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Investigation of Selected Heavy Metal Ions in Irrigation Water, Soil and Managu *(Solanum Nigrum)* from Homahills, Homabay County, Kenya

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Abstract: Levels of selected heavy metals of Mn, Cd, Pb, Zn, Fe and Co were evaluated in irrigation water, soil and managu *(Solanum Nigrum)* from Homahills, Homabay County, Kenya. The samples were collected purposively and randomly then transported to KALRO Kericho to be analysed using Inductive Coupled Plasma Optical Emission Spectroscopy. Descriptive statistics and t-test analysis for the heavy metal concentrations were done using SPSS Version 21, transfer factor was also calculated. The levels of heavy metals detected in irrigation water were; 0.89, 0.01, 0.18, 0.35, 4.20 and 0.04 mg/L for Mn, Cd, Pb, Zn, Fe and Co respectively. The overall concentration of heavy metals detected in soil under irrigation were; 315.56, 1.00, 13.00, 19.17, 59.05 and 12.50 mg/kg for Mn, Cd, Pb, Zn, Fe and Co respectively. The overall levels of heavy metals detected in *Solanum Nigrum* under irrigation were 10.16, 5.23, 4.02, 41.42, 479.56 and 11.41 mg/kg for Mn, Cd, Pb, Zn, Fe and Co respectively. Using paired t-test, the mean heavy metals level recorded in irrigated *Solanum Nigrum* from two Sub locations were significantly different ($p < 0.05$) in Mn, Pb, Zn and Co but not significantly different in Cd and Fe. The results revealed that levels of Cd, Mn, Fe and Pb in soil and *Solanum Nigrum* were above the FAO/WHO limit. These levels pose risks to the consumers rendering them not safe for consumption. Therefore, regular monitoring for these metals in food is vital in ensuring consumption of safe food and avoiding bioaccumulation in the food chain.

Keywords: Heavy Metals, Bioaccumulation, *Solanum Nigrum*, Irrigation Water and Soil

1. Introduction

Soils is considered as the fine earth and are vital for life as they provide the medium for plant growth, home for many organisms, filter surface water among others [1, 2]. Currently, due to increased development activities soil pollution has become a common occurrence. Some of the main sources of soil contamination consist of agricultural practices, industrial emissions or effluents and natural sources among others [3-6]. Polluted soil can be a major route of exposure of heavy metals to humans through uptake of polluted food crops and can cause in increased harm because of bioconcentration [7-9]. Vegetables grown on heavy metals polluted farmlands can take up the metals and prolong exposure of heavy metals even at very low concentrations can result in long lasting cumulative health effects in humans [10-12]. Concentration of heavy metals in leafy vegetables plants is influenced by parameters like the levels of heavy metals in soils, climatic condition of the region, the soil type, atmospheric depositions, and the extent of maturity of the plants during sampling [13, 14].

Elevated levels of cadmium causes cancer through DNA damage, kidney disease, teratogenic defects among others [15, 16]. Zinc is known to cause damage to brain, respiratory track and increases the risks of prostate cancer [17, 18]. Copper is reported to cause developmental toxicity, liver and kidney damage among others [19, 20]. Manganese can cause effect to development of human fetus and neurological damage [21, 22]. An elevated dietary iron intake increase risk of cancers [23, 24]. An elevated level of lead is known to impair neuro development in children, kidney damage, causes cancer through DNA damage, and death [16, 25, 26].

Water pollution by heavy metal is generally unavoidable in some areas because of natural environmental process such as volcanic eruption, weathering of rocks and human activities such as agricultural practices such as farming and industrial air and liquid effluents. Plants can take up heavy metals from soil especially in soluble form [27-30].

A research carried out by [31] on heavy metal in water, sediments and plants from Sosiani River, Uasin-Gishu County, Kenya reported 0.18 ppm, 0.46 ppm and 0.70 ppm of Cu Pb and Zn respectively from the water collected and also reported elevated levels of Zn in the studied plants.

