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Evaluation of Levels of Selected Heavy Metals in Kales, Soils and Water Collected from Irrigated Farms along River Moiben, Uasin-Gishu County, Kenya

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Abstract

There has been a rapidly increasing urbanization and industrialization as well as increased usage of agrochemicals in the recent few years which have resulted in accumulation of heavy metals in cultivated food, soils and water. This research aimed at establishing the levels of Zn^{2+}, Cd^{2+}, Cu^{2+}, Cr^{2+}, Mn^{2+}, Fe^{2+} and Pb^{2+} metal ions in kales, soil and irrigation water on farms along river Moiben. Twenty seven samples of vegetables, soil and water samples were collected using purposive sampling method, that is, the samples were collected from the households who had kales in their farms. Samples were then dried, grounded, digested and analyzed using Inductive Couple Plasma-Optical Emission Spectroscopy (ICP-OES). The results showed that the Fe had the highest mean in soil and water with the values of 250.22 ± 85.37 and 0.72 ± 0.33 mg/kg respectively, while in kales Zn value was highest with a value of 0.0154 ± 0.007 mg/kg. The metal ion concentrations in the soils and the irrigation water were higher than in kales. The concentrations on the metal ions were following this order Fe > Mn > Zn > Cu > Cr > Pb > Cd for soil as well as for water but for the kales sample it followed slightly different order Zn > Fe > Mn > Cu > Cr > Pb > Cd. In soil samples, metal ions concentrations (mg/kg) were found to be high compared to the levels in water and kales. ANOVA tests revealed that the mean difference in heavy metals concentration from different stations within the area was insignificant ($p > 0.05$) with an exception of Cd ($p = 0.001$) in water samples, Fe ($p = 0.007$) in kales samples, Zn ($p = 0.016$) and Cd ($p = 0.011$) in the samples of soil. Results were compared to the acceptable levels set by World Health Organization (WHO) and the study showed that for kales, concentrations of the metal ions were all lower than the (WHO) set standards. For water samples, Fe, Pb, Mn metal ions were above the WHO set standards. The presence of the investigated heavy metals in the samples could be pointed to excessive use of agrochemicals as indicated by our earlier survey on the use of agrochemicals. We therefore recommend thorough investigations and monitoring of the said heavy metals in the commercially distributed agrochemicals.

Keywords

Heavy Metals, Kales, Soils and Water Irrigated Farms

1. Introduction

The main path of heavy metal introduction for human beings is through food chain pollution (Khan et al., 2008). Heavy metals are natural components of the Earth's outer layer but activities by human beings have adjusted their balance, biochemical and geochemical rotations. Heavy metals have been defined as elements having a density higher than five milligram/liter (Akenga et al., 2017). A number of metals are indispensable micronutrients for the health of human beings and may be very lethal when they are over consumed (Fytianos et al., 2001). Heavy metals including arsenic, cadmium, lead and mercury have unknown value to humans and are known to be injurious if exposure elevated levels.

Copper and zinc are essential within some levels although at elevated levels bring about oxidative trauma by redox reactions (Halliwell, 2006; Gaetke & Chow, 2003; Rotilio et al., 2000). Lead toxicity is associated with oxidative trauma and in growing infants it brings about hinders mental development (Ab Latif Wani & Usmani, 2015; Hou et al., 2013). Persistent contact with cadmium is known to spoil glomerula as well as changing the metabolism of Zn, Cu and Se (Noël et al., 2004; Matović et al., 2011) whereas a few oxidative varieties of chromium Cr (VI) are carcinogenic (Costa & Klein, 2006).

Due to increased demand and the need for higher productivity, farmers have adopted modern farming methods which include use of fertilizers, pesticides, compost manure, and irrigation (Atafar et al., 2010). In the developing countries, agricultural chemicals are believed to be strong weapons that improve the yield of agriculture (Sharma & Singhvi, 2017). Heavy metal accumulation in soils used for agricultural purposes may lead to contamination of the environment at the same time have an effect on the quality and security of food (Sharma et al., 2016).

