concentrations of heavy metals in sewage effluents, long term uses of sewage often result in built up of these metals in the soil and consequently taken up by plants. Other sources of heavy metals in the soils include industrial and domestic effluents in addition to agricultural applications of fertilizer and pesticides (Singh *et al.* 2009; Kalaskar, 2012).

The reuse of domestic and industrial waste water for plant growth is one of the options during water scarcity, and remains the common sources of water for irrigation of vegetables in most urban towns and cities of Nigeria. It contains an appreciable quantity of plant requirement though are a chief contributor to metal load in irrigated land from wastewater (Rattan *et al.,* 2005; Mahmood and Malik, 2013). This leads to environmental pollution which brings food safety issues and potential health risks due to the accumulation of heavy metals in agricultural soil and plants. It also possesses potential barriers for international trading of food stuff (Cui *et al*., 2004). Most crops irrigated with wastewater are vegetables. Vegetables accumulate heavy metals existing in the environment in their edible and non-edible parts. Intake of vegetables that is contaminated is an important path of heavy metal toxicity to humans (Wang *et al.,* 2005; Rattan *et al.,* 2005 and Osma *et al.,* 2012). 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. 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 important for the safety of the environment and for reducing 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, chemical plants, etc.), domestic emissions, and weathering of building and pavement surfaces (Rattan *et al.,* 2005). Human activities in most cases have introduced potentially hazardous metals to the environment. This is as a result of the industrial revolution and urban development promoting a major threat to ecology and human well-being (Mahmood and Malik 2013). 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 plant, specifically leading to great 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 been assumed that these metals are retained in agricultural soils (Bichi and Bello, 2013).

Despite all the glaring negative 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 paper therefore seek to investigate the heavy metals uptake and accumulation in some selected vegetables leaves, stems and roots in Minna; as well as bringing forth useful recommendations for the farmers, the consumers and the policy makers.

2. Materials and Methods:

2.1 Background and description of the Study Area

Niger state is one of the North-central states in the Guinea Savannah Zone of Nigeria. It is 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 6º 00′ 00′′ E and Latitude 10º 00′ 00′′ N as presented in figure 1. It is characterized 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 ºC and 20 ºC respectively.

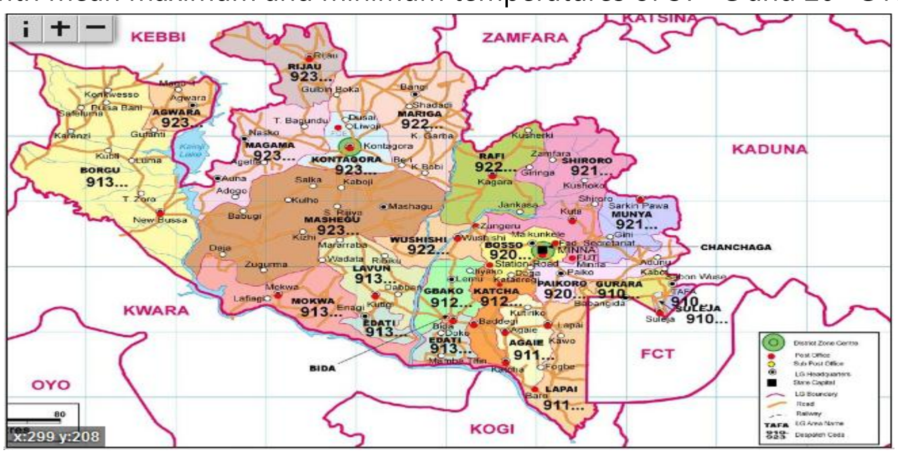

Fig. 1: Map of Niger State showing its boundary with other states of Nigeria

2.2 Experimental Set-up/Arrangements

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 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 set-up is as presented in figure 2.

2.3 Soil and Water Samples collection and Analysis

Samples of water used for irrigation were collected in plastic bottles washed with detergent and distilled water and finally rinsed with the samples were stored at 4ºC before taken to the Chemistry laboratory of Sheda Science and Technology Complex (SHESTCO) Abuja, Nigeria. Soil samples from the selected plots were collected by digging a hole of 15 cm and a representative samples were made by the cone and quarter method after removing unwanted debris. The collected soil samples were then dried in an oven and then sieved, store in a labeled polyethylene bags.