Heavy metals have a tendency to stay long in the environment and also bioaccumulate in food-chains. The leafy vegetables have a tendency to accumulate more heavy metals as compared to fruits and grains [32, 33]. Food ingestion of heavy metals can cause long term body build up and its effects can only be felt after numerous years of exposure [34]. Consequently, consistent monitoring of heavy metals in the food especially leafy vegetables should be carried out in order to avert accumulation of heavy metals in the human food chain. Therefore, the present study was undertaken to assess the extent of toxic trace heavy metal in irrigation Water, Soil and Managu *(SolanumNigrum)* Homahills, Homabay County, Kenya.

2. Methodology

Homa Bay County lies within latitude of 0° 54' 08"S and a longitude of 34° 18' 00"E. It borders Migori Kisumu Siaya Kisii and Nyamira counties, Lake Victoria and Uganda. The county covers an area of 4,267.1 km^2 inclusive of the water surface with geographical coverage of 1,160 km^2 [35, 36].

The study was conducted in Homahills which is situated about 50 kilometers north of Kendu Bay. The area which lies on the Nyanzan Rift covers an area of roughly 150 km^2 and. The homahill has 6 kilometres in long axis and 5 kilometres in short axis with an evelation of 1571 metres above sea level. Homa hills area is characterized by black cotton soils and dark loam soils, which are derivatives of basalts, tuff, rhyolites and andesite [37-39].

The main economic activities are small-scale agriculture, fishing, trade and livestock keeping. The major crops grown in the region are maize, sorghum, sweat potatoes and millet both for domestic and trade purposes. The area is dominated by clay loam sandy soils derived from igneous rocks. The Bala hot spring also dominates the irrigated farms in some parts of Kauma and Kakdhimu location. The greater Lake Victoria is situated on the eastern parts next to Kendu-Bay all the way to Kakdhimu location [40].

2.1. Experimental Procedures

Two agro-ecological zones were purposively sampled, many residents in these zones were irrigating their crops using the water from the Lake. The two zones were Lower Midland 3 where Kanam B location falls and Lower Midland 4 Kokoth Kata location falls. Four farms in each sub-location were purposively sampled where irrigation of vegetables were practiced. A line transect was used to identify the sites where soil and vegetables samples were collected.

Two leaves of vegetables were plucked at maturity, inserted into khaki bags and transported to laboratory for preparation and analysis. The leaves were then cleaned with tap water and rinsed with distilled water to remove soil particles and other debris. It was then air dried and cut into small sizes and finally using a stainless grinder crushed into fine powder and placed in a well labeled khaki bags and stored for further analysis.

Composite soil samples were sampled from the depth of (0-10 and 11-15 cm) in the same site where the vegetable plants were collected. The soil auger was used to collect approximately 0.5 g of soil samples and stored in dry well labeled khaki bags. The samples were collected in triplicate and a total of 18 samples were collected during the research. The collected samples were transported to University of Eldoret biotechnology laboratory where it was dried using an oven at a temperature approximately 90 degrees centigrade in order to eliminate the moisture and then using a stainless steel grinder grounded to fine powder. Then, the ground samples were placed in khaki bags awaiting digestions and analysis. The samples were finally taken to KALRO Kericho for digestion and analysis using inductive couple plasma.

Water which was used for irrigation in the selected three selected farms was sampled into 500 ml clean glass vials using purposive sampling. The vials were labeled and a drop of HNO_3 (65%) was added to make their pH < 2 to avoid precipitation of metals and stored at 5°C awaiting transportation to University of Eldoret labs and finally to KALRO Kericho for samples digestion. Nine samples were collected during the study.

