
Health Risk Assessment of Heavy Metals Accumulation in Tomatoes Irrigation Farms at Kwadon, Gombe, Nigeria

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ABSTRACT

This study determined the levels of heavy metals in soils and tomatoes, and assessed the health risk via consumption of tomatoes grown by the irrigation at Kwadon, Gombe, Nigeria. A total of 45 soil and tomato samples were collected and analyzed for Mn, Cd, Ni, Cr, Pb, Cu and Zn using Atomic Absorption Spectrophotometer (ASS). The results were subjected to further assessment; Transfer Factor (TF), Daily Intake of Metals (DIM) and Health Risk Index (HRI). The results showed that the mean concentrations ranged from (1.91 to 2.99 mg.kg⁻¹) Mn, (2.21 to 3.00 mg.kg⁻¹) Cd, (0.31 to 0.42 mg.kg⁻¹) Ni, (0.40 to 0.51 mg.kg⁻¹) Cr, (0.99 to 1.44 mg.kg⁻¹) Pb, (0.88 to 1.00 mg.kg⁻¹) Cu and (3.15 to 4.30 mg.kg⁻¹) Zn in soil samples and were all found to be below the World Health Organization (WHO, 1996) and Department of Petroleum Resources standards (DPR, 2002) except Cd higher than recommended value; while the values recorded for tomatoes ranged from (0.99 to 1.00 mg.kg⁻¹) Mn, (0.98 to 1.09 mg.kg⁻¹) Cd, (0.08 to 0.11 mg.kg⁻¹) Ni, (0.12 to 0.22 mg.kg⁻¹) Cr, (0.68 to 0.71 mg.kg⁻¹) Pb, (0.43 to 0.54 mg.kg⁻¹) Cu and (1.99 to 2.13 mg.kg⁻¹) Zn. The values of TF obtained from this study were decline in the following order: Cu > Zn > Pb > Mn > Cd > Cr > Ni. The DIM and HRI values of studied heavy metals in all the studied sites were found to be < 1, this indicated no probable adverse health effects to exposed population.

Keywords: Assessment, Daily Intake, Health Risk, Tomatoes, Transfer Factor

INTRODUCTION

Tomato is one of the world's most cultivated vegetable with a worldwide production of 129,650,000 tons, grown in almost all parts of the world and make about 10% of total vegetables. Tomatoes fruits are usually eaten raw as whole in salad, cooked in sauces, soups, meat and fish dishes or consumed as pastes (Shi and Emaguer, 2000). Tomatoes varieties have been classified due to fruit weight and size, the weight of usual egg shaped or round tomatoes is 80 to 100 g, at a size of 47 to 67 mm, the small sized cherry tomatoes are only 16 to 25 mm of size and 8 to 25 g of weight and big fruit varieties form fruits of up to 250 g (Krug *et al.*, 2002). Tomatoes contains many anti-oxidants, essential nutrients and secondary metabolites such as organic acids, vitamin C and E, lycopene, beta-carotene, chlorophyll and flavonoids which are important for human health (Giovannelli, 2010). However, several studies revealed that fruits and leafy

vegetables are vulnerable to heavy metals contamination from air, water and soil. The contamination of these vegetables with heavy metals derives primarily from contaminated soil (Gunduzet *et al.*, 2012).

Soil contamination by heavy metals is one the serious environmental problem and has significant implications for human health and animals (Moore *et al.*, 2009). The transfer of these heavy metals from soil to plants has been documented by several researchers (Mahmood and Malik, 2014; Ibrahim and Salem, 2017). Heavy metals get accumulate with time in soils and plants due to irrigation wastewater and absorbed minerals settle in edible tissue of the vegetables (Lokeshwari and Chandrappa, 2006), this metal are non-biodegradable and accumulate when it get to human through the food chain. The consumption of these vegetables produced in contaminated areas, in addition to ingestion or inhalation of contaminated particles from various emissions, are two principal factors contributing to human exposure to heavy metals (Zhuang *et al.*, 2008; Ogbonna and Okezie, 2011). Therefore, health risk assessment of heavy metals in vegetables is necessary in order to ascertain the safety of the vegetables consumed. This study aims to determine the levels of heavy metals in soil and tomato samples, and assessed the health risk exposure via consumption of these tomatoes.

