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RESEARCH ARTICLE

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Field Accumulation in Selected Heavy Metal Ions and Associated Health Risks in Irrigation Water, Soil and Tomatoes Collected from Homa Hills, Homabay County, Kenya

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Abstract

Accumulation of metal ions in irrigation water and soils can lead to uptake by food crops. The accumulated heavy metals when ingested pose a threat to human health. The current study intends to assess potential health risk of heavy metal contaminations in irrigation water, soil and tomatoes collected from Homa Hills, Rachuonyo North Sub- County, Homabay County, Kenya. Purposive sampling method was used to collect 10 tomato samples, 10 soil samples and 8 irrigation water samples. The following metal ions were investigated in the tomato, soil and irrigation water samples Chromium (Cr), Zinc (Zn), Cadmium (Cd), Manganese (Mn), Lead (Pb), Copper (Cu), Cobalt (Co) and Iron (Fe). The levels of the metal ions present in the samples collected were determined and quantified using Inductive Couple Plasma-Optical Emission Spectroscopy (ICP-OES) Perkin Elmer model 8000 DV. The results revealed that all the metal ions concentrations in tomatoes were beyond WHO recommended values except Co. The concentrations of all the metals in the soil were within the recommended levels in agricultural soil. In the irrigation water samples, the concentration of the metal ions was within the recommended values in irrigation water except Fe and Co. t-statistic revealed that the concentration of the metal ion in the tomatoes collected from the two locations (Kanam B and Kokoth Kata) of Rachuonyo North Sub-County did not vary significantly. The concentration of Zn, Cd, Co, Pb, Fe and Cu in tomatoes and irrigation water were significantly different except for Mn (p=0.06). The average concentration of metals in soil and water were significantly different. The calculated translocation factor (TF) for Fe, Cd, Cu and Zn was greater than 1 whereas Co, Pb and Mn TF<1. The concentration of Pb, Mn and Cu in soil and tomatoes showed weak positive correlation whereas all the other had negative correlation. The concentration of all the metals in water and tomatoes showed negative correlation except Co that showed weak positive correlation. The health risk index (HRI) for all the studied metals were less than 1 except for Cd, however, on computation of total target hazard quotient (THQ) the values for all the metals were less than 1. The study reveals that the presence of these metals did not pose any health risk. Since Cd had high values of both HRI and THQ relative to other metals further monitoring to establish its' source is recommended.

Keywords: Accumulation of Metal Ions, Food Crops, uman Health, Soil, Tomato, Irrigation, Water

INTRODUCTION

The increase in population has resulted in demand for increased food production (KC et al., 2011; Mueller et al., 2011; Byrnes & Bumb, 2017). The pressure on demand of agricultural products has forced mankind to change farming practices characterized by intensive application of fertilizer and pesticides (Mózner et al., 2012; Nicholls et al., 2020; Baweja et al., 2020; Carvalho, 2017; Muhammad et al., 2020). The uses of agrochemicals have been reported to introduce chemical products in the agricultural fields including heavy metals (Kelepertzis, 2014; Sharma & Singhvi, 2017; Wimalawansa, 2016; Atafar et al., 2010; Mendoza et al., 2006; Mohammed et al., 2011; Gupta et al., 2014; Zwolak et al., 2019; Lekfeldt et al., 2017; Savci, 2012; Singh et al., 2017; Fang & Zhu, 2014; Zhou et al., 2020). Fertilizers especially nitrogen and phosphate fertilizers are known to contain certain levels of heavy metals (Allan et al., 2021; Yargholi, & Azarneshan, 2014; Cheraghi et al., 2012; Sarwar et al., 2010; Aboyeji et al., 2020; Huang & Jin, 2008; Thomsen et al., 2017). Improper disposal of industrial and sewage effluents on agricultural land for a long term is becoming a major source of heavy metal contamination in irrigated soils and groundwater (Bansal & Singh, 2014; Rajendiran et al., 2015; Raja et al., 2015; ur Rehman et al., 2019). Heavy metal accumulation in soils and irrigation water is of great concern in agricultural production due to the adverse effects on food quality, crop growth and environmental health (Murtić et al., 2018; Nagajyoti et al., 2010; Rai et al., 2019; Wang et al., 2017; Kooner et al., 2014; Lu et al., 2015). These metals at low levels may not pose risk; however, they may accumulate to a toxic concentration level which can lead to impairment in the quality of human life (Jaishankar et al., 2014; Ali et al., 2019; Sardar et al., 2013; Akoto et al., 2014). It must also be noted that one-time use of fertilizer may not pose any hazard of soil or plant contamination; however, continued application in the same agricultural field contributes to the accumulation of heavy metals in the soil (Kumar et al., 2017; Koupaie & Eskicioglu, 2015). Another implicated source of contaminants to agricultural fields is the quality of irrigation water (Arora et al., 2008; Hassan et al., 2013; Balkhair & Ashraf, 2016). The quality of irrigation water is dictated by their sources and the conditions under which the water is used (Avni et al., 2013). For instance, it is cited that in poor countries, this water may take the form of diluted raw sewage (Mustapha & Adeboye, 2014; Keraita et al., 2008). The accumulated metal ions in soils may be up taken by plants through several possible mechanisms and finally enter the food chain at high concentrations which are capable of causing health risks to the consumers (Latif et al., 2018; Baby et al., 2010; Kumar et al., 2020; Nkwunonwo et al., 2020; Ukpong et al., 2013; Orisakwe et al., 2012). Apart from accumulation of metal ions in soils, highly toxic metals like cadmium may be present in food and water at low concentration, however, they are known to build up in kidneys causing serious kidney diseases (Osma et al., 2012; Jaishankar et al., 2014; Johri et al., 2010; Sankhla et al., 2016).