Soils in farms under irrigation have been reported to accumulate heavy metals including Zn, Ni, Cd, Pb, and Cr within the soil; hence, growing crops in farms containing elements such as Cr, Cd and Ni have a greater chance of becoming a health hazard for consumers (Alghobar & Suresha, 2015). Accumulation of metals in soil may as well be caused by extended usage of polluted irrigation waters

(Rattan et al., 2002).

Vegetables have a vital role in the safety of food and nutrition in Kenya. Exotic vegetables mainly kale and cabbage account for 90 percent of the vegetables consumed in Kenya compared to 3.7 percent of indigenous vegetables at any given time (Otieno, 2013). The major sources of elements in vegetable crop are their developing media which includes air, soil and nutrient solutions and the elements are absorbed by their foliage or roots. A number of plants for instance *Brassica* vegetables are demonstrated to over accumulate metals in their parts which are consumed by human beings (Kumar et al., 2007). One quarter of known lead hyperaccumulators belong to the genus Brassica which includes vegetables such as cabbage, broccoli, and kale (Gall & Rajakaruna, 2013). A number of the Brassica species have been documented to be suited for heavy metals accumulation such as Pb, Zn, Cd, Ni and Cu (Robinson et al., 2009).

Previous studies conducted by Home et al. (2017) in Maili saba and Kibera found in Nairobi in Kenya demonstrated elevated levels of cadmium and lead in irrigated kales, however, arrowroots and black night shade from the same soils had lower concentration of cadmium and lead in their leaves.

Therefore, it is essential to monitor these levels in agricultural food, soils and irrigation water to ensure they do not exceed the WHO permissible limits. This study sets out to evaluate levels of selected heavy metal ions on kales, soils and irrigation water collected from irrigated farms along River Moiben, Uasin-gishu County, Kenya.

2. Material and Methods

2.1. Study Area

The study was carried out in Uasin Gishu County which stretches between longitudes 34˚50"E and 35˚37"W and latitudes 0˚03"S and 0˚55"N. It is bordered by Trans-Nzoia County (North), Kericho County (South), Baringo County (South East), Elgeyo Marakwet County (East), Nandi County (South West) and Kakamega County to the North West (Uasin Gishu County, 2013). It occupies an area of 3345.2 Square kilometers. The soils composing of red clay soils, red loam soils, brown loam soils and brown clay soils majorly sustain sunflower, maize, potatoes, pyrethrum, barley and wheat. In addition, they sustain forestry and livestock keeping. It receives an evenly distributed rainfall throughout the year with 2 distinctive climax arising from March to September; and/or from May to August. Dry seasons occur from November to February. Its temperatures range from 7˚C to 29˚C (Uasin Gishu County, 2013). The research was undertaken along River Moiben Uasin Gishu County, Kenya. The samples were gathered during February and March of the year 2019.

2.2. Sample Collection and Preparation

2.2.1. Water Samples

Nine water samples were collected from three varying points along River Moiben and put in 500 mL plastics bottles. Prior to their use, the bottles were thoroughly washed with soap and double-distilled water. They were rinsed with several rounds of distilled and finally with dilute nitric acid. Approximately 400 mL of sample water were put in the clean plastic bottles and to each one milliliters of concentrated nitric acid were poured into the samples to ensure that all the metals are dissolved and to avoid oxidation of some metals. The samples were stored and transported using blue large cooler box to the laboratory where they were then stored under low temperatures in the laboratory awaiting analysis. During digestion, 50 mL of water samples was added to 7.5 mL of HNO_3 (65%) and they were left to evaporate close to dryness using a burning plate. They were then digested using a mixture of $HClO_4$ and HNO_3 15 mL of 1M HCl was added to the residue which was made up to a volume of 50 mL using distilled water. The mixture was filtered and analyzed for Pb, Cr, Co, Zn, Fe, Cu and Mn using ICP–OES (Perkin Elmer model 8000 DV).