MATERIALS AND METHODS

Study Area

Kwadon is located about 9 km on Gombe-Biu road in Yamaltu-Deba local Government area of Gombe State, Northeastern Nigeria. It is situated between latitudes $10^{\circ}27$ N and between longitudes $11^{\circ}28$ E and 306 M altitude above sea level in the northern Guinea Savannah ecological zone of Nigeria. The study area falls into Guinea savannah climate. The climate is tropical with two distinct seasons; a rainy season (May-October) and a dry/harmattan season (November-April) with 30.5°C and 62.5 mm mean annual temperature and precipitation respectively, and with the relative humidity ranged from 58% to 72% annually.

Sample Collection

The soil samples were collected from five different farms, 100 g of composite soil samples were collected around the roots of the plants from each sampling sites where the plants were uprooted using plastic spade vertically from 0-15, the samples were air dried and kept in tightly closed clean sample bottles till analysis.

The tomatoes were also collected from five farmlands, each farmland was divided into four, and three tomatoes were randomly collected. The samples were washed with tap and followed by double washing with distilled water placed into separate polythene bags and labelled according to the farmland number. They were then taken to the laboratory for preparation and analysis. A total of 45 samples of both soil and tomato were collected for the study.

Determination of Physico-chemical Properties

The physico-chemical parameters determined were pH, electrical conductivity, organic matter and soil texture. The pH was determined using WTW pH Electrode, conductivity was determined using a CO150 conductivity meter, soil organic matter (OM) was determined by the potassium dichromate titrimetric method and the soil texture was determined by using hydrometer test.

Digestion Procedures

The air-dried soil samples were crushed in a mortar with pestle and sieved through 2 mm mesh standard sieve. 2.5 g were digested in 10 mL freshly prepared aqua regia, (3:1 HCl: HNO₃) and placed on a hot plate at 95 °C for 1 h. The sample was then diluted to 50 mL using deionized distilled water and was left to settle overnight. The total concentrations of Mn, Cd, Ni, Cr, Pb, Cu and Zn were then determined, using Atomic Absorption Spectrophotometer (AAS). The tomato samples were cut into smaller pieces with a plastic knife. The samples were put in different crucibles and ash in a furnace at 650 °C for two hours. (0.4 g) of ash from each plant sample was weighed separately into a beaker. To each, 3 mL of concentrated HCl and 1 mL of concentrated HNO₃ were added, and heated on a hot plate at 100 °C for 10 minutes to destroy any oxidizable materials and carbonates. The solutions were added with deionised water to the 30 mL mark and filtered using a Whatman filter paper. The filtrate were analysed for the presence of heavy metals.

Quality Control Analysis

Quality control measures were taken to ensure reliability of the study results. Standards were prepared for each heavy metal from their stock solution to calibrate the instrument. The percent recovery obtained ranged from 98.0% to 100% and 95.8% to 101% for soil and tomato, respectively. The samples analysis was replicated three times.

Statistical Analysis

The data obtained were statistically analyzed using SPSS software version 20, and one way ANOVA was used to compare the mean values obtained from different sampling sites at $p < 0.05$. Pearson correlation of different metals in soil and tomato samples was also calculated.

Transfer Factors (TF)

Transfer factor is the ratio of the concentration of heavy metals in a plant to the concentration of heavy metals in soil. It is also the relative ability of a metal to be accumulated in roots and edible tissue of plant, which was calculated by using the following equation:

$$TF = C_p / C_s \quad (1)$$

Where: C_p is concentration of heavy metals in plants and C_s is concentration of heavy metals in soil.

Daily Intake of Metal (DIM)

The daily intake of metals (DIM) was calculated to averagely estimated the daily metal loading into the body system of a specified body weight of a consumer which informs the relative phyto-availability of metal (Mahmood and Malik, 2014; Ftsum and Abraha, 2018).

The daily intake metals (DIM) was determined using the following equation:

$$DIM = C_m \times C_f \times D_{ft} / B_w \quad (2)$$

Where: C_m is heavy metal concentrations in plants (mg.kg^{-1}), C_f factor is conversion factor (0.085), D_{ft} food intake is daily intake of vegetables, B_w is average body weight (kg). B_w values employed in this study were obtained from (WHO, 2007).

