# ACCUMULATION OF HEAVY METALS IN VEGETABLES GROWN ON FARMLANDS IRRIGATED WITH TREATED SEWAGE EFFLUENT

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**Abstract:** Soil and vegetables (lettuce, carrots, and garden egg) were collected fromfarmlands irrigated with treated sewage effluent from Durumi area of Abuja, Nigeria. Heavy metal ions were quantified using atomic absorption spectrometry (AAS). The levels of Zn (4.93 ± 0.10 mg/Kg) at Durumi III, Ni (3.90 ± 0.10 mg/Kg) and Mn (3.95 ± 0.10 mg/Kg) at Durumi II, and Cu (0.96 ± 0.10 mg/Kg) at Durumu I were highest in soil. Highest Zn (2.40 ± 0.01 mg/Kg) and Cu (0.45 ± 0.00 mg/Kg) concentrations in carrots were recorded at Durumi II and Durumi I, respectively. The most accumulated metals in garden egg were Zn (2.30 ± 0.01) and Cu (0.35 ± 0.10 mg/Kg) at Durumi II, and Ni (1.33 ± 0.01 mg/Kg) and Mn (1.15 ± 0.01 mg/Kg) at Durumi III. Lettuce at Durumi II accumulated the highest metal concentrations. Metal concentrations in soil and vegetables varied in the order of Zn > Mn > Ni > Cu > Pb and Zn > Ni > Mn > Cu > Pb, respectively. Carrots accumulated the highest metal concentrations, and the least in lettuce. Cd was the most mobile metal, while Pb the least. Soil-vegetable metal correlations for Pb (0.9584) in carrots and lettuce at Durumi I, Zn in carrots (0.9701) and Mn in lettuce (0.9701) at Durumi III were positively strong. Metal contents in vegetables and soil were not significantly ($p \leq .05$) different. Metal levels in irrigated soil and vegetables were within the FAO/WHO acceptable limits for irrigation and consumption, respectively.

**Keywords:** Heavy metals, sewage, effluent, irrigated soil, vegetables, transfer factor.

## Introduction

Vegetables form the major component of most African dishes, providing themost needed nutritional needs of the consumers, such as minerals, vitamins, iron, calcium, protein and other nutritional requirements (Habib *et al*., 2012; Tsafe *et al*., 2012; Subramani *et al*., 2014). Vegetables accumulate both essential and toxic elements at wide range of concentrations (Akan *et al*., 2009; Salawu *et al*., 2015; Bukar *et al*., 2016). Some metals including Cd, AS and Cr are known to be mutagens or carcinogens (Al-musharafia *et al*., 2013; Abdulraheem *et al*., 2015). Food chain contamination is one of the important pathways for the entry of toxic pollutants into the human body (Zhangren *et al*., 2012; Denbachew *et al*., 2015; Rolli *et al*., 2016). Cu, Zn, Pb and Cd are environmental elements of most concern that have been often reported to cause contamination of soil and food chains (Preeti and Fazal, 2013; Hossein *et al*., 2016).Plants are important components of ecosystems, asthey transfer elements from abiotic into bioticenvironments (Chojnackaa *et al*., 2005; Krzystof *et al*., 2012).

The bioavailability of elements to plants is controlled by soil and climatic conditions, plant genotype and agronomic management, active/passive transfer processes, sequestration and speciation, redox states, the type of plant root system and the response of plants to elements in relation to seasonal cycles (Kabata-Pendias and Henryk, 1984). Plants take up essential and non-essential elements from soils in response to concentration gradients induced by selective uptake of ions by roots, or by diffusion of elements in the soil (Xuedong *et al*., 2012). Uptake of trace elements from the soil solution by plants occurs when ions are in equilibrium with those located in the solid phase through various reactions, which include adsorption, complexation with organic and inorganic ligands, redox reactions, and precipitation-dissolution reactions (Hough *et al*., 2003; Tukura *et al*., 2013).