Fig. 2: Experimental Plot Design

2.4 Vegetable Samples Collection

Three hundred grams of edible portion of different vegetables grown at the study area 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 105ºC. These samples were grinded into 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. Dry-ashing process was carried out in a muffle furnace (Swastik Scientific Co.Mumbai, P.14, Se.No 1021) by 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.

2.5 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:

$$TF = C_{plant/}C_{soil} \qquad (1)$$

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).

Health risk index of heavy metals was calculated by knowing the exposure levels of these metals on humans. The statistical package used for analyzing the collected data was SPSS software 22.0, 2006 version. One way ANOVA was used for evaluating the significant difference between heavy metal concentrations in vegetables cultivated on the plots in dry and wet seasons.

3. Result and Discussions

3.1 Result of heavy metal concentration in irrigation water

The concentration of heavy metals in the wastewater samples used for irrigation were higher than their concentration in well water used for irrigation at the control plots, Cadmium (Cd) and chromium (Cr) higher above standard as mentioned in WHO/FAO (2007) and USEPA (2010). However, the Iron (Fe) and copper (Cu) concentrations are within the permissible level set by WHO/FAO (2007). The results are as presented in tables 1 and 2.

Table 1: Results of wastewater heavy metal analysis

Samples	Heavy metal composition (mg/l)				
	Cr	Cd	Mn	Cu	Fe
1	0.19	0.04	0.71	0.04	2.81
2	0.19	0.04	0.71	0.04	2.81
3	0.19	0.04	0.71	0.04	2.81

Table 2: Results of well water heavy metal analysis

Samples	Heavy metal composition (mg/l)				
	Cr	Cd	Mn	Cu	Fe
1	0	0	0.02	0	0
2	0	0	0.02	0	0
3	0	0	0.02	0	

3.2 Heavy Metals Concentrations in the Soil

Concentrations of heavy metals in the soil before and after irrigation are as presented in Tables 3 and 4. Wastewater and well water plots (control plots) in dry season show higher concentrations of iron in both plots while wet season show less sign of heavy metal concentration. However the concentration was even less on the control plots as indicated in table 5. It could be deduced that the availability of these metals in the soil at its original state might have contributed to the uptake of some of these metals before the wastewater application.

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

Sample	Cr^m	Fe^m	Cu^m	Cd^m
Before Irrigation	26.10*	730.06**	0.26*	0.00*
After Irrigation	76.24*	777.50**	0.00*	0.02*

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

Table 4: Mean of Metals (mg/kg) in Wet season for Soil Samples at Wastewater Plots

Sample	Fe^m	Cr^m	Cu^m	Cd^m
Before Irrigation	557.32	0.00*	0.00*	0.00*
After Irrigation	496.01	0.00*	0.00*	0.00*

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

3.3 Heavy Metals Concentrations in Vegetables Parts

The ANOVA test shows that concentrations of heavy metals are significant while some are not with respect to season's interactions. The availability of heavy metals in plant parts may be due to the ability of the plant parts to store metals in their tissues, which is in line with the works of Chauhan and Chauhan (2014).

Table 5: Mean of Metals (mg/kg) in Dry Season for Soil Samples at well water Plots (Control plots)

Sample	**Cr^m**	**Fe^m**	**Cu^m**	**Cd^m**
Before irrigation	25.10*	730.24*	0.26*	0.00*
After irrigation	20.10*	71.240.26*	0.00*	0.00*

The differences in the concentration of heavy metals in plant parts may also be due to their physiology and ability of the individual plants to take up, remove and store the metals in their various parts. This result also conforms to the results obtained by Arora *et al.,* (2008), Kalaskar, (2012) and Akan *et al.,* (2013) who had a similar work and found out those different concentrations in vegetables grown using different sources of water. The concentration of heavy metals like Fe, Cu, Cr and Cd varies with the plant parts, but all are below the tolerable limit as stated by FAO/WHO, (2010) and USEPA, (2010) standards. Rainy season's accumulations were the list compared to the dry season analyzed. This might be due to the rain water that washes the heavy metals in the soil and wastewater below the root zone. Okra leaves, pepper leaves and fruits irrigated with wastewater are seen to have accumulated higher concentrations of metals investigated. This is also in line with the works of Bichi and Bello (2013) in Kano, Nigeria and Singh *et al.*, (2010) in India which confirmed that vegetables have different accumulation capacity.