Health Risk Index (HRI)

The health risk assessment is a multi-step procedure that comprises of data collection, gathering and analyzing the site data relevant to human health (Sulaiman *et al.*, 2016). The health risk index (HRI) was determined using the following equation:

$$\text{HRI} = \text{DIM}/\text{R}_{\text{fd}} \quad (3)$$

Where: DIM is daily intake of metals and R_{fd} is reference oral dose. R_{fd} values employed in this study were obtained from (US-EPA IRIS, 2006).

If the value of HRI is less than 1 then the exposed population is said to be safe (US-EPA IRIS, 2003).

RESULTS AND DISCUSSION

Physico-chemical Properties

The physico-chemical properties of the soil samples are presented in Table 1. The pH values observed in all the studied soil samples ranged from 6.90 to 7.5. The cation exchange capacity of soil samples ranged from 19.51 to 21.54 in all the studied samples. The soil samples recorded organic carbon percentage ranged from 1.58 to 2.11 %. The soil organic matter is important for the retention of metals by soil solids, thus decreasing mobility, however at lower pH, metals tend to be more soluble and mobile in soils (Nachtergaele *et al.*, 2002). The percentage of soil texture ranged from 78.29 to 75.60 % sand, 3.43 to 4.76 % silt and 17.36 to 19.23 % clay. The texture of the studied soil samples were all found to be sandy loam.

Table 1: Physico-chemical properties of the soil samples in the study areas

Locations	pH	OC%	CEC	Sand%	Silt%	Clay%	Texture
F1	7.50±0.10 ^b	1.61±0.01 ^a	19.51±0.11 ^b	78.26±0.32 ^c	4.45±0.63 ^b	17.36±0.20 ^a	SL
F2	7.43±0.05 ^b	1.58±0.04 ^b	20.42±0.54 ^a	77.93±0.15 ^c	3.43±0.05 ^a	18.63±0.11 ^b	SL
F3	6.90±0.10 ^a	2.11±0.01 ^c	21.54±0.15 ^c	75.60±0.10 ^a	5.16±0.05 ^c	19.23±0.05 ^c	SL
F4	6.90±0.15 ^a	1.80±0.00 ^a	19.67±0.02 ^d	78.29±0.10 ^c	4.33±0.15 ^b	17.46±0.15 ^a	SL
F5	7.36±0.11 ^b	1.70±0.00 ^{ab}	19.99±0.01 ^c	76.43±0.05 ^b	4.76±0.15 ^d	18.80±0.10 ^b	SL

F = Farm, CEC = Cation exchange capacity, OC = Organic Carbon, SL = Sandy Loam

Concentration of Heavy Metals in Soils

The mean concentration of heavy metals in soil samples are presented in Table 2. The mean concentration of the analysed metals in the study was compared with maximum allowable limit set by World Health Organization (WHO, 1996) and Department of Petroleum Resources (DPR, 2002) standards. The results showed that the mean concentrations ranged from 1.91 to 2.99 mg.kg⁻¹ Mn, 2.21 to 3.00 mg.kg⁻¹ Cd, 0.31 to 0.42 mg.kg⁻¹ Ni, 0.40 to 0.51 mg.kg⁻¹ Cr, 0.99 to 1.44 mg.kg⁻¹ Pb, 0.88 to 1.00 mg.kg⁻¹ Cu and 3.15 to 4.30 mg.kg⁻¹ Zn. The concentration of Zn was found to be with the maximum value of (4.30 mg.kg⁻¹) in sample from F2, followed by the concentrations of Cd, Mn, Cu, Pb, Cr and Ni in all the studied samples. The highest concentrations of Mn and Ni were also found at F2; Cd and Cu at F3; Cr at F5 and Pb at F1 in the soil samples. The values obtained from the study were found to be below the set standard except Cd which was higher than (0.8 mg.kg⁻¹) standard for both WHO and DPR allowable limits. Cadmium is extremely toxic; the use of soil with high cadmium for the cultivation of vegetables and other food crops could cause adverse health effect to consumers such as cancer

and renal disease (Gorenc *et al.*, 2004; Amadi *et al.*, 2017). It is also reported that at high concentrations heavy metals in soil have strong toxic effects on plants which resulted in yield depression, weak growth, disorders in plant metabolism and reduced nutrient uptake (Ibrahim *et al.*, 2014). Moreover, the value of Cd recorded in this study was higher than the values reported by Ndinwa *et al.* (2014). The results of Cd, Cr and Pb in this study were also higher than the values reported by Ibrahim and Salem, (2017). However, the maximum concentrations of Pb, Cu, Ni, Zn, Cr and Mn values obtained in this study were lower than the values reported by Bassey *et al.* (2014).