2.2.2. Soil Samples

Nine soil samples from three different farms were extracted randomly at three different depths (0 - 20 cm, 20 - 40 cm and 40 - 60 cm) (Alghobar & Suresha, 2017) in each block with the use of a soil Auger. The soil samples gathered from all the depths was mixed up, dried, crushed and sieved with a two millimeter sieve. The prepared soil samples were then stored in khaki bags to be transported to the laboratory. The soil samples were then air-dried at 70˚C, grinded into a fine powder and sieved through (2 mm) sieve (Badawy et al., 2013). The samples were then digested using HNO_3, H_2SO_4 and 60% $HClO_4$ acid. The mixture was filtered and the filtrate filled up to 50 mL with the use of double distilled water. The water samples digested were directly aspirated to ICP-OES for metal ion concentration determinations.

2.2.3. Kale Samples

Nine leaf samples of collard kales were hand harvested from three different farms and prepared following a procedure developed by Chollet and Brock (Chollet & Brock, 2008). All the collard green leave samples were cleaned with distilled water so as to get rid of dust particles and airborne impurities then stored in dried khaki bags to be transported to the laboratory. The samples were sliced to small portions with the use clean razor. The samples were dried using an oven at 70˚C until stable weight obtained after which they were left to become cold to ambient temperature, mashed using a clean grinder and a mortar so as to acquire homogenized samples. The samples on the ground were filtered through a (0.2 mm) sieve. Then 1 gram of dry vegetable was digested using a combination of $HClO_4$, H_2SO_4 and HNO_3 in the proportion of 1:1:5 then digested at 80˚C. The samples which were digested were then sieved using filter paper Whatman No. 42 and double distilled water were added to the filtrate up to 50 mL so as to be diluted.

2.3. Statistical Analysis

Data entry and statistical analysis were done using MS Excel spreadsheets and statistical package for social science (SPSS) version 20. Using MS Excel, the means, standard deviations, and graphical representation of data were done. Correlations and experimental trials to test the level of significance ($p < 0.05$) were done using SPSS where ANOVA was used to test the difference in means of the data collected from different stations. The concentrations of heavy metals in the vegetables were divided by the total heavy metals in the soil in order to obtain the transfer coefficient.

3. Results and Discussion

3.1. Heavy Metal Ion Concentrations in Kales from Different Farms

The levels of heavy metal ion concentrations in kales sampled purposively from three farms along Moiben River were determined using ICP-OES. The farms were labeled Station 1, Station 2 and Station 3, from every station three samples were obtained. The concentration of each metal ion was determined in each sample separately. The average for the three samples from each farm was determined to be Zn, Pb, Fe, Mn, Cd, Cu and Cr were 0.01240 ± 0.00246, 0.00053 ± 0.0003, 0.01353 ± 0.00118, 0.00500 ± 0.0000, 0.0004 ± 0.0000, 0.00193 ± 0.0002, 0.00113 ± 0.0001 mg/kg respectively for Station 1, Zn, Pb, Fe, Mn, Cd, Cu and Cr were 0.00960 ± 0.0028, 0.00020 ± 0.0001, 0.01110 ± 0.0014, 0.00467 ± 0.0012, 0.00004 ± 0.0000, 0.00217 ± 0.0004 and 0.00150 ± 0.0003 mg/kg respectively for Station 2 and Zn, Pb, Fe, Mn, Cd, Cu and Cr 0.02417 ± 0.0068, 0.0006 ± 0.0004, 0.01097 ± 0.0009, 0.00433 ± 0.0006, 0.00014 ± 0.0001, 0.00270 ± 0.0007 and 0.00160 ± 0.0003 mg/kg respectively for Station 3. The average of each metal ion in the kales collected from the three farms was calculated to be Zn, Pb, Fe, Mn, Cd, Cu and Cr were 0.01539 ± 0.0077, 0.00043 ± 0.0003, 0.01187 ± 0.0016, 0.00467 ± 0.0007, 0.00007 ± 0.0000, 0.00227 ± 0.0005 and 0.00141 ± 0.0000 mg/kg respectively and are represented in **Figure 1**.

The levels of the metal ions in the kales samples were generally low compared to the occurrences in soil and water. The average concentration of metal ions in the kales sampled from the three stations followed the trend: Zn > Fe > Mn > Cu > Cr > Pb > Cd.