Tomato is among the vegetables grown in the area. Tomato originated from South American Andes and in mid 1500s, the Spanish conquistadors took the tomato seeds to Europe (Van Andel et al., 2022; Beynon & Quilley, 2006; Osma et al., 2012). It was later spread to Southern and Eastern Asia, Africa and Middle East (Onwuka et al., 2019; Jones, 2020). Currently, tomato is among the top most cultivated in the world, it contributes to healthy and well-balanced diet (Gaur & Goyal, 2016; Balaj et al., 2017; Thind et al., 2018; Pathak et al., 2020; Hensman, 2021; Noonari et al., 2015). Tomatoes are rich in minerals, vitamin B and C, essential amino acids, sugars and dietary fibres (Khokhar & HRI, 2013; Ali et al., 2011; Szabo et al., 2018). The tomato fruits are either consumed as fresh salads or cooked in sauces. At times they are processed into purées, juices, and ketchup (Akenga et al., 2016;

Motamedzadegan & Tabarestani, 2018; Wu et al., 2022; Morganelli, 2007).

The current study intended to evaluate the health risk associated with consumption of tomatoes grown on the slopes of Homa Hills. Homa Hills are known to have resulted from volcanic eruption and the farms are under irrigation with heavy use of agrochemicals. The population of Homa Hills engage in subsistence farming and the surplus are sold in the local markets.

METHODOLOGY

Description of Study Area

The soil, tomato and irrigation water samples were collected from Homa Hills, Homa Bay County, Kenya. Homa Bay County lies between latitudes 0º 15' S and 0º 52' S, and longitudes 34º 27' E and 35º 45' E (Ongeko et al., 2017). The land has a total surface area of 3,107.1 km^2 excluding the water surface with geographical coverage of 1160 km^2. Homa Bay County consist of Ndhiwa, Rachuonyo North, Suba, Rachuonyo South, Mbita and Homa Bay Sub-Counties (Oloo & Juma, 2019; Omito, 2018; Kembo et al., 2019).

Sampling and Collection Design

Collection of Tomato Samples

For our study, two agro ecological zones were purposively selected where intensive growing of tomatoes was practiced. The two agro-ecological zones were selected in Rachuonyo North sub county namely Kanam B and Kokoth Kata locations. Several villages were identified within the two locations where they were growing tomatoes. In each farm three samples were picked and mixed to form homogeneous sample. In Kanam B tomatoes were collected from six farms and were labeled WTT, KMT, KMT2, K2B (i) K2B (ii) and K2B (iii). It was identified that in Kokoth Kata four farms had tomatoes which were labeled KKA, KGA-1, KGA3-2 and KSA3.

Collection of Soil Samples

Soil samples were sampled from the corresponding farms where the tomatoes had been collected in Kanam(B) and Kokoth Kata. Using a soil auger, soil samples were extracted from a depth of 100 mm after removing the top humus soil. To obtain a representative sample three soil samples were collected diagonally from the farm and mixed to obtain one final sample. In Kanam (B) six soil samples corresponding to six tomato samples were taken and labeled, KMS, KMS2, WTS, K3B(i), K3B(ii), K3B(iii) while four samples were taken in Kokoth Kata labeled, KKA2, KGA2, KSA2D, KGA2D.

Collection of Water Samples

The tomato farming is concentrated close to the shores of L. Victoria and they use the water without further treatment. The farmers in each village pumped the water from the same point, hence for each pumping point collected three samples and formed one homogeneous sample. In Kanam(B) the water samples were labeled, KMW, WTW, and K4B, K4A while in Kokoth Kata the samples were labeled KSA1, KGA1, KKA1, and KMR1.

