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Assessment of Levels of Selected Heavy Metals in Soil and Vegetables grown in Eldoret Municipal Dumpsite, Kenya

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Abstract

Urban agriculture in developing countries is facing major challenges which include limited land spaces and the rising cost of artificial fertilizers. As a result, free land spaces are used to grow food crops and raw sewage sludge is applied to enhance fertility. In Eldoret town; Kenya, the old municipal dumpsite has become an ideal site for growing vegetables and sewage sludge is applied without regards to risks of toxic heavy metals and other contaminants. This research was conducted to determine levels of selected heavy metals in soil and vegetables grown in the dumpsite. A total of 42 samples were analysed using atomic absorption spectroscopy and all data were analysed using SPSS version 20.0 where significance was considered at $p \leq 0.05$. Results obtained from soil indicated the following mean concentrations: lead, 1.630 mg/Kg, cadmium, 0.070 mg/Kg, copper, 0.380 mg/Kg, zinc, 2.310 mg/Kg, iron, 101.530 mg/Kg and nickel, 10.370 mg/Kg. In kales mean concentration were as follows: lead, 1.356 mg/Kg; cadmium, 0.110 mg/Kg; copper, 0.095 mg/Kg; iron, 42.070 mg/Kg; zinc, 0.875 mg/Kg and nickel, 9.240 mg/Kg. In spinach the following concentrations were obtained: lead, 1.088 mg/Kg; cadmium, 0.090 mg/Kg; copper, 0.103 mg/Kg; iron, 22.110 mg/Kg; zinc, 0.800 mg/Kg and nickel, 9.190 mg/Kg. In onions mean concentration were as follows: lead, 0.404 mg/Kg; cadmium, 0.345 mg/Kg; copper, 0.109 mg/Kg; iron, 2.650 mg/Kg and zinc, 2.650 mg/Kg. Levels of all the heavy metals in soil were within the acceptable range of WHO/FAO while in vegetables, all the heavy metals were within the acceptable range except lead and cadmium which were above the acceptable limits. It was therefore concluded that the vegetables grown in the dumpsite are not good for human consumption due to high levels of lead and cadmium.

Keywords: Heavy metals, dumpsite wastes, wastewater, vegetables

1. Introduction

There is a rise in urban agricultural practices in developing countries due to the high rate of urbanization that comes with associated challenges, especially the increased demand for food and employment. In Kenya, urban agriculture is a common practice as it acts as a source of income and food that would have otherwise been scarce (Githongo, 2010). Indeed most urban and peri-urban residents in Kenya engage in agricultural activities on a full time basis while those who are not full time farmers are also involved in agriculture to support their income.

Although urban agriculture has many benefits, precaution should be taken to ensure safety of the produce. Farming in urban and peri-urban areas in developing countries is characterized by the use of wastewater which is regarded as a resource of global importance (Bruechler *et al*., 2002). The use of wastewater helps to circumvent the problem of water scarcity and nutrient deficiency in agricultural farms (Kassan, 2010; McKenzie, 2005). However, occurrence of uncontrolled urban sewage farming like the use of untreated or partially treated wastewater is a common site in African cities. In Kenya, the use of untreated sewage wastewater across urban and rural cities has increased with water scarcity and the rising cost of artificial fertilizer (Kutto *et al*., 2012). This practice exposes consumers of such produce to poisoning from heavy metals and other contaminants (Ebong *et al*., 2008).