Table 2: Mean concentration of heavy metals (mg.kg⁻¹) in soil samples

Locations	Mn	Cd	Ni	Cr	Pb	Cu	Zn
F1	2.29±0.01 ^b	2.21±0.01 ^a	0.30±0.01 ^a	0.43±0.00 ^b	1.44±0.01 ^c	0.95±0.00 ^c	3.15±0.00 ^a
F2	1.99±0.01 ^d	2.71±0.58 ^b	0.42±0.01 ^b	0.50±0.00 ^d	1.35±0.00 ^b	0.88±0.00 ^b	4.30±0.01 ^e
F3	1.94±0.04 ^c	3.00±0.01 ^c	0.32±0.01 ^a	0.40±0.01 ^a	1.02±0.02 ^a	1.00±0.01 ^d	3.80±0.00 ^c
F4	2.08±0.00 ^c	2.99±0.01 ^c	0.40±0.00 ^b	0.48±0.00 ^c	1.00±0.01 ^a	0.86±0.00 ^a	3.26±0.04 ^b
F5	2.30±0.00 ^d	2.37±0.00 ^b	0.31±0.01 ^a	0.51±0.00 ^d	0.99±0.00 ^a	0.94±0.00 ^c	4.21±0.01 ^d

Note: Values with the same super script in the same column are not significantly different at $p \leq 0.05$.

Concentration of Heavy Metals in Tomatoes

The mean concentration of heavy metals in tomatoes samples is presented in Table 3. The mean concentration of heavy metals in tomatoes ranged from 0.99 to 1.00 mg.kg⁻¹, 0.98 to 1.09 mg.kg⁻¹, 0.08 to 0.11 mg.kg⁻¹, 0.12 to 0.22 mg.kg⁻¹, 0.68 to 0.71 mg.kg⁻¹, 0.43 to 0.54 mg.kg⁻¹ and 1.99 to 2.13 mg.kg⁻¹ for Mn, Cd, Ni, Cr, Pb, Cu and Zn respectively. The concentration of Mn, Cd, Ni, Cr and Pb were above maximum permissible limit set for vegetables by FAO/WHO, (2011) and Weigert (1991), while Cu and Zn were below permissible limit. Similar study by Lugwisha and Othman, (2016) recorded the concentration of Cu below permissible limit in tomatoes. The results of heavy metals observed in this study varied from one sampling site to another, this may be due to different usage of agro-chemical application and other human activities at each sampling site. The general the trend for heavy metals content in tomato samples was decline in the following order: Zn > Cd > Mn > Pb > Cu > Ni. Results of the one way ANOVA revealed that the heavy metal concentration has significantly difference in tomatoes grown at different sampling site. The concentrations of Pb, Ni, Zn, Cr, Mn and Cu in this study were lower than the values reported by Osama *et al.* (2012) and Ndinwa *et al.* (2018). However, the results obtained in this study were higher than results reported by Fatoba *et al.* (2012). Sager (2017), reported that the levels Cd, Ni, Cr, and Pb were lower and Zn, Mn, and Cu were higher than the values obtained in this study. Similar study by Samuel *et al.* (2018), reported lower Cr concentrations of (0.05 mg.kg⁻¹).

Table 3: Mean concentration of heavy metals (mg.kg⁻¹) in tomatoes samples

Locations	Mn	Cd	Ni	Cr	Pb	Cu	Zn
F1	0.99±0.00 ^{ab}	1.02±0.01 ^b	0.11±0.00 ^b	0.13±0.00 ^{ab}	0.70±0.00 ^b	0.43±0.00 ^a	2.00±0.01 ^a
F2	0.99±0.00 ^c	1.02±0.01 ^b	0.11±0.00 ^b	0.13±0.00 ^b	0.70±0.00 ^a	0.43±0.00 ^c	2.00±0.01 ^c
F3	0.98±0.00 ^a	0.98±0.00 ^a	0.11±0.00 ^b	0.21±0.01 ^c	0.71±0.00 ^b	0.45±0.00 ^a	2.13±0.05 ^a

Locations	Mn	Cd	Ni	Cr	Pb	Cu	Zn
F4	0.98±0.00 ^a	1.01±0.01 ^{ab}	0.08±0.00 ^a	0.12±0.00 ^a	0.67±0.00 ^a	0.60±0.01 ^d	2.12±0.12 ^d
F5	1.00±0.00 ^{bc}	1.09±0.01 ^c	0.08±0.00 ^a	0.22±0.00 ^c	0.70±0.00 ^b	0.50±0.00 ^b	1.99±0.00 ^b

Note: Values with the same super script in the same column are not significantly different at $p \leq 0.05$.