One way Analysis of Variance test was done to compare the difference in levels of the metal ions from the three stations and the results revealed that Zn ($p = 0.016$) and Cd ($p = 0.011$) demonstrated significant mean difference ($p < 0.05$) while Pb ($p = 0.352$), Mn ($p = 0.579$), Cu ($p = 0.235$), Cr ($p = 0.138$) and Fe ($p = 0.067$) were not significantly different.

The levels were compared to the WHO (2001) acceptable standards and it was established that all the metal ions in kales were within the acceptable WHO standard limits as presented in **Table 1** and **Figure 2**.

The summary for the comparison is presented in **Figure 2**.

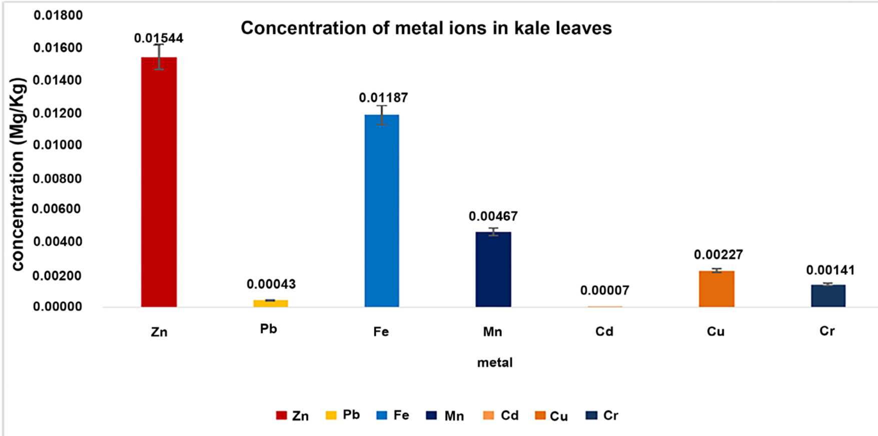

Figure 1. Concentration of different metal ions in kales leaves.

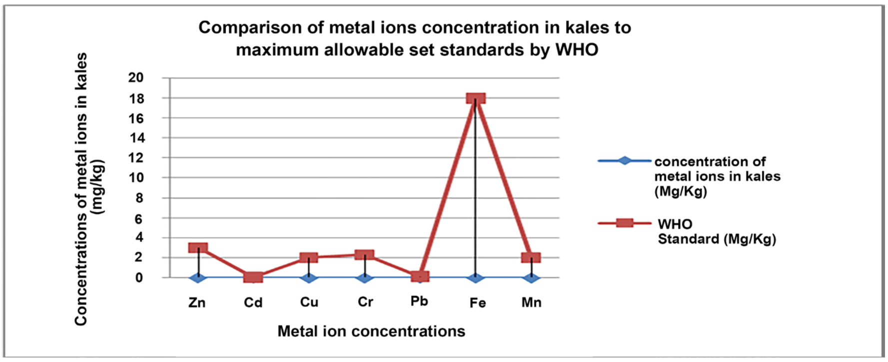

Figure 2. Comparison of metal ions concentration in kales to maximum allowable set standards by WHO.

Table 1. Mean heavy metals concentration in kales compared to recommended concentrations in food crops (FAO/WHO, 2001).

Metal ion	Concentration in Kales (mg/Kg)	WHO standards (mg/kg)
Zn	0.01538 ± 0.0077	3
Cd	0.00007 ± 0.0000	0.03
Cu	0.00227 ± 0.0005	2
Cr	0.00141 ± 0.0003	2.3
Pb	0.00043 ± 0.0003	0.1
Fe	0.01187 ± 0.0016	18
Mn	0.00467 ± 0.0007	2

Similar studies were done by Shirkhanloo et al. (2015). In their study, they investigated the levels of Co, V, Hg, As, Ni in leafy edible vegetables namely parsley, Persian leek, spinach, dill, and radish. They found out that the levels of V, Ni and Co in the investigated vegetables were greater than the acceptable limit of heavy metals when compared to WHO guidelines.