Effluents are treated to reduce heavy metal load; nonetheless, some heavy metal levels are transported into the environment (Al-musharafia *et al*., 2013; Mahmood and Malik, 2014). Due to scio-economic conditions in the third-world countries, effluent is used for agricultural purposes (Zhe *et al*., 2014; Shibao *et al*., 2016), especially in the peri-urban areas. Wastewaters carry appreciable amounts of trace toxic metals, and this varies from city to city (AL-Jaboobi *et al*., 2014; Bukar *et al*., 2016). Although the concentration of heavy metals in sewage effluents arelow, long-term use of these waste waters on agriculturallands may resultto elevated levels of the metals in soils (Naz *et al*., 2015). Crops grown on metal-contaminated soils accumulate metals in excess which may causeclinical problems both to animals and human being sconsuming these metal rich plants (Masona *et al*., 2011; Salawu *et al*., 2015).

Food and vegetable crops production and its security is an important aspect of a nation's economic stability. Sincefood chain contamination is one of the major routes forentry of metals into the animal system, monitoring metal levels in contaminated soils, and subsequent uptake by crops has generated a lot of interest. The research was carried out to assess the impact of heavy metals on some vegetables grown on farmlands irrigated with sewage effluent, discharged from domestic and municipal wastes treatment plant.

## Materials and Methods

### *Study area*

Three irrigation farmlands located at Durumi District in Federal Capital Territory, Abuja, Nigeria (Fig. 1) were considered for the study. The three farms where the vegetable crops are grown were irrigated during dry season using treated effluent, mainly from domestic sewage. Irrigation farming has been is carried out in the farm for some years.

### *Sampling and sample preparation*

Carrot *(Daucuscarota),* lettuce *(Lactuca sativa*), garden egg (*Solanum melongena*) and soilsamples were collected from three irrigated farmlands in Durumi district (Fig. 1) in Federal Capital Territory (FCT), Abuja. Surface soil samples were randomly collected at a depth of 1-10 cm from fifteen points in each of the farmland using hand trowel, and then packed into separate envelopes. The soil samples were homogenized to form composite samples for each of the farms, and then air-dried for seven days.

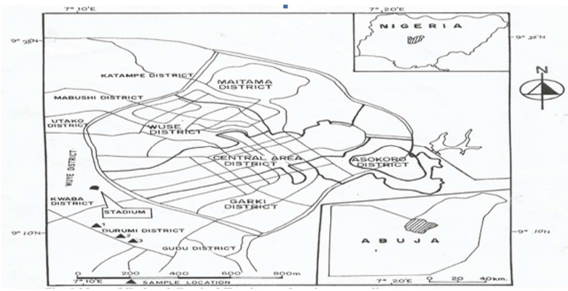


Fig. 1: Sampling locations in FCT, Abuja

***Sample digestion***
***Vegetables***

Digestion of vegetable leaves was carried out using Al-Omran (2010) method. Leaves of each of the vegetables were separated from the crops and dried in an oven at 80°C for 72 h (dry weight). The dry samples were crushed in a mortar and sieved through 1 mm sieve. 0.5 g of the sieved oven-dried sample was weighed into an acid-washed porcelain crucible and placed in a muffle furnace for 4 h at 500°C. The crucibles were removed from the furnace and cooled. 10 mL of 6M HCl was added, covered and heated on a steam bath for 15 min, and then 1 mL of $HNO_3$ was added and evaporated to dryness by continuous heating for 1 h in order to dehydrate silica and completely digest organic compounds. 5 mL of 6M HCl and 10 mL of water were added, and the mixture was heated on a steam bath to complete dissolution. The mixture was cooled and filtered through a Whatman no. 41 filter paper into a 50 mL volumetric flask, then made up to mark with distilled water.

***Soil***

Aqua regia was used for the digestion of soil (Rana*et al*., 2010). 28 $cm^3$ 37% HCl:70% $HNO_3$ (3:1 v/v) was added to 1.00 g of the dried sieved (2 mm) soil sample and left to stand for 24 h. The mixture was then heated on a hot plate at 140°C to near dryness. The residue was filtered through Whatman No. 41, and the solution transferred into 50 mL volumetric flask, made to mark with distilled water. This was preserved for metal analysis. Metal levels in the vegetable crops and soil samples were quantified in duplicates, using atomic absorption stectrophotometer (AA 600 model).