2.1.1. Vegetable Samples Digestion

A 0.3 g of finely ground dried vegetable sample was weighed placed into separate pre-cleaned digestion tubes. A 4.4 ml of the digestion mixture and reagent blanks were added to each tube. At 350°C the tubes were heated in a block digestor for 2 hours until it became colourless. Then the tubes were detached from the digester and it was left to cool at the normal room temperature. A 25 ml of distilled water was then added, thoroughly mixed and topped up 50 ml with distilled water. The contents were then eventually transferred into a 50 ml volumetric flask and left to settle. The clean solution was finally decanted to be used for analysis using ICP-OES.

2.1.2. Soil Samples Digestion

2 g of each soil sample was bench dried for 5 days in the laboratory then crushed in a mortar with pestle to fineness. The ground soil sample was sieved through a 10-mesh (2 mm) sieve and moisture dried in the oven separately at 105°C until constant weight was obtained. The wet digestion was done by reflux digestion of 1 g sub-sample with 10 ml of

concentrated HCl/HNO_3 in 1:4 ratios. A few boiling chips were added and temperature regulated at 100°C for 3 hours by using Aluminium digestion block. The mixture cooled and acid was added with 12.5% v/v HNO_3 then filtered (Mazira, 2012 and Salano, 2014). The samples were analyzed using ICP-OES using the standard procedure stipulated by the author in (Melaku *et al.,* 2005).

2.1.3. Water Digestion

The samples were shaken in their vials, and then a 100 ml was measured and transferred to a conical flask and digested on a hot plate using a mixture of conc HNO_3/HCl until a light coloured clear solution was produced. 2 ml of concentrated hydrochloric acid heated slightly to dissolve any remaining residue. Few drops of hydrogen peroxide was then added to ensure complete digestion. The solution was then diluted with distilled water to the mark and stored in refrigerator awaiting ICP-OES analysis (Cobbina, *et al.,* 2015; Mazira, 2012; Du Plessis, 2015).

2.2. Statistical Analysis

Descriptive statistics and t-test analysis for the heavy metal concentrations (Mn, Pb, Cu, Zn, Co, Fe and Cd) in irrigation water, soil, and vegetables were done using SPSS Version 21. Data were presented in tables and figures. Transfer factor was also calculated as follows $TF=C_{plant}/C_{Soil}$ Where C_{plant} and C_{soil} represents the toxic metal concentration in extracts of plants and soils on dry weight basis, respectively.

3. Results

3.1. Heavy Metal Concentrations in Water Used for Irrigation

The mean levels of heavy metal (mg/L) of the irrigation water are shown in figure 1. The highest recorded was Fe (4.20 mg/L) and Cd (0.01 mg/L) was the lowest concentration. The order of concentration (according to mean values of all areas) was Fe>Mn>Zn>Pb>Co>Cd in the water.

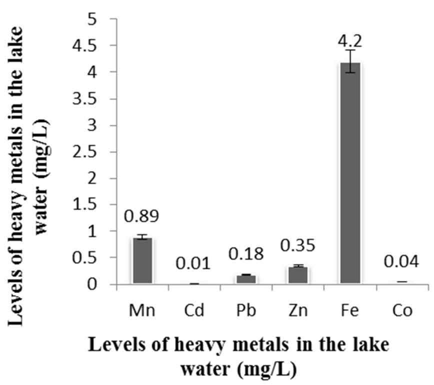

Figure 1. *Heavy metals concentration in Irrigation Lake Victoria water from Homahills region.*

The levels of heavy metals detected in water used for irrigation were; 0.89 ± 0.58 mg/L for Mn, 0.01 ± 0.00 mg/L for Cd, 0.18 ± 0.08 mg/L for Pb 0.35 ± 0.14 mg/L for Zn, 4.20 ± 2.20 mg/L for Fe and 0.04 ± 0.01 mg/L for Co.