Correlation Analysis

Pearson correlations between the metals contents in the soil and tomato were established using bivariate statistics. The levels of significance ($P < 0.05$) and ($P < 0.01$) of multi-element correlation for soil and tomato samples was evaluated. The significant correlations are marked in bold as presented in Table 4. The correlations of Mn to Cd ($r = -0.672$), Mn to Ni ($r = -0.535$), Cd to Pb ($r = -0.725$), Ni to Cr ($r = 0.467$), Ni to Cu ($r = -0.813$), Cr to Cu ($r = -0.716$) and Cr to Zn ($r = 0.468$) in soil samples, and Mn to Cd ($r = 0.562$), Cd to Ni ($r = -0.510$), Cd to Zn ($r = -0.537$), Cr to Pb ($r = 0.602$), Pb to Cu ($r = -0.879$) in tomato samples. The results indicated that some metal pairs have strong and positive correlations, but most of metal pairs have strong and negative correlations, while other pair metals are having weak and positive correlation ($P < 0.05$) and ($P < 0.01$).

Table 4: Pearson correlation matrix for the heavy metals in soil and tomato samples

Soil Samples							
Metals	Mn	Cd	Ni	Cr	Pb	Cu	Zn
Mn	1						
Cd	-0.672**	1					
Ni	-0.535*	.260	1				
Cr	.338	-.357	.467*	1			
Pb	.209	-.725**	.057	-.020	1		
Cu	.003	.000	-.813**	-.716**	-.118	1	
Zn	-.218	-.205	.199	.468*	-.143	.039	1

Tomatoes Samples							
Metals	Mn	Cd	Ni	Cr	Pb	Cu	Zn
Mn	1						
Cd	.562*	1					
Ni	.268	-.510*	1				
Cr	-.003	.392	-.131	1			
Pb	-.122	-.007	.159	.602**	1		
Cu	.009	.075	-.420	-.384	-.879**	1	
Zn	-.242	-.537*	.238	-.139	-.214	.345	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Transfer Factor (TF) of the Heavy Metals

The transfer factor of the heavy metals from soil to tomato sampled is presented in Figure 1. The transfer factor (TF) refers to the tendency of a metal to migrate from the soil and accumulated in roots and edible tissue of plant. The (TF) values recorded in this study ranged from 0.33 to 0.513 Mn, 0.32 to 0.46 Cd, 0.21 to 0.37 Ni, 0.25 to 0.52 Cr, 0.49 to 0.58 Pb, 0.45 to 0.69 Cu and 0.56 to 0.66 Zn. Cu recorded the highest value of transfer factor in almost all the studied sites followed by Zn. The greater value of 0.50 transfer coefficient, the greater the chances of vegetables for metal contamination by anthropogenic activities (Khan *et al.*, 2009). The transfer factor in this study decline in the order of: Cu > Zn > Pb > Mn > Cd > Cr > Ni. The variation in transfer factors among different samples may be attributed due to differences in metals concentrations in soil samples or fertilizer application and other human activities, and differences uptake by the vegetables (Cui *et al.*, 2004).

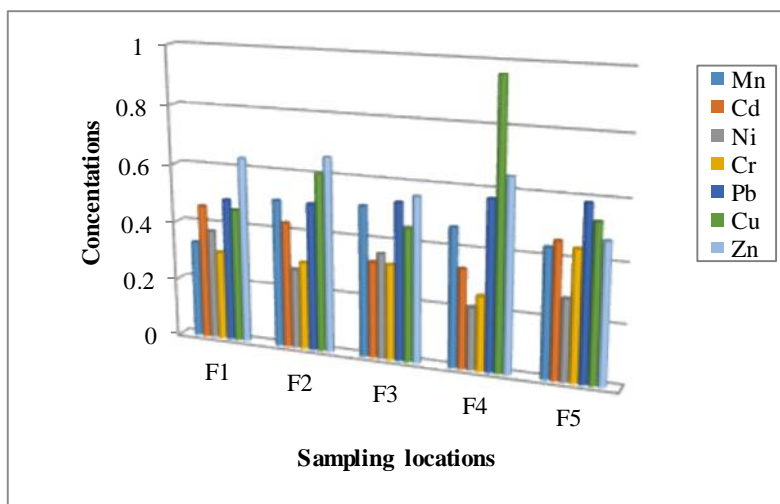


Fig. 1: Transfer factor of the heavy metals from soils to tomatoes

Daily Intake of Metals (DIM)