Sample Preparation

Preparation of Tomato Samples

The tomato samples were prepared for heavy metal ion determination following a procedure developed by Lugwisha and Othman (2016) with little modification. Briefly, 2 g of ground tomatoes were placed in a clean crucible. The sample was then ashed in a muffle furnace at 450-500ºC overnight (12 hours). The ashed sample was allowed to cool in a desiccator. The ash was dissolved in 5 mL acid mixture of volume ratio 1:1 of 20% (v/v) nitric acid and 20 % (v/v) hydrochloric acid. The solution was warmed slowly to dissolve any residues until almost dryness. 0.05 mL of 25% (v/v) HCl of volume was added to the heated mixture and filtered using Whatman filter paper No 42 into a 50 mL volumetric flask. The solution was diluted to the mark using deionized water ready for elemental analysis using ICP-OES (Perkin Elmer model 8000 DV).

Preparation of Soil Samples

The soil samples were prepared for metal ion determination by adopting a protocol developed by Yusuf et al. (2015) with some modifications. 1 g of oven dried ground soil sample was placed in a clean 250 mL beaker. The sample was reacted with a mixture of 5 mL concentrated nitric acid, 15 mL of concentrated sulphuric acid and 0.3 mL of perchloric acid. The mixture was placed in a hot plate under fume cupboard, the heating continued until dense white fumes appeared. The mixture was removed from the hot plate, allowed to cool and diluted with deionized water. The mixture was filtered using Whatman filter paper No 42 into a 50 mL volumetric flask. The solution was diluted to the mark using deionized water ready for elemental analysis using ICP-OES (Perkin Elmer model 8000 DV).

Preparation of Water Samples

The collected water samples were prepared for elemental analysis following a procedure developed by Akenga et al. (2020) with some modification. Briefly, 50 mL of water sample was added to 7.5 mL of concentrated nitric acid and evaporated close to dryness using a hot plate. The sample was digested using a mixture of perchloric and nitric acid. The mixture was treated with 15 mL of 1 M hydrochloric acid and the volume made up to 50 mL using deionized water. The solution was diluted to the mark using deionized water ready for elemental analysis using ICP-OES (Perkin Elmer model 8000 DV).

Translocation Factor

The translocation factor refers to the ability of a given metal ion to translocate to the edible parts of the food crop and can be determined by the accumulation factor (AF). The following equation (Abdu et al., 2011) was used to calculate the AF values for the selected heavy metals.

$$AF = \frac{Heavy\ metal\ concentration\ in\ the\ edible\ part\ of\ the\ plant}{Heavy\ metal\ concentration\ in\ soil}$$

Daily Intake of Metals and Health risk index

To ascertain the associated health risks related to consumption of vegetable (tomato) containing metal ions of a given concentration, a formula used by Salama et al. (2019) was adopted. The daily intake of metals (DIM) was calculated using the following formulae

$$DIM = \frac{C_{Metal} x C_{Factor} x D_{Intake}}{B_{Weight}}$$

Where C_{metal} –metal concentration in the food crop, C_{factor} – conversion factor (0.85 for conversion of fresh vegetables/tomato to dry weight), D_{intake} – Daily intake of food crops was considered to be 0.527 kg person^{-1}d^{-1}, B_{weight} – Body weight for adult population was 60 kg

The values used to calculate DIM were used to calculate health risk index (HRI). Health Risk Index refers to the ratio of the daily intake of metals in the food crops to the oral reference dose (RfD) and it was calculated using the following equation:

$$HRI = \frac{DIM}{RfD}$$

HRI> 1 indicates that the consumers of the food crop containing the metal poses health risk

Target Hazard Quotient (THQ)

The evaluation of health risk exposed to the consumers of the tomatoes containing the heavy metals was evaluated using THQ. To work out the THQ an approach used by Salama et al. (2019) was adopted. Conventionally, when the THQ is greater than unity, it indicates increasing level of concern. The following equation was used to estimate THQ of each metal investigated.

$$THQ = \frac{EF_r x ED x FI x MC}{RfD x BW x AT} x 0.001$$

Where EF_r – Exposure frequency (365 days per year), ED – the exposure duration (Assuming to be 60 years for an adult in this study), FI –food ingestion, MC – metal concentration in food ($mgkg^{-1}$ fresh weight), DIM(daily intake of metals)=FI*MC, RfD- Oral reference dose ($mgkg^{-1}day^{-1}$), BW is average body weight for an adult (60 kg), AT- Average exposure time (365 days $year^{-1}$x number of exposure years, 60 years in this study)

Statistical Evaluation

The mean and standard deviations (s.d) of the heavy metal ion concentrations were calculated for tomato, soil and irrigation water samples and were presented as mean ± s.d of triplicate measurements. Furthermore, descriptive statistical analyses were worked out using SPSS software version 20. Statistic t (t-test) was used to establish the differences between the critical t-value and calculated values of the metal ion concentration of tomato, soil and irrigated water samples using a probability factor $p<0.05$.