Recent studies have revealed that, irrigation with wastewater leads to accumulation of heavy metals in the soil which often leads to degradation of soil (Khan *et al*., 2008; Rattan *et al*., 2001; Singh *et al*., 2004; Murtaza *et al*., 2003). These metals are taken up by plant parts and are finally transferred to man and animals through consumption of the food crops (Benson & Ebong, 2005). Although trace quantities of certain heavy metals such as iron, nickel, cobalt, copper, manganese, chromium and zinc are essential micronutrients for higher animals and plant growth; excessive concentration of the heavy metals in food and feed plants are of great concern (Adefemi & Awokunmi, 2009; Lokeshwari & Chandrappa, 2006; FDA, 2001). Heavy metal ions form complexes with proteins in which carboxylic acid (–COOH), amine ($-NH_2$)

and thiol (–SH) groups are involved. These modified biological molecules lose their ability to function properly and result in the malfunction or death of the cells and inactivation of important enzyme systems. This type of toxin may also cause the formation of radicals; dangerous chemicals that cause the oxidation of biological molecules (Neal & Guilarte, 2012).

The high rate of urbanization has led to increased pressure on the urban infrastructure (Tinker, 1994). Availability of land for farming has been affected negatively since fertile lands in the urban and peri-urban settlements are being used for building and other industrial activities. As a result, urban residents especially the low income earners make use of free land spaces to grow food crops. Residents of Huruma especially the low income earners, grow vegetables and grains in the old Eldoret municipal dumpsite because of limited land spaces and use liquid slurry from the Eldoret sewage to enhance fertility of the food crops. The dumpsite was uncovered and unlined therefore leachates from the wastes got access to the soil. Waste dumpsites can transfer significant levels of toxic and persistent metals into the soil (Udosen *et al*., 2006 and Cobb *et al*., 2000). The sewage sludge on the other hand is regarded to be a rich source of nutrients although an earlier study conducted by Khazenzi (1996) showed that domestic and industrial sewage in Eldoret is a potential source of contaminants. Additionally, the available sewerage system in the area is very poor; some pipes are broken therefore effluent find their way to the vegetable farm. The growing of vegetables in a dumpsite and irrigation using sewage wastewater is potentially harmful to human beings therefore the present study was undertaken in an attempt to address part of this problem by assessing levels of heavy metal contaminants in soil and vegetables grown in the dumpsite. Below are some photos of vegetables grown at the old Eldoret municipal dumpsite.

Plate 1: Photographs of vegetables grown in the old Eldoret municipal dumpsite (Source: Author, 2015).

2. Methodology

2.1. Sample Preparation

The vegetables samples were placed under a running tap to wash off soil particles and other debris then rinsed with distilled water. The samples were chopped then air-dried for 2 days after which they were dried in an oven at 60 ºC for 24 hours. The dry samples were crushed in a mortar and pestle. The resulting powder was sieved then stored in clean stoppered containers. Soil samples were oven dried for 72 hours at 80 °C after which the samples were crushed using a pestle and a mortar, sieved then stored in clean dry stoppered containers.

2.2. Analysis of Heavy Metals

Concentrations of heavy metals were analysed using a spectra 200 atomic absorption spectrometer according to the standard procedure of Okalebo *et al*. (2002) with few modifications. Complete dissolution of samples was achieved using acid digestion method.

2.3 Data Analysis and Presentation

All data were analysed using descriptive methods. Statistical analysis was done using SPSS version 20.0. Comparison of mean concentration of heavy metals in soil and in grown vegetables was done using t-test. Comparison of mean concentration of heavy metals in vegetables during dry and wet season was done using paired t-test. In all analysis, significance was considered at $p \leq 0.05$. The heavy metal transfer factor from soil to the vegetables was calculated as follows: Transfer factor = Metal content in plant (mg/Kg)/ Metal content in soil (mg/Kg)

3. Results and Discussion

3.1 Mean Concentration of Heavy Metals in Soil

Table 3.1: *Mean concentrations of heavy metals in soil during dry and wet seasons*

Heavy metals	Mean	Std. Deviation
Cadmium in soil during dry season	0.0689	± 0.0110
Cadmium in soil during wet season	0.0646	±0.0068
Copper in soil during dry season	0.4381	± 0.5280
Copper in soil during wet season	0.3267	±0.4168
Iron in soil during dry season	58.5100	±19.7196
Iron in soil during wet season	144.5571	±56.9054
Lead in soil during dry season	1.7357	±0.5659
Lead in soil during wet season	1.5257	±0.6650
Zinc in soil during dry season	2.6762	±1.1229
Zinc in soil during wet season	1.9392	±3.2936