Mutune et al. (2014) while studying heavy metal concentration of chosen leafy vegetables of Africa planted in peri-urban as well as urban Nairobi city in Kenya reported that all the vegetables metals content except Cu were in some sites above the acceptable limits. Guerra et al. (2012) reported that Cd levels were from 0.01 to 0.18 mg/kg, Cr concentrations ranged from 0.01 to 0.60 mg/kg while Pb levels vary from 0.02 to 2.50 mg/kg.

3.2. Concentration of Heavy Metal in Soil in Different Farms

The soils samples were gathered purposively from the different farms where kales had been grown. Overall of 9 samples of soil were gathered from Station 1, Station 2 and Station 3. Levels of Zn, Cd, Cu, Cr, Pb, Mn and Fe were determined in each sample using ICP-OES. The average metal ion concentration for the three samples from each farm were Zn, Fe, Pb, Mn, Cr Cu and Cd determined to be 46.9033 ± 14.68526, 352.3333 ± 17.00980, 9.9163 ± 2.68538, 47.3333 ± 7.76745, 9.6733 ± 0.20033, 12.0333 ± 0.06110, 0.5253 ± 0.15101 respectively for Station 1, Zn, Fe, Pb, Mn, Cd Cu and Cr 37.5567 ± 2.1139, 196.3333 ± 68.88638, 9.1953 ± 2.33523, 162.6667 ± 31.81719, 9.3400 ± 0.5912, 12.2400 ± 0.53329, 0.6143 ± 0.06447 respectively for Station 2 and Zn, Fe, Pb, Mn, Cd Cu and Cr were 33.5233 ± 1.23249, 202.0000 ± 25.23886, 11.5313 ± 4.05069, 179.6667 ± 24.58319, 9.5600 ± 0.77660, 12.4267 ± 0.65546 and 0.7167 ± 0.1158 respectively for Station 3. The average concentrations of metal ions from the three stations were also calculated and the following results were obtained as follows Zn, Fe, Pb, Mn, Cd Cu and Cr 39.3278 ± 9.5259, 250.2222 ± 85.37532, 10.2143 ± 2.88813, 163.2222 ± 24.80815, 9.5544 ± 0.50932, 12.2333 ± 0.45659 and 0.6188 ± 0.13026 respectively and are represented in Figure 3 below.

The results showed that the level of metal ions the followed trend: Fe > Mn > Zn > Cu > Cr > Pb > Cd. The significance mean tests performed using One way ANOVA showed that the mean levels of the metal ions in the collected soil samples were significantly different ($p < 0.05$) for Fe ($p = 0.007$) metal ions while the

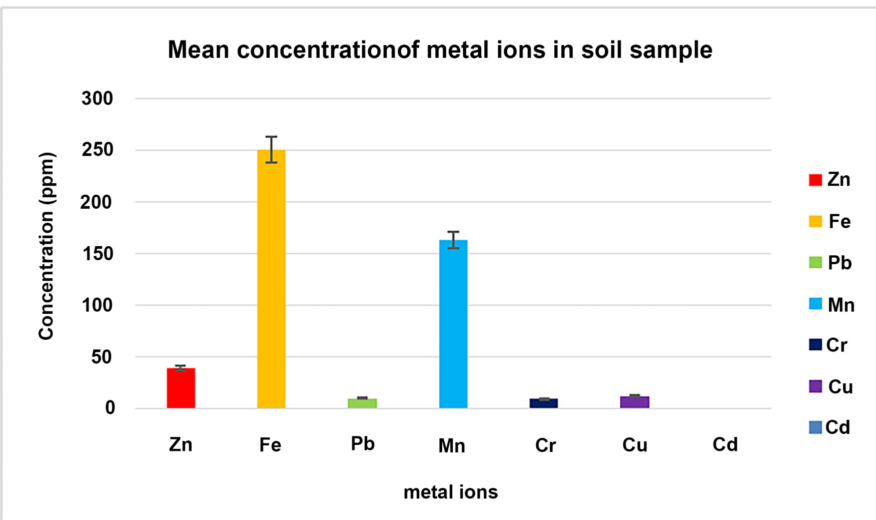

Figure 3. Concentration of different metal ions in soil samples.

other metals; Zn ($p = 0.228$), Pb ($p = 0.667$), Cr ($p = 0.887$), Cu ($p = 0.638$), Mn ($p = 0.316$) and Cd ($p = 0.210$) showed insignificant difference in means ($p > 0.05$).