RESULTS AND DISCUSSION

Levels of Selected Heavy Metal Ions in Tomato Samples

Tomato samples were collected from two different locations, that is, Kokoth Kata and Kanam B both in Rachuonyo sub county, Homa Bay County. The concentration of Mn, Zn, Co, Cu, Fe, Cd and Pb metal ions were determined in all the tomato samples using ICP-OES. Descriptive statistics were performed using SPSS software, it was found out that the mean levels of metal ions in tomato samples from Kanam B were Mn (3.116±2.397 mg/kg, n =6), Cu (33.12±0.926 mg/kg, n =6), Fe (493.333±86.393 mg/kg, n =6), Zn (42.148±28.554 mg/kg, n =6), Cd (4.99±0.300 mg/kg, n =6), Co (9.951±0.735 mg/kg, n =6), Pb (3.36±1.448 mg/kg, n =6) whereas the mean levels of metal ions in tomato samples collected from Kokoth Kata were Mn (1.84±0.631 mg/kg, n =4), Cu (32.927±1.879 mg/kg, n =4), Fe (486.5±71.914 mg/kg, n =4), Zn (41.615±17.137 mg/kg, n =4), Cd (4.892±0.183 mg/kg, n =4), Co (8.965±0.641 mg/kg, n =4), Pb (3.165±2.197 mg/kg, n =4).

Therefore, average heavy metal ion concentration in tomato samples obtained from Rachuonyo-North sub-county were compared with acceptable limits as set by FAO/WHO 2001 as used by Kacholi and Sahu (2018) and are summarized in table 1 below.

Table 1: The mean concentration of heavy metal ions in tomato samples collected from Rachuonyo-North sub-county

Metal Ion	Concentration of metal ions in tomato samples (mg/kg) n =10	Acceptable limit of metal ions in vegetables (mg/kg) as set by FAO/WHO, 2001
Mn	2.606±1.939	2
Cu	33.043±1.289	4
Fe	490.6±76.700	42.5
Zn	41.935±23.496	6
Cd	4.951±0.252	2
Co	9.557±0.835	50
Pb	3.282±1.669	0.1

The concentration of heavy metals followed the trend Fe>Zn>Cu>Co>Cd>Pb>Mn. Comparing the levels with the FAO/WHO acceptable limits in vegetables it was established that all the investigated metal ions were in excess except cobalt. It was also noted the average levels of Cu, Fe, Zn, and Co were high compared to the levels in soil. This possibly implies that the tomato plant is a good bioaccumulator of Cu, Fe, Zn and Co or it could mean it obtained the said minerals from the agrochemicals applied on tomato plant, that is, Folia, fungicides and pesticides. Anagaw et al. (2019) studied concentration of Pb, Cr, Cd and Cu in tomato and in their support, soil samples from horticulture and fluoriculture industrial area in Ziway, Ethiopia. They discovered that the concentration of the heavy metals reduced with the increase in distance from the industrial area. However, in all the samples collected the concentrations of the metal were within the WHO acceptable limit. Lugwisha & Othman (2016) carried out a similar study in Morogoro region, Tanzania. They established that Cd, Cu, Cr, Pb and Zn at 90 % of the sampled sites were above the WHO/FAO limit.

Levels of Selected Heavy Metal Ions in Soil Samples

The soil samples also were collected from farms where tomatoes were cultivated in both Kanam B and Kokoth Kata of Rachuonyo North sub-county. Similarly, the soil samples were digested as described above and metal ion concentration determined using ICP-OES. The data obtained was further analyzed using descriptive statistics and the mean metal concentration in Kanam(B) were, Mn (311.5±66.226 mg/kg, n=6), Cu (15.833±1.602 mg/kg, n=6), Fe (54.666±6.408 mg/kg, n=6), Zn (18.833±2.483 mg/kg, n=6), Cd (<1 mg/kg, n=6), Co (12.666±0.816 mg/kg, n=6), Pb (9.166±2.136 mg/kg, n=6). Similarly, in Kokoth Kata location, the means of the concentrations of the metal ions were; Mn (334.5±75.323 mg/kg, n=4), Cu (18±0.816 mg/kg, n=4), Fe (61.75±6.849 mg/kg, n=4), Zn (23.75±4.5 mg/kg, n=4), Cd (<1 mg/kg, n=4), Co (13.25±0.5 mg/kg, n=4), Pb (10.25±0.957 mg/kg, n=4).

The average metal ion concentration in soil samples in Rachuonyo- North Sub-County were compared to WHO acceptable limits in agricultural soil and summarized in table 2 below.