3.2 Mean Concentration of Heavy Metals in Vegetables

Table 3.2*: Mean concentrations of heavy metals in kales during dry and wet seasons*

Heavy metals	Mean	Std. Deviation
Cadmium in Kales during dry season	0.1121	±0.0162
Cadmium in Kales during wet season	0.1087	±0.0075
Copper in Kales during dry season	0.1010	±0.0211
Copper in Kales during wet season	0.0901	±0.0168
Iron in Kales during dry season	3.3200	±1.3123
Iron in Kales during wet season	80.8357	±18.1534
Lead in Kales during wet season	2.0700	±0.0860
Nickel in Kales during wet season	9.2430	±3.1923
Lead in Kales during dry season	1.2429	±0.1180
Zinc in Kales during dry season	1.4948	±0.6170
Zinc in Kales during wet season	0.2658	±0.0363

Table 3.3: *Mean concentrations of heavy metals in spinach during dry and wet seasons*

Heavy metals	Mean	Std. Deviation
Cadmium in spinach during dry season	0.0933	±0.0167
Cadmium in spinach during wet season	0.0860	±0.0187
Copper in spinach during dry season	0.1054	±0.0162
Iron in spinach during dry season	4.1786	±3.3488
Copper in spinach during wet season	0.1000	±0.0173
Iron in spinach during wet season	40.0571	±24.1056
Lead in spinach during dry season	1.0571	±0.1861
Lead in spinach during wet season	1.7186	±0.8058
Nickel in spinach during wet season	9.1876	±2.9491
Zinc in spinach during dry season	1.1413	±0.1727
Zinc in spinach during wet season	0.4626	±0.1666

Table 3.4: *Mean concentrations of heavy metals in onions and soil*

Heavy metals	Mean	Std. Deviation
Cadmium in onions	0.3457	±0.0168
Cadmium in soil of onion	0.3307	±0.0203
Copper in onions	0.1091	±0.0134
Copper in soil of onion	0.4021	±0.1284
Iron in onions	2.6522	±0.3991
Iron in soil of onion	27.4733	±11.2221
Lead in onions	0.7044	± 0.0566
Lead in soil of onion	1.2833	± 0.1166
Zinc in onions	1.2238	±0.1819
Zinc in soil of onion	2.9160	±0.8806

Mean concentration of lead in soil in this study ranged from 1.53 to 1.74 mg/Kg. This concentration was within the safe limit of 100 mg/Kg set by WHO/FAO (2001). The concentration was also lower compared to those reported in literature; Njagi (2013) reported a range of 19.79 to 60.22 mg/Kg while Premarathna *et al*. (2011) reported a range of 15 to 311 mg/Kg. Similarly Kabata-Pendias & Pendias (1992); Haluschak *et al*. (1998); McGrath *et al*. (2001); Kimani (2007) reported high values of 189 mg/Kg, 55 mg/Kg, 80 mg/Kg and 34.5 mg/Kg respectively. Mean concentration of lead in kales, spinach and onions for dry and wet season ranged from 0.7 mg/Kg to 2.1 mg/Kg. Mean concentration of lead was higher in kales followed by spinach then onions. Level of lead in kales was significantly higher during wet season than dry season. The mean concentrations of lead in vegetables of the present study was in agreement with reports of Njagi (2013); Orisakwe *et al*. (2012); Naser *et al*. (2009); Akubugwo *et al*. (2012). They reported values of between 0.39±0.20 to 1.59±0.03 mg/Kg, 0.35 to 3.89 mg/Kg, 0.49 to 1.97 m/Kg and 0.13 to 0.73 mg/Kg respectively. Muhammad *et al*. (2008) reported lead metal levels in spinach, coriander, lettuce, radish, cabbage and cauliflower with values of 2.251, 2.652, 2.411, 2.035, 1.921 and 1.331 mg/Kg respectively. The levels of lead in vegetables of the present study were significantly higher than the accepted limit of 0.30 mg/Kg set by WHO/FAO (2001) and standard of 0.2 mg/Kg according to Luo *et al*. (2011). This is in agreement with a study carried out by Odai *et al*. (2008) on vegetables grown in a dumpsite in Kumasi which showed that level of lead and cadmium in vegetables were higher than recommended values of WHO/FAO. The vegetables are not good for human consumption with respect to lead; gastrointestinal tract, kidneys and central nervous system among other organs are affected by high levels of lead (E.C., 2002; Jarup, 2003; Szyczewski *et al*., 2009; Brevik & Burgess, 2013). Children exposed to lead are at risk of impaired development, lower IQ, shortened attention span, hyperactivity and mental deterioration (Canfield *et al*., 2003; Chen *et al*., 2005; Morgan, 2013).