3.2. Heavy Metal Concentrations of Soil Found in Homahill, Homabay County

3.2.1. Heavy Metals Levels in Irrigated Soil from Kokoth Kata and Kanam B Sub Locations in Homahills

Mn (315.56 mg/kg) recorded the highest concentration while Cd (1 mg/kg) had the lowest concentration. The order of concentration (according to mean values of all areas) was Mn>Fe>Zn>Co Pb>Cd in the soil. Results are presented in table 1 below.

Table 1. *The overall levels of heavy metals concentration found in the soil under irrigation in Kokoth Kata and Kanam B sub locations from Homahills region.*

	N	Mean		Std. Deviation
	Statistic	Statistic	Std. Error	Statistic
Mn	18	315.56	13.59	57.64
Cd	18	1.00	0.00	0.00
Pb	18	9.06	0.37	1.55
Zn	18	19.17	1.42	6.03
Fe	18	59.06	1.73	7.34
Co	18	12.50	0.19	0.79

The overall levels of heavy metals detected in soil under irrigation were; 315.56 ± 13.59 mg/Kg for Mn, 1.00 ± 0.00 mg/Kg for Cd, 13.00 ± 0.37 mg/Kg for Pb, 19.17 ± 1.42 mg/Kg for Zn, 59.06 ± 1.73 mg/Kg for Fe and 12.50 ± 0.19 mg/Kg for Co.

The levels of heavy metals detected in soil under irrigation from Kokoth Kata were; 313.89 ± 15.21 mg/kg for Mn, 1.00 ± 0.00 mg/Kg for Cd, 7.89 ± 0.20 mg/Kg for Pb, 15.00 ± 0.37 mg/Kg for Zn, 58.56 ± 2.96 mg/Kg for Fe and 12.11 ± 0.26 mg/Kg for Co.

The levels of heavy metals detected in soil under irrigation from Kanam B were; 317.22 ± 23.50 mg/Kg for Mn, 1.00± 0.00 mg/Kg for Cd, 10.22 ± 0.43 mg/Kg for Pb, 23.33 ± 2.03 mg/Kg for Zn, 59.56 ± 2.96 mg/Kg for Fe and 112.89 ± 0.20 mg/Kg for Co.

3.2.2. Spatial Comparisons of Heavy Metals Found in Soil from Kokoth Kata and Kanam B Sub Location

Using paired t-test, the mean heavy metals level recorded in soil was ($p < 0.05$) significantly different in Pb, Zn and Co were Pb (P=0.000, df=8 T=-5.715), Zn (P=0.003, df=8 T-4.211) and Co (P=0.043, df=8 T=-2.401) respectively. However, paired t-test, the heavy metals mean level recorded was not significantly different Mn (P=.879, df=8 T=-0.157) and Fe (P=0.776, df=8 T=-0.295).

3.3. Heavy Metal Concentrations of Solanum Nigrum Found in Homahill, Homabay County

3.3.1 Heavy Metals levels in solanum nigrum from Kokoth Kata and Kanam B Sub Locations in Homahills

Fe (479.56 mg/Kg) had the highest concentration and Pb (5.2 mg/Kg) recorded the lowest concentration. The order of concentration (according to mean values of all areas) was Fe>Zn>Co>Mn>Cd>Pb>in the *solanum nigrum*. Results are presented in table 2 below.

Table 2. *The overall levels of heavy metals concentration found in the Solanum Nigrum under irrigation in Kokoth Kata and Kanam B sub locations from Homahills region.*

	N	Mean		Std. Deviation	Variance
	Statistic	Statistic	Std. Error	Statistic	Statistic
Mn	18	10.16	1.69	7.17	51.46
Cd	18	5.22	0.08	0.34	0.1
Pb	18	4.02	0.23	0.99	0.99
Zn	18	41.42	4.16	17.63	310.90
Fe	18	479.56	19.8	84.04	0.01
Co	18	11.41	0.38	1.60	2.56

The overall levels of heavy metals detected in *Solanum Nigrum* under irrigation were; 10.16 ± 1.69 mg/Kg for Mn, 5.22 ± 0.08 mg/Kg for Cd, 4.02 ± 0.23 mg/Kg for Pb, 41.42 ± 4.16 mg/Kg for Zn, 479.56 ± 19.81 mg/Kg for Fe and 11.41 ± 0.38 mg/Kg for Co.