**Metal transfer factor**

Soil to plant metal transfer factor (TF) was computed as ratio of the concentration of metal in plants to that in soil (Hough *et al*., 2003; Tukura *et al*., 2013):

$$TF = \frac{Metal concentration in plant}{metal concentration in soil}$$

**Statistical analysis**

Mean and standard deviations of results were determined. Pearson's correlation analyses were carried out to assess the relationships between metal levels in soil and in vegetable crops. Any significant variations in heavy metal concentrations in soils and vegetable crops were determined using Analysis of Variance (ANOVA). Statistical analyses were performed using SPSS V. 20 software.

**Results and Discussion**

Metal levels in soils from the irrigation farmlands (Table1) indicated that concentrations of Na (14.35 ± 1.00 mg/kg), Ca (61.00 ± 2.00 mg/kg) and Mg (36.25 ± 2.00 mg/kg) at Durumi III, and K (16.60 ± 1.00 mg/kg) in Durumi II were highest. Durumi II also recorded the highest concentrations for Ni (3.90 ± 0.10 mg/kg) and Mn (3.95 ± 0.10 mg/kg). Relatively low levels of metals were recorded at Durumi I, except for Cu and Pb. Metal concentrations in Carrots are presented in Table 2. The levels of Cd (0.03 ± 0.00 mg/kg) and Zn (2.40 ± 0.01 mg/kg) at Durumi II, Pb (0.02 ± 0.00 mg/kg) at Durumi III and Cu (0.45 ± 0.00 mg/kg) at Durumi I were highest. The lowest concentrations of Ni (1.15 ± 0.01 mg/kg) and Mn (1.15 ± 0.01 mg/kg) were recorded at Durumi I and Durumi II, respectively.

**Table 1: Levels (mg/kg) of metal ions in irrigated soils**

| Metal ions | Durumi I | Durumi II | Durumi III |
|---|---|---|---|
| $Na^{+}$ | 13.85 ± 1.00$^{a}$ | 13.70 ± 1.00$^{a}$ | 14.35 ± 1.00$^{b}$ |
| $K^{+}$ | 16.10 ± 1.00$^{a}$ | 16.60 ± 1.00$^{a}$ | 16.25 ± 1.00$^{a}$ |
| $Ca^{2+}$ | 55.60 ± 2.00$^{a}$ | 54.00 ± 2.00$^{a}$ | 61.00 ± 2.00$^{b}$ |
| $Mg^{2+}$ | 28.90 ± 2.00$^{a}$ | 33.50 ± 2.00$^{b}$ | 36.25 ± 2.00$^{c}$ |
| $Cd^{2+}$ | 0.03 ± 0.001$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.03 ± 0.00$^{a}$ |
| $Pb^{2+}$ | 0.04 ± 0.00$^{a}$ | 0.03 ± 0.00$^{a}$ | 0.04 ± 0.00$^{a}$ |
| $Zn^{2+}$ | 4.40 ± 0.10$^{a}$ | 4.83 ± 0.10$^{a}$ | 4.93 ± 0.10$^{a}$ |
| $Ni^{2+}$ | 3.54 ± 0.10$^{a}$ | 3.90 ± 0.10$^{a}$ | 3.65 ± 0.10$^{a}$ |
| $Mn^{2+}$ | 3.63 ± 0.10$^{a}$ | 3.95 ± 0.10$^{a}$ | 3.82± 0.10$^{a}$ |
| $Cu^{2+}$ | 0.96 ± 0.10$^{a}$ | 0.94 ± 0.10$^{a}$ | 0.95 ± 0.10 |

Concentrations of metal ions with the same alphabet within the same row are not significantly ($p \leq .05$) different