The daily intakes of metal recorded values are presented in Figure 3. The results of this study were all found to be less than one (< 1) with regard to recorded values of DIM, this values suggest that the consumption of tomatoes vegetable grown in the studied area were safe for consumption. The results was in the following order of Zn > Cd > Mn > Pb > Cu > Cr > Ni. The values of DIM recorded in this were similar to the values reported by Geetanjali and Chauhan, (2014) and Samuel *et al.* (2018).

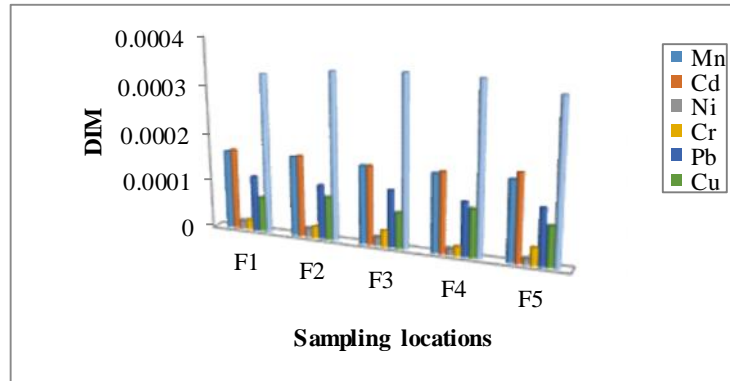


Fig. 2: Daily Intake of Metals (DIM) in Tomatoes

Health Risk Index (HRI)

The Health risk index for heavy metals is presented in Figure 3. The HRI represents the harmful effect of heavy metals to humans in which consume vegetables contaminated with them (Ftsum and Abraha, 2018). If the value of HRI is < 1, populations are safe to eat those kinds of vegetables (Yang *et al.* 2012). The study showed HRI to be less is < 1, suggest that the consumption of tomatoes in the area of study is acceptable, and is free of risks for all studied heavy metals.

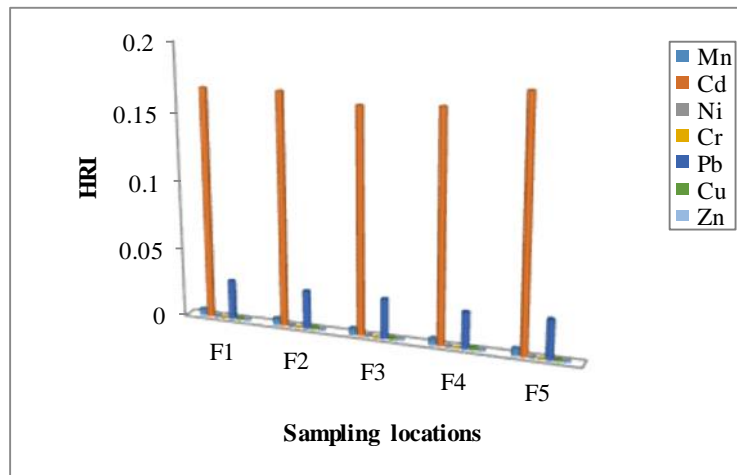


Fig. 3: Health Risk Index (HRI) in Tomatoes

CONCLUSION

Soil, tomato were collected from Kwadom, Gombe. These samples were analyzed for metals such as for manganese, cadmium, nickel, chromium, lead, copper and zinc. Heavy metal levels in soils were within the standard expects cadmium, while that of tomato were higher standard limit. The values of TF obtained from this study were decline in the following order: Cu > Zn > Pb > Mn > Cd > Cr > Ni. The finding of this study regard to DIM and HRI showed that their values were less than one, this suggest that the consumption of tomatoes in the area of study is free of risks for all studied heavy metals.

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