The levels of heavy metals detected in *Solanum Nigrum* under irrigation in Kokoth Kata Sub location were; 9.43 ± 0.28 mg/Kg for Mn, 5.18 ± 0.11 mg/Kg for Cd, 4.16 ± 0.24 mg/Kg for Pb, 40.67 ± 5.06 mg/Kg for Zn, 476.44 ± 30.56 mg/Kg for Fe and 11.46 ± 0.52 mg/Kg for Co.

The levels of heavy metals detected in *Solanum Nigrum* under irrigation in Kanam B Sub location were; 10.88 ± 2.61 mg/Kg for Mn, 5.26 ± 0.12 mg/Kg for Cd, 3.87 ± 0.41 mg/Kg for Pb, 42.16 ± 6.90 mg/Kg for Zn, 482.67 ± 27.04 mg/Kg for Fe and 11.36 ± 0.58 mg/Kg for Co.

3.3.2. Spatial Comparisons of Heavy Metals Found in Irrigated Solanum Nigrum from Kokoth Kata and Kanam B Sub Location

Using paired t-test, the mean heavy metals level recorded *Solanum Nigrum* under irrigation was ($p < 0.05$) significantly different in Pb, Zn and Co were Pb (P=0.000, df=8 T=-5.715), Zn (P=0.003, df=8 T-4.211) and Co (P=0.043, df=8 T=-2.401) respectively. However, paired t-test, the heavy metals mean level recorded was not significantly different Mn (P=0.402, df=8 T=0.885) and Fe (P=0.776, df=8 T=-0.295).

3.4. Transfer Factors of the Heavy Metals from Soil to Vegetables

The calculated transfer factor for Mn, Cd, Pb, Zn, Fe and Co did not vary greatly in Kokoth Kata and Kanam B Location (Table 3).

Table 3. *Transfer factor values for heavy metals obtained from Kokoth Kata and Kanam B location.*

Heavy Metal	Kokoth Kata Transfer factor	Kanam B transfer Factor
Manganese	0.03	0.04
Cadmium	5.18	5.26
Lead	0.53	0.38
Zinc	2.711	1.81
Iron	8.14	8.105
Cobalt	0.96	0.88

From table 3 it's observed that Cd, Zn and Fe had the highest transfer factor compared to other elements with Fe having the highest and Mn having the lowest. The sequence of TF for the elements followed the decreasing order Cd>Fe>Zn>Co>Pb>Mn.

4. Discussions

The levels of heavy metals detected in irrigation water were 0.89, 0.01, 0.18, 0.35, 4.20 and 0.04 mg/L for Mn, Cd, Pb, Zn, Fe and Co, respectively. The World Health Organization [41] standard for heavy metals in water used for irrigation are 0.2, 2, 5, 5, 0.2, 0.1 mg/L for Mn, Zn, Pb, Fe, Cu and Cd respectively. Therefore, only Mn concentrations were above WHO standards. The high levels of Mn could be due to weathering of rocks and erosion from homahill. It can also be attributed to agricultural activities in the region [42]. [43] in their study on heavy metals in Urban and Peri-Urban Farms in Eastern Nairobi, Kenya recorded the concentrations (mg/L) to ranged from 3.09-3.54, 0.01-0.03, 0.21-0.28, 4.79-8.07, 0.17-0.22 and 0.42-0.47 mg/L for Mn, Zn, Pb, Fe, Cu and Cd respectively. [44] Reported ranges of Cd (0.00–0.006 mg/L) and Pb (0.012–0.088 mg/L), in water used for irrigation in Dinapur, Varanas agricultural fields.