**Table 2: Concentrations (mg/kg) of metal ions in carrots**

| Metal ions | Durumi I | Durumi II | Durumi III |
|---|---|---|---|
| $Cd^{2+}$ | 0.02 ±0.00 | 0.03 ± 0.00 | 0.02 ± 0.00 |
| $Pb^{2+}$ | 0.01 ± 0.00 | 0.010 ± 0.00 | 0.02 ± 0.00 |
| $Zn^{2+}$ | 2.15 ± 0.01 | 2.40 ± 0.01 | 2.30 ± 0.01 |
| $Ni^{2+}$ | 1.15 ± 0.01 | 1.30 ± 0.01 | 1.30 ± 0.01 |
| $Mn^{2+}$ | 1.15 ± 0.01 | 1.05 ± 0.01 | 1.15 ± 0.01 |
| $Cu^{2+}$ | 0.45 ± 0.00 | 0.25 ± 0.00 | 0.30 ± 0.00 |

**Table 3: Concentrations (mg/kg) of metal ions in garden egg**

| Metal ions | Durumi I | Durumi II | Durumi III |
|---|---|---|---|
| $Cd^{2+}$ | 0.03 ± 0.00 | 0.02 ± 0.00 | 0.03 ± 0.00 |
| $Pb^{2+}$ | 0.01 ± 0.00 | 0.01 ± 0.00 | 0.01 ± 0.00 |
| $Zn^{2+}$ | 2.15 ± 0.01 | 2.30 ± 0.01 | 2.01 ± 0.01 |
| $Ni^{2+}$ | 1.13 ± 0.01 | 1.23 ± 0.01 | 1.33 ± 0.01 |
| $Mn^{2+}$ | 1.12 ± 0.01 | 1.00 ± 0.01 | 1.15 ± 0.01 |
| $Cu^{2+}$ | 0.30 ± 0.00 | 0.35 ± 0.00 | 0.15 ± 0.00 |

Metal concnrtations in Garden egg (Table 3.) varied according to sites. Cd: DurumI ≈ Durumi III > Durumi II; Zn: Durumi II > Durumi I > Durumi III; Ni: Durumi III > Durumi II > Durumi I; Mn: Durumi III > Durumi I > Durumi II and Cu: Durumi I > Durumi III > Durumi II. Pb levels did not vary greatly in the studied areas. Pb and Cd levels in lettuce (Table 4) did not vary according to sites. The highest concentrations of Zn (2.30 ± 0.01 mg/kg), Ni (1.22 ± 0.01 mg/kg), Mn (1.21 ± 0.01 mg/kg), and Cu (0.23 ± 0.01 mg/kg) were recorded at Durumi II. Cd levels were similar in the studied sites.

**Table 4: Concentrations (mg/kg) of metal ions in lettuce**

| Metal ions | Durumi I | Durumi II | Durumi III |
|---|---|---|---|
| $Cd^{2+}$ | 0.02 ± 0.00 | 0.02 ± 0.00 | 0.02 ± 0.00 |
| $Pb^{2+}$ | 0.01 ± 0.00 | 0.01 ± 0.00 | 0.01 ± 0.00 |
| $Zn^{2+}$ | 2.25 ± 0.01 | 2.30 ± 0.01 | 2.02 ± 0.01 |
| $Ni^{2+}$ | 1.21 ± 0.01 | 1.22 ± 0.01 | 1.20 ± 0.01 |
| $Mn^{2+}$ | 1.10 ± 0.01 | 1.21 ± 0.01 | 1.20 ± 0.01 |
| $Cu^{2+}$ | 0.02 ± 0.01 | 0.23 ± 0.01 | 0.10 ± 0.01 |