The occurrences of the investigated metals ions followed a different trend Cu > As > Fe > Co > Pb > Cd > Zn > Ni in a related study done by Opaluwa et al. (2012). The difference in the trend could be attributed to the differences in the geographical zones where the soil samples were collected. When studying heavy metal concentration of chosen African leafy vegetables sown in urban and peri-urban Nairobi, Kenya, Mutune et al. (2014) reported that the metal contents in soil were within acceptable levels by WHO/FAO apart from some cases in Cd.

3.3. Heavy Metal Concentration in Water from Different Points along the River

The selected farms for sampling were all located along river Moiben and the source of irrigation water was River Moiben. Three water samples were obtained from three different points of the River making a total of nine samples. The concentration of the metal ions under investigation was determined in each sample and the average obtained. The average from the three stations was determined to be Zn (0.05075 ± 0.0095), Pb (0.04725 ± 0.02978), Fe (1.02225 ± 0.33047), Mn (0.27125 ± 0.049742), Cd (0.00150 ± 0.00100), Cu (0.06475 ± 0.00050) and Cr (0.04575 ± 0.00171) for Station 1, Zn (0.04800 ± 0.00804), Pb (0.02150 ± 0.00776), Fe (0.66900 ± 0.130519), Mn (0.19650 ± 0.00759), Cd (0.00500 ± 0.000816), Cu (0.06475 ± 0.00095) and Cr (0.04975 ± 0.002217) for Station 2 and Zn (0.71600 ± 0.181606), Pb (0.06500 ± 0.01416), Fe (0.06175 ± 0.035650), Mn (0.22400 ± 0.045811), Cd (0.00325 ± 0.0005), Cu (0.06525 ± 0.00050) and Cr (0.05000 ± 0.00336) for Station 3. The average of each metal ion in the water collected from the three farms was calculated to be Zn (0.06058 ± 0.01200), Pb (0.03658 ± 0.03000), Fe (0.72396 ± 0.32600), Mn (0.23058 ± 0.04800), Cd (0.00308 ± 0.00200), Cu (0.04533 ± 0.00500) and Cr (0.0485 ± 0.00300). The levels are represented in **Figure 4** below.

The metal ions levels in the water samples were generally low compared to the occurrences in soil. The trend of heavy metals contents were Fe > Mn > Zn > Cu > Cr > Pb > Cd. The trend of concentrations of metal ions is closely related to the observed trend in kales and soil.

The significance mean tests performed using One way ANOVA revealed that the mean levels of the metal ions in the collected water samples were significantly different ($p < 0.05$) for Cd ($p = 0.001$) while Zn ($p = 0.113$), Pb ($p = 0.164$), Cr ($p = 0.073$), Cu ($p = 0.748$), Mn ($p = 0.067$) and Fe ($p = 0.83$) showed insignificant difference in means ($p > 0.05$).

3.4. Correlation between Heavy Metals in Soil and Kales

Simple bivariate correlation was undertaken to establish the relationship of heavy metal levels in kales and soil they were grown on. At $p < 0.05$ most metals showed