Although the values of lead in the dumpsite soil were within the permissible levels for agricultural soils, the transfer factor of this metal to the vegetables was significant and this could explain why the vegetables had higher than permissible levels of lead. The high lead concentrations recorded in vegetables may have been contributed by lead containing waste materials like batteries, discarded plumbing materials and solders which are commonly discarded from Eldoret town, the application of raw sewage sludge and water run offs that carry different wastes. Levels of lead in kales and spinach recorded high values during wet season compared to dry season. In kales the level was significantly higher during wet season than in dry season. This implies that lead was soluble depending on factors like pH leading to high uptake during wet season. Also availability of lead at high levels in vegetables during wet season may have been contributed significantly by water runoffs which carry wastes from different sources including sewage effluent. The transfer factor of lead was high; that of spinach and kales during wet season was greater than 1. This implies that there were other sources of lead to vegetables apart from the soil. Traces of lead may have entered into the vegetables through leaf surfaces as a result of deposit of sewage sludge and other wastes due to application of sludge and water run offs.

Mean concentration of cadmium in soil ranged from 0.065 to 0.069 mg/Kg and is within the safe limit of 3 mg/Kg set by WHO/FAO (2001). Mean concentration of cadmium in kales, spinach and onions for dry and wet season ranged from 0.08 mg/Kg to 0.35 mg/Kg. The mean concentration of cadmium was higher in onions followed by kales then spinach. Concentration of cadmium in kales and spinach was slightly lower during wet season compared to dry season. Levels of cadmium in kales, onions and spinach were significantly higher than the accepted standard of 0.02 mg/Kg (WHO/FAO, 2001) and standard of 0.05 mg/Kg used by Luo *et al*. (2011). This is in agreement with a study of Sharma *et al*. (2007) who concluded that the use of wastewater for irrigation increased the contamination of Cd and Pb in edible portion of vegetables causing health risk in the long term. Similar findings have been documented from a study conducted in Harare, Zimbabwe where farmers used wastewater for irrigating leafy vegetables (Mapanda *et al*., 2005). This implies that the vegetables are not safe for human consumption as far as level of cadmium is concerned. Excessive exposure of cadmium to human beings may cause kidney damage, skeletal damage, irritation of the lungs and gastrointestinal tract, cancer of the lungs and prostate, abdominal pain and diarrhoea (Young, 2005; Ikem & Egiebor, 2005; FDA, 2001). The enhanced level of cadmium in vegetables may be attributed to application of sewage sludge to the vegetable and decay of abandoned electric batteries and other electronic components which are commonly disposed off in Eldoret. Sewage sludge and Ni-Cd electric batteries are known to be good sources of cadmium (Jarup, 2003; Mull, 2005; Brevik & Burgess, 2013). It is also known that the application of agricultural inputs such as fertilizers, pesticides as well as the disposal of industrial wastes increases the total concentration of cadmium in soil and vegetables. The level of cadmium in soil was significantly lower than its level in leafy vegetables; the transfer factor was more than 1. This implies that soil was not the only source of cadmium to the vegetables; cadmium may have entered into the vegetable tissues through deposits on leave surfaces consequent to the applied raw sewage, water runoffs and polluted air. The mean concentration of cadmium was higher in onions followed by kales then spinach. Onions had high levels of cadmium compared to the surface vegetables because they grow underground and as cadmium is leached it comes to contact with onions. Additionally, onions takes long to mature hence have a long time of contact with the contaminants. Cadmium recorded the lowest concentration in soil in all the locations compared to other metals in this study. This is in agreement with the report provided by Udosen *et al*. (2006) in a research conducted from a municipal dumpsite in Nigeria. This may be attributed to the low level of the metal in the earth's crust and as a non-essential element for plants.