**Table 5: Pearson's correlation coefficients for soil to plant metal ion concentrations**

| Metal ions | Carrot | | | Garden egg | | | Lettuce | | |
|---|---|---|---|---|---|---|---|---|---|
| | D I | D II | D III | D I | D II | D III | D I | D II | D III |
| $Cd^{2+}$ | -0.6063 | 1.15E-15 | -0.6006 | -0.4036 | 1.15E-15 | 0.5547 | -0.5718 | 1.15E-15 | -0.2774 |
| $Pb^{2+}$ | 0.9584 | 0.3536 | 0.1689 | -0.0289 | 0.3535 | 0.1688 | 0.9584 | 0.3526 | 0.1688 |
| $Zn^{2+}$ | -0.2611 | 1.60E-14 | 0.9701 | -0.8000 | 1.60E-14 | -0.7080 | -0.1741 | 0.4231 | -0.2691 |
| $Ni^{2+}$ | 0.1066 | 0.1387 | -0.9864 | -0.1066 | 0.1357 | -0.6576 | 0.6652 | -0.8321 | -0.8093 |
| $Mn^{2+}$ | -0.3101 | -0.9176 | -0.5608 | -0.3000 | -0.9176 | -0.7398 | 0.1387 | -0.8679 | 0.8212 |
| $Cu^{2+}$ | -0.5718 | 0.5547 | 0.4160 | 0.0220 | 0.5547 | -0.9707 | -0.2691 | 0.6455 | 0.1890 |

Significant at $p \leq .05$

Concentrations of heavy metals for each of the vegetables in the three sites (Fig. 2) did not vary greatly, except for Cu and Zn levels in lettuce, which were the lowest. The order of heavy metals accumulation in soil was Zn > Ni > Mn > Cu > Cd > Pb. The results obtained in this study were similar to the results reported by various authors (Al-Omran, 2010; Aljaboobi *et al*., 2014; Shibao *et al*., 2016). Zn and Cd levels were also reported to be the highest and lowest, respectively for wastewater irrigated soils in Hirare (Masona *et al*., 2011).

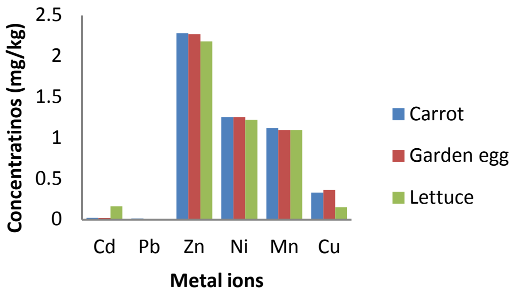


Fig. 2: Variations in mean values of metal concentrations (mg/kg) in vegetable crops

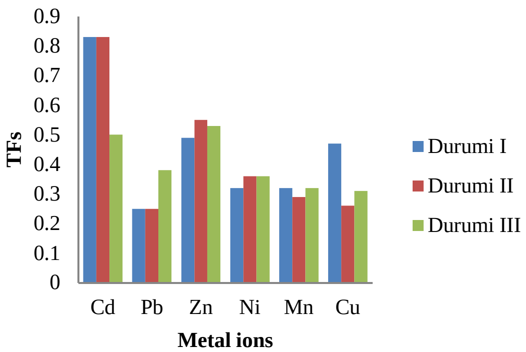


Fig. 3: Transfer factors (TFs) for heavy metals in carrot

Metal transfer factor (TF) from soil to plants is a key module of human exposure to heavy metals via food chain. TF of metals is essential to investigate the human health risk index (Mahmood and Malik, 2014). TF of metals varied in the different vegetables. TFs for heavy metals in Carrot (Fig 3.) did not adhered to any specific trend. TF for Cd was highest in all the sites, except for Cu at Durumi III. TFs for Cd, Mn, and Cu were lowest at Durumi II, while Pb and Zn the highest. From Fig. 4, TFs for Cd in garden egg for all the sites were similar and the highest. TF for Zn and Ni did not vary at Durumi I and II. Pb and Zn TFs increased and decreased from Durumi to Durumi III, respectively, while for lettuce (Fig 5.), Cd, Pb and Cu were highest at Durumi II. Zn TFs decreased from Durumi I to Durumi III. Mn TFs were similar in all the sites. Lack of consistent variations in metal TFs indicates that uptake of metals by crops does not increase linearly with increasing concentrations of metals in soils, which was in agreement with the findings of Al-Omran (2010).