Table 2: Concentration in soil samples compared with the WHO standard

Metal Ion	Concentration in soil samples (mg/kg) n =10	Acceptable limit of metal ions in soil (mg/kg) as set by WHO Codex Alimentarius Commission (1994)
Mn	320.7±66.849	2000
Cu	16.7±1.702	36
Fe	57.5±7.199	7000-550,000
Zn	20.8±4.077	50
Cd	<1	0.8
Co	12.9±0.737	100
Pb	9.6±1.776	85

The concentration of heavy metal ions followed the trend Mn>Fe>Zn>Cu>Co>Pb>Cd. The results revealed that the levels of the studied metal ions in collected soil were all within the acceptable limits in agricultural soil as set by WHO (1996). In a similar study, Chang et al. (2014) investigated accumulation of heavy metals in leaf vegetables from agricultural soils in Pearl River Delta, South China. In their study, they found that the mean metal concentration of Pb, Cr, Hg, Cd and As in soil did not exceed the limit set by Environmental Protection Agency of China.

Levels of Selected Heavy Metal Ions in Irrigation Water Samples

Basically, the tomato farming was done close to Lake Victoria, hence, irrigation water samples were collected from the lake adjacent to the tomato farms. The water samples were prepared as described earlier and elemental analysis done using ICP-OES (Perkin Elmer model 8000 DV). The average metal ion concentration in Kanam-B were, Mn (1.284±2.384 mg/L, n=4), Cu (0.063±0.025 mg/L, n=4), Fe (5.615±9.089 mg/L, n=4), Zn (0.230±0.279 mg/L, n=4), Cd (0.012±0.001 mg/L, n=4), Co

(0.037±0.030 mg/L, n=4), Pb (0.061±0.028 mg/L, n=4). Similarly, in Kokoth Kata the mean concentration of heavy metals was, Mn (0.498±0.483 mg/L, n=4), Cu (0.096±0.048 mg/L, n=4), Fe (2.79±1.626 mg/L, n=4), Zn (0.474±0.482 mg/L, n=4), Cd (0.012±0.001 mg/L, n=4), Co (0.032±0.01 mg/L, n=4), Pb (0.165±0.216 mg/L, n=4).

The average metal concentration in water samples of Rachuonyo North sub-county were compared with the WHO/FAO acceptable limits in water and were summarized in Table 3 below.

Table 3: Heavy metal concentration in irrigation water samples Rachuonyo North sub-county

Metal Ion	Concentration of metal ion water samples (mg/L) n =8	Acceptable limit of metal ions in irrigation water (mg/L) as set by FAO & WHO (2003)
Mn	0.891±1.647	0.200
Cu	0.08±0.039	0.017
Fe	4.202±6.23	5
Zn	0.352±0.387	0.200
Cd	0.012±0.001	0.010
Co	0.035±0.021	0.050
Pb	0.113±0.153	0.065

Heavy metals in irrigation followed the following trend, Fe>Mn>Zn>Pb>Cu>Co>Cd. The levels of Mn, Cu, Zn, Cd and Pb were within WHO/FAO set limits except Fe and Co. In a similar study, Shirkhanloo et al. (2015) investigated the levels of heavy metals in irrigation water, vegetables and soil in South of Tehran province. They found that the concentration of V, Ni and Co in vegetables and well water samples were above the WHO permissible limits. However, the concentrations of the same metals in agricultural soils were in accordance to soil references.

Test of Significant Difference (t-tests for Equality of Means)

Using SPSS, at α=0.05, sample t- test was used to see if there was a statistical significance difference in levels of heavy metals in tomatoes from the two locations, that is, Kanam(B) and Kokoth Kata. sample t-test was also used to determine if there were significant difference in the levels of heavy metals in tomatoes, agricultural soil and irrigation water. Four different sample t-tests were done, that is:

i) *Test of significant difference in heavy metal concentration in tomato samples collected from the two locations (Kanam(B) and Kokoth Kata)*

To find if the difference in levels of heavy metals in Kanam(B) and Kokoth Kata was significant the hypothesis, H_0: $\mu_{\text{metal ions in Kanam(B)}} = \mu_{\text{Metal ions in Kokoth Kata}}$ *Vs* H_1: $\mu_{\text{metal ions in Kanam(B)}} \neq \mu_{\text{metal ions in Kokoth Kata}}$, was tested. After data analysis using SPSS on equality of means, the following were the t-values and the significance levels; Mn (^{t}(5.986)=1.242, p=0.261), Cu(^{t}(3.988)=0.19, p=0.859), Fe (^{t}(7.426)=0.136, p=0.896, Zn (^{t}(7.984)=0.037, p=0.972, Cd (^{t}(7.991)=0.637, p=0.542, Co (^{t}(7.229)=2.245, p=0.058, Pb (^{t}(4.752)=0.156, p=0.882).