Mean concentration of copper in soil of the present study ranged from 0.33 to 0.44 mg/Kg. This concentration is within the safe limit of 100 mg/Kg set by WHO/FAO (2001). The research work by Njagi, (2013) revealed copper levels that were much higher than those in this study with values ranging between 143.02 and 2089.61 mg/Kg. Awokunmi *et al*. (2010) reported even higher levels of copper ranging from 95 to 6726 mg/Kg in soil collected from several dumpsites in Nigeria. Mean concentration of copper in kales, spinach and onions for both dry and wet season ranged from 0.09 mg/Kg to 0.1 mg/Kg. There was no significant difference in concentration of copper in the vegetables during dry and wet season. Levels of copper in kales, spinach and onions were within the accepted limit of 40 mg/Kg (WHO/FAO, 2001) and standard of 10 mg/Kg used by (Luo *et al*. 2011). The low concentration of copper in vegetables of the current study may be explained by its low concentration in soil. Other studies have reported much higher values; Njagi, (2013) reported levels ranging from the lowest value of 0.38±0.19 mg/Kg to 1.72±0.11 mg/Kg while Uwah *et al*. (2011) recorded copper values of between 0.81 mg/Kg and 1.75 mg/Kg in spinach and lettuce grown in Nigeria respectively. Akubugwo *et al*. (2012); Muhammad *et al*. (2008) reported similarly high results in the range of 1.20 to 3.42 mg/Kg and 0.25 mg/Kg to 0.92 mg/Kg respectively while Sharma *et al*., (2006) reported copper concentration of (2.25-5.42 mg/Kg) in vegetables grown in wastewater areas of Varanasi, India. Mean concentration of copper in vegetables in this study was found to be much lesser than concentration in its soil; uptake of copper by vegetables in this study was low as revealed by the low transfer factors. This could be explained by the fact that copper contents do not mobilize in plants and remain stagnant in roots (Bakere *et al*., 1994). There was no significant difference in concentration of copper in soil and plants for both seasons. This implies that concentration of copper was independent of seasonal variations. This can also support the fact that copper has low mobility in soil and plants.