3.4 Transfer Factor of Metals

Transfer factors of metals in vegetables grown using industrial/municipal wastewater is the ratio of concentration in plant tissues to the concentration of pollutant in the soil. As shown in figures 3 – 6, transfer factors of metals from soil to plant were found to be higher in dry season at wastewater plots with the values greater than 1, indicating that bioaccumulation has taken place while the values less than 1 indicates that bioaccumulation has not taken place (Akpofure, 2012).

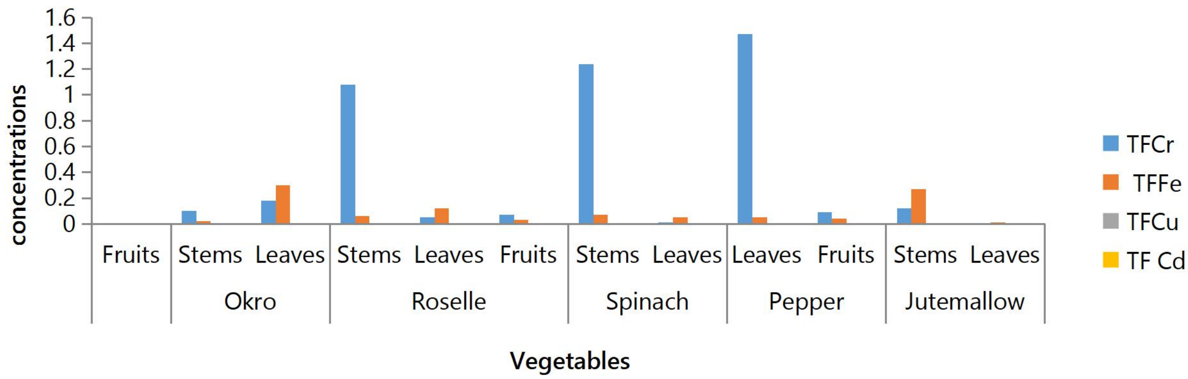

Fig 3: Transfer Factor (TF) of Metals (mg/kg) in Dry Season for Wastewater Plots

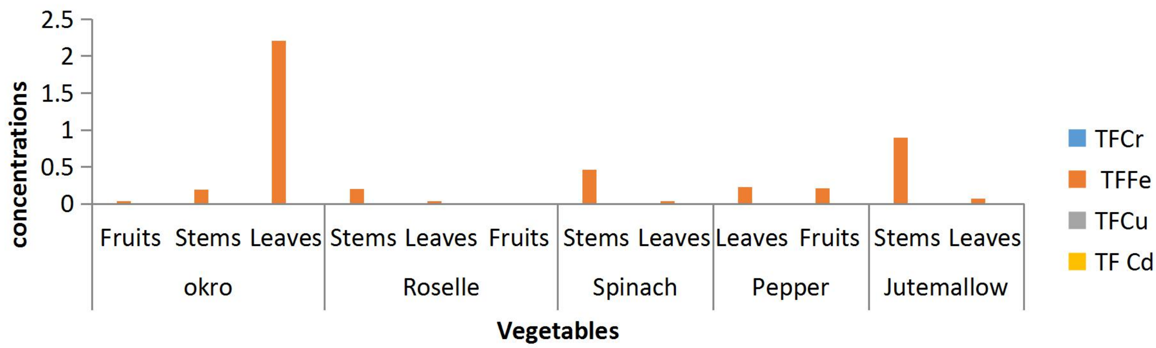

Fig 4: Transfer Factor of Metals (mg/kg) in Wet Season for Wastewater Plots

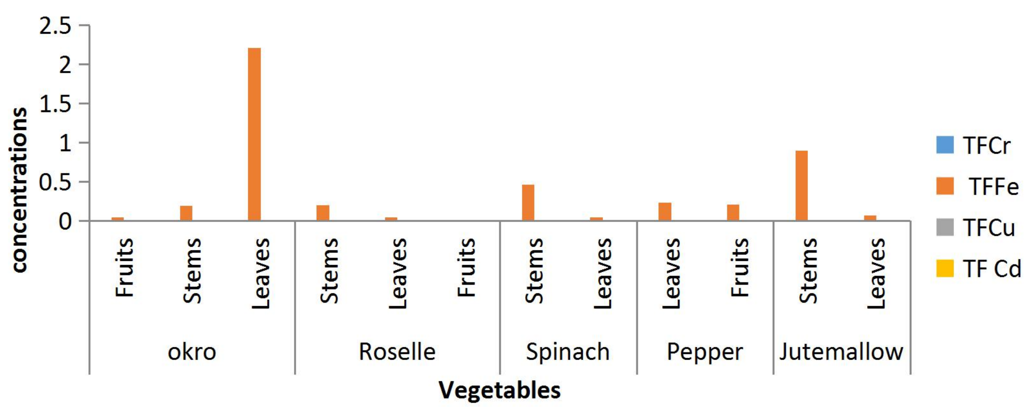

Fig 5: Transfer factor of Metals (mg/kg) in Dry Season for well water Plots (Control plots)

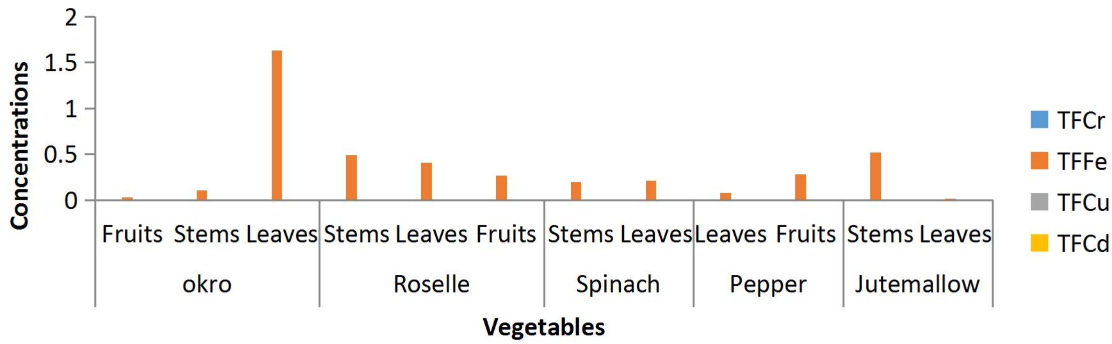

Fig 6: Transfer factors of Metals (mg/kg) in Wet Season for well water Plots (Control Plots).

Chromium was found to be highly transferred with values that ranges from 0.01mg/kg to 1.47mg/kg with non-edible parts having the highest except for Roselle fruits that has a value of 0.07mg/kg. Iron was found to be present in all the vegetable parts analyzed with a range of 0.01mg/kg – 0.27mg/kg. The transfer value of Copper and Cadmium were negligible, and could be due to the inability of the crops to absorb the element in dry season due to the soil pH. In comparing the transfer factors of the studied elements in vegetables parts, the transfer factor for leaves was higher than the other parts signifying that bioaccumulation will occur first in leaves before other parts. This outcome is in accordance with that of Akpofure (2012). From the wastewater plots in which irrigation was supplementary