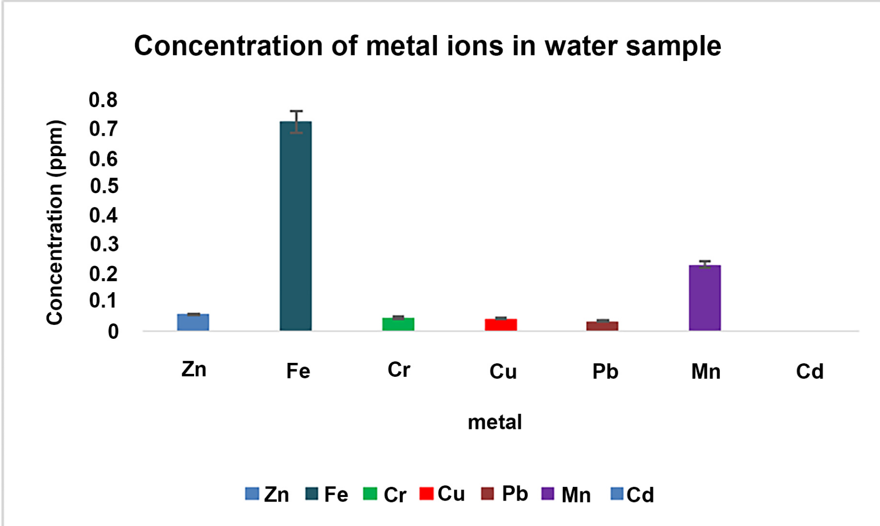

Figure 4. Concentration of different metal ions in water samples.

positively insignificant relationship. The stronger linear relationship was evident in Cu. Correlation in Cu = 0.556 while the other metals showed weak relationship; Zn = 0.425, Fe = 0.128, Mn = 0.197, Cr = 0.195, Cd = 0.45. Pb metal showed insignificant negative correlation, r = −0.133.

In this case the positive relationship between the metals made us to conclude that a percentage of metal ions are drawn from the soil and that Pb ions were not drawn from soil, most probably from the agrochemicals used.

3.5. Correlation between Heavy Metals in Water and Kales

Another simple correlation was done to establish the relationship between the metal ions in the irrigation water and those in kales. At $p < 0.05$ most metal ions were insignificantly positively correlated. The stronger positive correlation was evident in Cr. Correlation in Cr = 0.608 while the other metal ions showed weak relationship. Zn = 0.351, Fe = 0.219, Cu = 0.104 and Cd = 0.438. Pb and Mn ions showed negative correlations. Correlation in Pb = −0.214, Mn = −0.224.

The positive relationship between the metals made us to conclude that a percentage of metal ions are drawn from the water. Pb and Mn ions are drawn from somewhere else but not from water, most probably from the agrochemicals used.

3.6. Heavy Metals' Transfer Factors from Soil to Kales

The calculated transfer factor of heavy metals to the leaves of kale from soil is indicated in Table 2 below.

The Transfer Factor value for Zn, Fe, Cr, Cu, Pb, Mn and Cd from soil to kales found were 39.1×10^{-5}, 4.7×10^{-5}, 227.9×10^{-5}, 18.5×10^{-5} d 0.703×10^{-5}, 4.2×10^{-5}, 2.8×10^{-5} and 0.73×10^{-5} respectively. Results indicated that there was a very low transfer ration of heavy metals from soil to kales. Elevated transfer factor shows comparatively deprived withholding in soil or larger effectiveness of vegetables to take up metals while low transfer factor shows the physically

Table 2. Transfer factor of heavy metals from kales planted along Moiben River.

Metals	Transfer Factor
Zn	39.1×10^{-5}
Fe	4.7×10^{-5}
Cr	227.9×10^{-5}
Cu	18.5×10^{-5}
Pb	4.2×10^{-5}
Mn	2.8×10^{-5}
Cd	0.73×10^{-5}

powerful assimilation of metals to the colloids (Osu & Ogoko, 2014). The trend of the transfer factor were Cr > Zn > Cu > Fe > Pb > Mn > Cd. A study done by Rehman et al. (2018) recorded the trend of metal transfer factors for varying vegetables to be in the following order: Cu > Ni > Cr > Mn > Zn.

4. Conclusion and Recommendation

It is evident that Moiben sub-county is relatively concentrated with the heavy metals. The results pointed out that all the metal ions (Fe, Zn, Mn, Pb, Cd, Cr, and Cu) were present in all the samples collected though the concentrations of heavy metals detected in the samples were quite different. From the analysis, soil samples recorded the highest levels of metal ions followed by water and lastly the kales sample. All metal ions in kales were below the WHO standards. Some of the metal ions (Fe, Mn, Pb) were above the permissive set standards for water samples and therefore there is crucial need to investigate the route source of the metal contaminants. In some cases, adding organic manure to the soil can chemically reduce metal concentration in soil by "tie up" process therefore limiting the uptake by the plants.

Conflicts of Interest

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

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