Mean concentration of zinc in soil ranged from 1.94 mg/Kg to 2.68 mg/Kg. This concentration was within the safe limit of 300 mg/Kg set by WHO/FAO (2001) and was much lower compared with those reported by some studies done earlier. Njagi (2013) reported a range of 128.11 mg/Kg to 289.27 mg/Kg. McGrath *et al*. (2001); Kimani (2007) reported the following values of zinc in different countries 200 mg/Kg and 133 mg/Kg respectively. Awokunmi *et al*. (2010) reported much higher zinc levels in soil ranging between 350-3052 mg/Kg. Mean concentration of zinc in kales, spinach and onions ranged from 0.26 mg/Kg to 1.49 mg/Kg. The mean concentration of zinc was higher in onions followed by spinach then kales. Levels of zinc in spinach and kales were higher during dry season than in wet season. The difference was only significant in kales with p=0.002. The mean concentrations of zinc in all the vegetables were within the accepted level of 99.4 mg/Kg as per the requirements of WHO/FAO (2001). The low concentration of zinc in vegetables can be explained by its low concentration in soil. Results of this study on levels of zinc in vegetables were within the range reported by Njagi (2013) of 0.38±0.19 mg/Kg to 2.43±0.15 mg/Kg and Muhammad *et al*. (2008) who reported level of zinc in leafy vegetable samples as 0.461(spinach), 0.705 (coriander), 0.743 (lettuce), 1.893 (radish), 0.777 (cabbage) and 0.678 (cauliflower) mg/ Kg respectively. Akubugwo *et al*. (2012) reported higher values of zinc than those reported in this study with values ranging from 1.06 ± 0.02 to 2.82 ± 0.01 mg/Kg in *Amaranthus hybridus* vegetables. Levels of zinc in spinach and kales in this study were significantly higher during dry season than in wet season. This implies that zinc was soluble in the soil and hence easily washed away. The mean concentration of zinc was higher in onions followed by spinach then kales. Amount of zinc in onions which grow underground was the highest during wet season, this also support the fact that zinc was soluble and likely leached hence coming in contact with onions growing underground. The transfer factor of zinc was higher compared to that of copper. This implies that zinc was soluble in the soil hence high uptake and accumulation in plant tissues.

The mean concentration of iron in soil ranged from 58.50 mg/Kg to 144.60 mg/Kg. This is within the safe limit of 300 mg/Kg set by WHO/FAO (2001). Results reported was within the range range reported by Akubugwo *et al*. (2012); Njagi, (2013) of between 73.62 mg/Kg to 226.39 mg/Kg and between 22.01 mg/Kg to 525.50 mg/Kg respectively. Other studies have reported higher values than those in the current study. Tsafe *et al*. (2012) reported a value of 195.25 mg/Kg in the soil studied while Awokunmi *et al*. (2010) reported values between 1100 to 10,920 mg/Kg. Mean concentration of iron in leafy vegetables ranged from 2.65 mg/Kg to 80.80 mg/Kg. In onions, the concentration ranged from 2.25 mg/Kg to 3.24 mg/Kg. Mean concentrations of iron in kales, spinach and onions for both dry and wet seasons in this study were within the accepted level of 425 mg/Kg (WHO/FAO, 2001). This levels are also within the ranges reported by Tsafe *et al*. (2012) with mean content of 54.05 mg/Kg and Uwah *et al*. (2011) who reported an iron content of 15.96 ± 0.18 mg/Kg in *Amaranthus caudatus* vegetables and values of 42.84 ± 0.27 mg/Kg in *Lactuca sativa* vegetables. Akubugwo *et al*. (2012) reported higher iron metal content of up to 147.41±0.01 mg/Kg in the *Amaranthus hybridus* vegetables. Although iron recorded the highest mean concentration in soil, its transfer factor was low compared to other metals. This implies that solubility of iron in the dumpsite soil was low depending on factors like pH and hence low mobility. The low transfer factors of iron explain why mean concentration of iron was within safe limits in vegetables yet high levels were recorded in soil. Mean concentration of iron in spinach and kales were significantly higher during wet season compared to dry season. The high level of iron in spinach and kales during wet season may have come as result of water run offs. Level of iron was higher in kales followed by spinach then onions. Thus onions which grow underground were not affected highly with iron contamination compared to kales and spinach which grow above the soil surface, this also support the fact that high level of iron in spinach and kales during wet season may have resulted from water run offs therefore affecting surface vegetables more. Solubility of iron was low as indicated by the low uptake by vegetables therefore iron was not leached and this also explain why its concentration in onions growing underground was low. The results revealed that iron recorded the highest mean metal concentration in soil at all the locations compared to other metals. This is in agreement with the report of Amusan *et al*. (2005) during a research on plants from some rural and municipal dumpsites within Ife, Nigeria. This could be attributed to the availability of the metal in the earth's crust, at dumpsites and its high utilization by plants.