From the results the significance levels of the equalities of means were greater than our chosen α=0.05, therefore the null hypothesis is accepted and a conclusion that the mean levels of metal ions in tomatoes in the two locations were not significantly different was drawn.

ii) Test of significant difference in heavy metal concentration in tomato and agricultural soil collected from Rachuonyo sub-county

To determine if the difference in mean levels of heavy metal in tomatoes and agricultural soil was significant, the following hypothesis was tested, $\mathbf{H_0}$: $\mu_{tomatoes} = \mu_{agricultural\ soil}$ *Vs* $\mathbf{H_1}$: $\mu_{tomatoes} \neq \mu_{agricultural\ soil}$. The performed t-tests using SPSS gave the t-values and the significance level as follows: Mn (^{t}(9.015)=-15.041, p<0.001), Cu (^{t} (16.769)=24.192, p<0.001), Fe (^{t} (9.159)=17.778, p<0.001), Zn (^{t} (9.541)=2.808, p=0.02), Cd (^{t} (9)=49.427, p<0.001), Co (^{t} (17.731)=-9.489, p<0.001), Pb (^{t} (17.931)=-8.197, p<0.001). From the results apart from Zn (p=0.02), all the metal ions had p<0.001. All the significance levels were less than our chosen α=0.05. Therefore, the null hypothesis is rejected and a conclusion that the mean levels of metal ions in tomatoes and agricultural soil were significantly different was reached.

iii) Test of significant difference in heavy metal concentration in tomatoes and irrigation water collected from Rachuonyo sub-county

Also, to determine the difference in means between the levels of metals in tomatoes and irrigation water was significant the hypothesis: $\boldsymbol{H_0}$: $\mu_{tomatoes}=\mu_{irrigation\ water}$ *Vs* $\boldsymbol{H_1}$: $\mu_{tomatoes}\neq\mu_{irrigation\ water}$ was tested**.** Using SPSS, the mean difference of the levels of metal ions in irrigation water and tomatoes was analyzed and the t-values and the significance levels were as follows: Mn (^{t} (15.912)=2.027, p=0.06), Cu (^{t} (9.021)=80.769, P<0.001), Fe (^{t} (9.148)=19.971, p<0.001), Cd (^{t} (9)=61.78, p<0.001), Co (^{t} (9.015)=36.042, p<0.001), Zn (^{t} (9.006)=5.595, p<0.001), Pb (^{t} (9.19)=5.972, p<0.001). Zn, Cd, Co, Pb, Fe and Cu metal ions, had p<0.001 which is less than α=0.05 therefore the null hypothesis is rejected and a conclusion that the mean levels of Zn, Cd, Co, Pb, Fe and Cu ions was significantly different in tomatoes and irrigation water was made. However, Mn ions had p=0.06 which is greater than the significance level at α=0.05 therefore the null hypothesis is accepted and a conclusion that the mean level of Mn ions in tomatoes and irrigation water is not significantly different was determined.

iv) Test of significant difference in heavy metal concentration in agricultural soil and irrigation water

The hypothesis, $\boldsymbol{H_0}$: $\mu_{agricultural\ soil}=\mu_{irrigation\ water}$ *Vs* $\boldsymbol{H_1}$: $\mu_{agricultural\ soil}\neq\mu_{irrigation\ water}$ was tested to determine if there was significant difference in levels of heavy metals in agricultural soil and irrigation water. sample t-tests on irrigation water and agricultural soil was also done and it was found that the t-values and significance levels were as follows; Mn (^{t}(9.014)=15.123, p<0.001), Cu (^{t} (9.012)=30.852, p<0.001), Fe (^{t} (15.863)=16.824, p<0.001), Zn (^{t} (9.203)=15.771, p=0.02), Cd (^{t} (7)=3016.862, p<0.001), Co (^{t} (9.019)=55.17, p<0.001), Pb (^{t} (9.168)=16.810, p<0.001). All the metal ions had p<0.001 which is less than α=0.05 hence the null hypothesis is rejected and a conclusion that the mean levels of metal ions in soil and water is significantly different was drawn.

Correlation Studies

The presence of heavy metals in tomatoes could be occurring naturally in the plant or sourced either from the soil, irrigation or agrochemicals applied. In this study it was considered paramount to establish the correlation between the metal concentrations subject in agricultural soil verses metal concentration in tomatoes and also correlate metal concentration in irrigation water verses metal concentration in tomatoes.

The correlation coefficients (r) of the various metal was analyzed using SPSS at two levels (i) between metal concentration in agricultural soil and tomatoes, (ii) between metal concentration in irrigation water verses tomatoes.