In this study the overall mean metal concentrations of heavy metals in the soils under irrigation were; 315.56, 1.00, 13.00, 19.17, 59.05 and 12.50 mg/kg for Mn, Cd, Pb, Zn, Fe and Co respectively. According to [41], the permissible limits for Mn, Zn, Pb, Fe, and Cd in soil are 300, 100, 60, 300 and 3 mg/kg respectively. According to the results, only Mn exceeded the permissible limits for soil. [45] recorded an iron metal content in the soils ranging between 73.62 mg/kg to 226.39 mg/kg which was slightly higher than this study. [46] recorded the heavy metal average levels to be 55.16 mg/kg for Cd which was higher than this study. [47] reported 28.24 mg/kg of Zn in agricultural soil in India.

The paired t-test heavy metals level recorded in soil was ($p < 0.05$) significantly different in Pb, Zn and Co were Pb from Kokoth Kata and Kanam B location. The difference can be attributed to different agricultural practices employed by farmers in each region and different distribution of different heavy metals types in parent rock and hence variations availability and uptake by plants in those regions.

The overall levels of heavy metals detected in *Solanum Nigrum* under irrigation were 10.16, 5.23, 4.02, 41.42, 479.56 and 11.41 mg/kg for Mn, Cd, Pb, Zn, Fe and Co respectively. According to [41], the permissible limit for Mn, Zn, Pb, Fe, and Cd in leafy vegetables are 0.2, 60, 0.3, 48 and 0.2 mg/kg respectively. Therefore, Mn, Cd, Pb, and Fe exceeded the standards.[48] and [42] reported lower levels of Fe level of 54.05 mg/kg in *Amaranthuscaudatus* and 147.41±0.01 mg/kg in the *Amaranthushybridus* vegetables respectively. [46] reported levels of Cu, Pb and Cd in vegetables from the contaminated area to range from 0.463 to 6.67, 0.00 to 1.47 and 0.00 to 0.71 mg/kg respectively. [49] recorded levels in the vegetable dry matter (mg/kg dry matter) to range between 0.15 – 0.66 mg/kg for Cadmium, 1.6 – 9.82 mg/kg for copper; 3.75 – 18.64 mg/kg for manganese, 1.96-8.02 mg/kg for lead and 11.60 – 59.15 mg/kg for zinc.

The paired t-test the mean heavy metals level recorded inirrigated *Solanum Nigrum* was ($p < 0.05$) significantly different in Mg, Pb, Zn and Co from Kokoth Kata and Kanam B location. These variations may be ascribed to the physical and chemical nature of the soil of the farm sites, absorption capacities of heavy metals by vegetables, atmospheric deposition of heavy metals. It can also be attributed to partly to different geological distribution of parent rock and to different agricultural practices employed by farmers in each region.

The highest metal TF was Cd, this could be attributed to a higher mobility of Cd with a natural occurrence in soil, and the low retention of Cd (II) in the soil than other toxic cations [50]. [51] recorded the TF of zinc and lead found from soil to plant Enhydrafluctuans and Oryza from Bangladesh to be 1.762 and 1.05; and 5.519 and 1.20 respectively.

5. Conclusion and Recommendation

The water used for irrigation obtained from Lake Victoria was polluted by Mn which exceeded the WHO standards for irrigation water, also the same applied to soil. The heavy metals in *Solanum Nigrum* which exceed the WHO standards were Mn, Cd, Pb, and Fe. The high levels in *Solanum Nigrum* were attributed to partially active volcanic Homahill and agricultural practices employed by farmers. High TF were recorded in Cd, Zn and Fe indicating that these metals are more easily transferred from soil to the edible parts of plants than ones with low transfer factor posing a health risks to the consumers. Therefore, the residents of these areas are in high health risks of toxic metal exposure. These levels pose risks to the consumers rendering them not safe for consumption. Therefore, regular monitoring for these metals in food is vital in ensuring consumption of safe food and avoids bioaccumulation in the food chain.

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