Soil in this study recorded concentrations of nickel that were lower than the safe limit of 50 mg/Kg with values ranging from 4.6-13.6 mg/Kg. Literature report values were higher than those reported in the present study. Values of 5250.62 – 11968.76 mg/Kg, 450 mg/Kg, 98 mg/Kg, 100 mg/Kg, 1650 mg/Kg and 2360 mg/Kg recorded by Njagi (2013); Kabata-Pendias & Pendias (1992); Haluschak *et al*. (1998); McGrath *et al*. (2001); Awokunmi *et al*. (2010); Adefemi & Awokunmi (2009) respectively. Mean concentration of nickel in kales and spinach were 9.24 mg/Kg and 9.18 mg/Kg respectively. These levels are within accepted level of 67 mg/Kg set by WHO/FAO (2001). The low levels of nickel in vegetables can be attributed to its low level in soil. The mean concentration of nickel in leafy vegetables in this study is within the range reported by Premarathna *et al*. (2011) with values ranging from 2.3 to 37.80 mg/Kg in various vegetables. Other studies have reported high values of nickel in vegetables. Njagi (2013) reported a range of 13.02±0.54 to 35.23±1.04 mg/Kg. Okoronkwo *et al*. (2005) reported values of between 22.59 mg/Kg and 24.47 mg/Kg in the vegetables under study. On the other hand, Naser *et al*. (2009) in Bangladesh reported lower levels of nickel than those of this study (5.369 mg/Kg) in the vegetables. In this study the transfer factor of nickel to vegetables was high; approximately 0.9 (90%). This is attributed to the fact that nickel in plants is highly mobile and is likely to accumulate in both leaves and seeds (Sengar *et al*., 2008).

In general, levels of all the heavy metals in soil were within the acceptable limits of WHO/FAO (2001). This is in agreement with findings of Ebong *et al*. (2008) in a study to determine heavy metal contents of municipal and rural dumpsite soils in Uyo, Nigeria. Moreover, results obtained in this study have shown that waste dumpsites contribute significant levels of toxic metals to soil and finally to crops. The results have also indicated that vegetables can accumulate heavy metals to high levels beyond recommended standards even if the levels are within safe limits in soil. Thus vegetables should not be grown in contaminated soil and information about heavy metal content in soil alone cannot be used to draw conclusion on safety of food stuffs from the soil.

The soil to plant transfer factors was in the order cadmium> lead> nickel> zinc> copper> iron. Cadmium had the highest transfer factor while iron had the lowest mobility although concentration of iron in soil was the highest while that of cadmium was the lowest. This implies that uptake of heavy metals by vegetables does not increase linearly with increasing concentrations of metals in soil. The apparent advantage of this phenomenon is that although long term polluted water and municipal wastes result into elevated levels of metals in soil, the same will not be proportionately transferred to the food chain.

4. Conclusion

This research work has revealed that plants grown in dumpsite soil and irrigated using raw sewage sludge can accumulate more toxic metals to levels that are harmful to human health even if their levels in soil are within safe limits. Soil and vegetables grown at the old Eldoret municipal dumpsite were contaminated with toxic heavy metals which included lead, cadmium, copper, zinc, iron and nickel. In soil all the heavy metals were within safe limits. In vegetables, levels of copper, zinc, iron and nickel were within safe limits for human consumption while levels of lead and cadmium exceeded the standard of WHO/FAO (2001). Therefore the vegetables are not safe and should not be consumed. Although no severe contamination problems are currently apparent in the dumpsite for all the heavy metals apart from lead and cadmium which were above the safe limits, continuous dumping and decay of wastes at the dumpsite may lead to enrichment of the soil with other pollutants that are presently at uncontaminated levels. Therefore the use of the old Eldoret municipal dumpsite for growing vegetables should be discontinued.

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