Correlation between metal concentration in agricultural soil verses tomatoes

The correlation coefficient of the metal ions of the studies were established as follows:

Mn (r=0.271), Cu (r=0.24), Fe (r=-0.144), Zn (r=-0.052), Co (r=-0.291), Pb (r=0.451). Mn, Cu and Pb had a weak positive correlation suggesting that these metal ions accumulated in tomatoes emanated from the agricultural soil. Zn, Co and Fe had a weak negative correlation to suggest unsuitability of these metal ions accumulation in tomatoes from agricultural soil.

Correlation between metal concentration in irrigation water and tomatoes

The correlation coefficient of the studies metal ions was established as follows; Mn (r=-0.172), Cu (r=-0.13), Fe (r=-0.286), Zn (r=-0.403), Cd (r=-01), Co (r=0.418), Pb (r=-0.175).

Co had weak positive correlation suggesting a suitability of this metal ions accumulation in tomatoes from the irrigation water. Mn, Cu, Fe, Zn, Cd and Pb had a weak negative correlation to suggest the unsuitability of these metal ions accumulation in tomatoes from the irrigation water.

Translocation Factor

During the data analysis, the translocation factor based on the accumulation factor (AF) was calculated to determine the ability of the metal ions to translocate from the agricultural soil to the edible part of the tomato (the fruit). TF is an important parameter used in the study of heavy metals remediation potential, phytoremediation. TF is calculated as follows;

$$AF = \frac{\text{Heavy metal concentration in the edible part of the plant}}{\text{Heavy metal concentration in soil}}$$

The translocations factors of the metal ions were, Mn (0.08), Cu (1.978), Fe (8.532), Zn (2.016), Cd (4.951), Co (0.741), Pb (0.341). Figure 1 below shows the translocation factors.

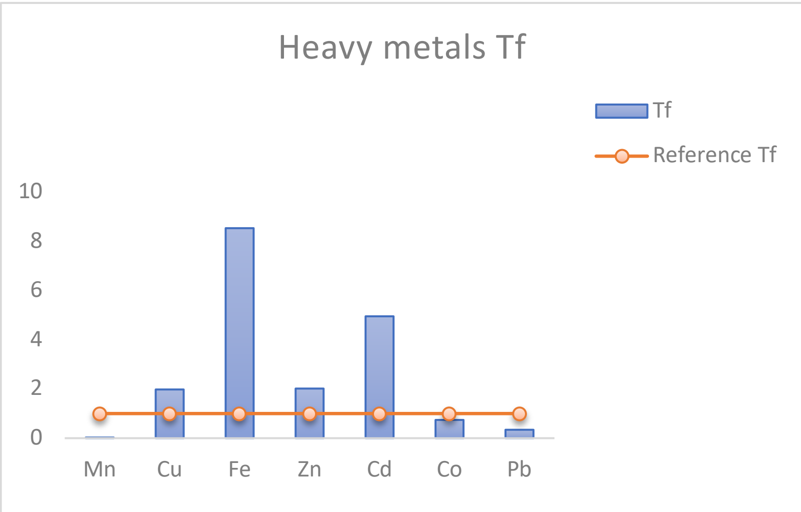

Figure 1: Translocation factors of heavy metals.

From the results Fe, Cd, Cu and Zn had TF>1 while Co, Pb and Mn had a TF<1. This suggests tomato fruit is a good bioaccumulator of Fe, Cd, Cu and Zn. In a similar study, uptake and distribution of Ni, Cr, Cu, Zn, Pb and Mn by tomato plants was investigated by Murtic et al. (2018). They established that the tomato plant was not good bio accumulator of heavy metals. They attributed the low uptake to chemical properties of the soil that makes the metals unavailable for uptake. In another similar study by Lugwisha & Othman (2016) worked out bioconcentration factors (BCF) for uptake of Cr, Cd, Cu and Zn from soil to tomato fruits. They found that the BCF for all studied metals were greater than 1 except for Cd. Their findings suggested tomato fruit had high uptake of metal ions from soil and that their consumption could pose human health risk. In another related study, Chang et al. (2014) worked out bioconcentration factor (BCF) of Cd, Hg, Cr and As from soil to vegetables. They found that the BCF value of Cd in vegetables was approximately 30-fold that of Hg and 50-fold those of Cr, Pb and As. They attributed the high BCF value of Cd to competition of Cd^{2+} and Ca^{2+} where it is easier for Ca^{2+} to be replaced by Cd^{2+} than other metals because they have comparable ionic radius and valence.

Daily Intake of Metals and Health Risk Intake

To appraise the health risk associated with heavy metal contamination in tomatoes, the daily intake of metals and the risk index were calculated and presented in table 5. The results revealed that the daily intake of Fe was high in tomatoes while Cd recorded the lowest daily intake of metals are expressed as mg/kg/day.