during the wet season, iron were found to have higher transfer factor with a value that ranges from 0.01mg/kg to 0.43 mg/kg with leaves of Okra been the highest; however, the transfer factors of chromium, copper and cadmium were negligible. Consequently in dry season iron has the highest transfer factor in the control plots with a value that ranges from 0.00 mg/kg to 2.21mg/kg, while chromium, copper and cadmium were also negligible. This might be due to the important of iron in chlorophyll of vegetables. Result also showed that iron has the highest transferred factor with a range of 0.02 mg/kg to 1.63 mg/kg in the leaves of okra in the well water plot during the rainy season, while copper, chromium and cadmium were negligible. Plots of transfer factors are as shown in figures 3, 4, 5 and 6 in the appendix pages. On metal toxicity in all the seasons for all the plots considered, wet seasons and dry season well water plots (Control plots) were found to be the safest.

4. Conclusions

The assessment of heavy metals uptake by vegetables cultivated on soil receiving industrial wastewater in Minna, Nigeria was successfully carried out during the 2016/2017 wet and dry seasons. Concentrations of heavy metals were found to increase after the application of the domestic/industrial wastewater for irrigation on the plots. Uptake of heavy of heavy metals like iron, chromium and cadmium by vegetables was also identified, most especially on the leaves of the plant. This is an indication that the population who consume such vegetables might have health related problems since such metals are harmful to human season. It is however recommended that in as much as vegetables are very vital to human health, the growing processes must be done with qualitative and quantitative water.

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