Apparent advantage of this phenomenon is thatalthough long-term sewage irrigation resulted into elevated concentration of metal in soil; the same may not be proportionately transferred to food chain (Musarat *et al*., 2007). The results show that the potential for metal uptake from soil by vegetable varied in decreasing order of Cd >Zn>Ni > Mn>Cu>Pb. This order is in agreement with the results reported by (Rattan *et al*., 2005; Rana *et al*., 2010). Relative efficiency of crops to absorb metals fromsewage-irrigated soil occurred in theorder of carrots > garden egg > lettuce. Transfer quotient of 0.1 indicates that plant is excluding the element from its tissues.For transfer coefficient greater than 0.50, greater are the chances for the vegetables to be contaminated by heavy metals, due to anthropogenic activities (Alina, 2004). Metal levels in soil and vegetable crops were within the FAO/WHO (2011) irrigation limits and consumption, respectively.

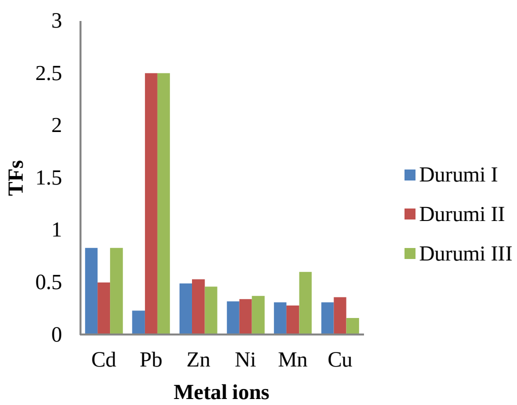


Fig. 4: Transfer factors (TFs) for heavy metals in garden egg

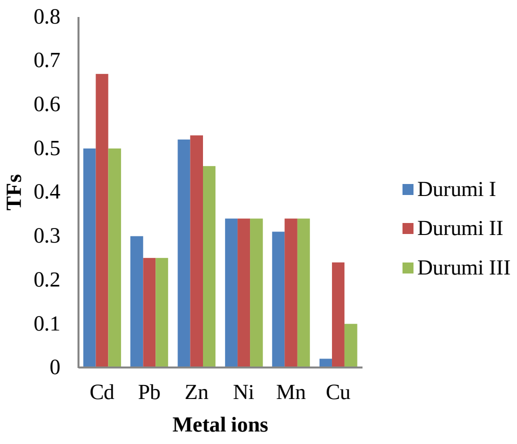


Fig. 5: Transfer factors (TFs) for heavy metals in lettuce

Correlation coefficients between metal concentrations in soil and vegetables are presented in Table 5. Pb in carrots and lettuce from Durumi I correlated strongly (0.9554), and also Mn in lettuce (0.8212) at Durumi III. Correlations for Cu in carrots (0.5547) and lettuce (0.6455) at Durumi III were moderately strong. Ni also correlated moderately in lettuce at Durumi I. Correlation for Zn (0.9701) in carrots at Durumi III was very strong. Negatively strong correlations were observed for Ni in carrots (-0.9864) at DIII, Mn (-0.9176) and Cu (-0.9864) in garden egg at Durumi II. Strong and positive correlations could serve as reliable predictions of crop uptake. Negative correlations entails that metal contents were not in the toxic range, which might be attributed to the strong ability of the root tissues to retain the metals from the soil against their transport to shoots (Rattan *et al*., 2005).

ANOVA (Table 1) show that metal concentrations in irrigated soils not significantly ($p \leq .05$) different, except for Mg in all the farms, and Na and Ca at Durumi III. Heavy metal concentrations in the vegetable crops from each of the sites (Tables 2-4) were also not significantly ($p \leq .05$) different.

**Conclusion**

Zn and Pb levels in the irrigated soil were highest and lowest, respectively. Zn and Cd demonstrated stronger transfer capabilities in the soil-plant system, therefore, were likely to become more accumulated in the vegetables. Relative efficiency of crops to absorb metals fromsewage-irrigated soil occurred in theorder of carrots > garden egg > lettuce. Concentrations of heavy metals for each of the vegetables in the three sites were not significantly different. Metal concentrations in soils and the vegetable crops were also not significantly ($p \leq .05$) different, except for Mg in all the farms, Na and Ca at Durumi III. Heavy metal contents in soil and vegetables were within the FAO/WHOacceptable limits for irrigation and consumption, respectively.

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