The health risk index (HRI) of metals from consumption of tomatoes is presented in table 5. The results revealed that Cd contamination in tomatoes posed a great health risk to the residence of Rachuonyo North sub-county. The health risk index was less than 1 for Mn, Cu, Fe, Zn, Co and Pb in tomatoes. Mn, Cu, Fe, Zn, Co and Pb were not found to present any risk to the population.

Table 4: Daily intake and Health Risk Index associated with consumption of tomatoes containing heavy metals ions

Heavy Metal	Daily Intake of metals (mg/kg/day)	Reference oral dose (RfD)	Health Risk Index (HRI)
Mn	0.002	0.003	0.667
Cu	0.027	0.037	0.730
Fe	0.396	0.700	0.566
Zn	0.034	0.300	0.113
Cd	0.004	0.001	4.000
Co	0.008	0.020	0.400
Pb	0.003	0.004	0.750

HRI> 1 indicates that the consumers of the food crop containing the metal poses health risk.

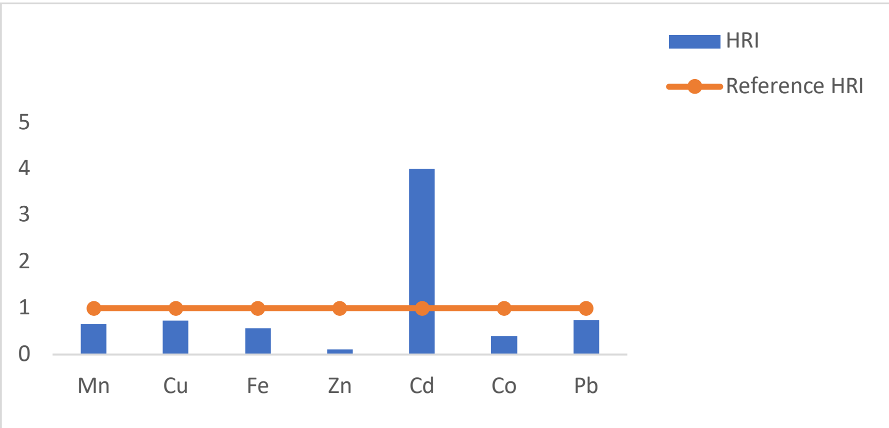

Figure 2: HRI of metals compared to the reference HRI (1).

Target Hazard Quotient
The results are represented in Table 5 below.

Table 5: Target hazard quotient for various heavy metals in tomatoes

Heavy Metal	EFr	ED	DIM	RfD	BW	AT	THQ
Mn	365	60	0.002	0.003	60	21900	0.0111
Cu	365	60	0.027	0.037	60	21900	0.0122
Fe	365	60	0.396	0.7	60	21900	0.0094
Zn	365	60	0.034	0.3	60	21900	0.0019
Cd	365	60	0.004	0.001	60	21900	0.0667
Co	365	60	0.008	0.02	60	21900	0.0067
Pb	365	60	0.003	0.004	60	21900	0.0125

The findings showed that the target hazard quotient (THQ) values of all the heavy metals were <1. This means that the exposure of the selected heavy metals in tomatoes had no apparent health risk to the population. In a similar study, Woldetsadik et al. (2017) evaluated the estimated daily intakes (EDIs) and target hazard quotient (THQs) associated with the consumption of vegetables in areas around Addis Ababa. They found out that the metal levels were below the recommended maximum limits. Consequently, the EDIs and THQ values revealed that there could be no potential risk to the consumers if they consume one or more of the vegetables analyzed.

CONCLUSION AND RECOMMENDATION

The results revealed that in tomatoes, all the investigated metal ions contents except Co were higher than vegetables WHO/FAO standards. In soil, all the investigated metal ion were below the set standards for agricultural soil while in irrigation water Mn, Cu, Cd, Pb and Zn metals were higher than the set standards. Sample t-tests showed that the mean levels of heavy metals in tomatoes were not significantly different as per the locations while the mean levels of heavy metals in tomatoes, soil and water were significantly different except for mean levels of Mn ions in tomatoes and water which was not significantly different. The study further revealed that tomato fruit is a good bioacummulator of Fe, Cd, Cu and Zn in comparison to Mn, Pb and Co as suggested by the calculated TF values. The findings on daily intake of metals (DIM), health risk index (HRI) and target hazard quotient (THQ) revealed that the consumption of tomatoes among the people of Rachuonyo North sub-county could pose a risk to human health due to high HRI level of Cd. Despite the low level of heavy metal ion in tomato their presence is not desirable. Therefore, this study recommends a regular scrutiny of levels of heavy metals present in vegetables, agricultural soil, irrigation water and agrochemicals to avoid extreme levels that can be acquired through the food chain posing a health risk to the human population. Moreover, this study recommends the environmentalists, public health workers and government administrators to create awareness on heavy metals in foodstuff such as vegetables grown in contaminated soil and contaminated water to reduce health risk.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.

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