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Status of Agricultural Soil Contamination by Heavy Metals in Uasin Gishu County

Teresa Akenga
Vice chancellor, University of Eldoret, P.O. BOX 1125, Eldoret, Kenya

Vincent Sudoi
Dean School of Environmental Studies, University of Eldoret, P.O. BOX 1125, Eldoret, Kenya

Walter Opande
Office of the Vice Chancellor, University of Eldoret, P.O. BOX 1125, Eldoret, Kenya

Emmy Kerich
School of Environmental Studies, University of Eldoret, P.O. BOX 1125, Eldoret, Kenya

Abstract

Heavy metals occur naturally in the environment but anthropogenic activities such as use of chemicals and inorganic fertilizers in farms has resulted in higher concentrations of these metals relative to their normal background values leading to environmental pollution. Soil plays a central role in food safety as it determines the possible composition of food and feed at the root of the food chain. Soil pollution by heavy metals has been on the increase with its main sources being application of agricultural chemicals, improper disposal of industrial wastes, among others. This study investigated different concentrations of the heavy metals in soils of farms during the two major crop seasons in Uasin Gishu County, Kenya. The presences of heavy metals (Lead, Copper, Cadmium, Cobalt and Zinc) were determined in the three agro-ecological zones in Uasin Gishu County. These agro-ecological zones include Lower highland (LH3), Upper midland (UH4) and Upper midland (UH2). Soil samples from randomly selected farmers in the study area at the depth of 0-10cm and 10-20 cm were obtained. A total of seventy two soil samples were collected and analyzed for presence of heavy metals using ICPE-900Shimadzu inductive coupled plasma. The results obtained indicated that concentrations of the heavy metals found in soils at the three agro-ecological zones during the dry and wet seasons varied significantly.The results obtained showed that the mean concentration of Pb, Cd, Co, Zn and Cu in UH2 ranged between 12.0 –15.5ppm, 2.8–4.7 ppm, 2.5–9.5 ppm, 2.3–4.0 ppm, 8.0–16.3 ppm respectively, while in LH3 the concentration range between 10.0 –18.6 ppm, 1.8–4.8 ppm, 2.3–10.0 ppm, 2.0–17.3 ppm, 7.9–17.3 ppm respectively and finally in UH4, the mean concentrations of the five metals ranged between 10.3 –13.0ppm, 1.7–4.3 ppm, 4.0–8.5 ppm, 2.0–2.5 ppm, 7.7–16.5 ppm respectively. The level of Cd concentrations was found to exceed the WHO standard of 3mg/l in the study area. All the heavy metals concentrations varied significantly ($P< 0.05$) during wet and dry season indicating their mobility in the soils. The presence of heavy metals above the natural levels in the study area is attributed to sources such intensive agricultural activities. The results of this study revealed that the three agricultural zones of LH3 (Lower highland), UH4 (Upper midland) and UH2 (Upper midland) contained variable levels of heavy metals (Pb, Cd Zn, Co and Cu). The levels of heavy metals were high and may be indicative of the level of pollution resulting from farm activities in the three locations. The high level of Cadmium could be attributed to the level of use of inorganic fertilizers in the farmers fields in the study area.
Keywords*:* Heavy metal; Agro-ecological zones; Agricultural soil; Soil depth; Uasin Gishu County.

1. Introduction

Soil is a very important natural resource to man as it is a source of his livelihood on this planet. Kenya's economy primarily depends on natural resources where over 68% of the population live in rural areas and derive their livelihoods mainly from these resources. Economic activities derived from, the natural resources include agriculture, industry, tourism, energy, water, trade, and mining (Authority, 2009). Due to intensified agricultural activities, Kenya has become the largest fertilizers user in Sub-Saharan Africa, according to Singh et al., (2004) three hundred and seventy one thousand, eight hundred and eighty six metric tonnes of fertilizers were imported in Kenya and close to eight thousand, three hundred and seventy tonnes of pesticides with a value of Kshs 4.68 billion were imported to Kenya in the year 2005 (Birech et al., 2006). In Uasin Gishu county farmers mostly use inorganic fertilizers such as Di-Ammonium Phosphate (DAP), Calcium Ammonium Nitrate (Buccolieri et al., 2010) and Nitrogen Phosphate potassium (NPK), Urea organic fertilizers, herbicides, pesticides and inorganic fertilizers in order to increase yield to sustain a growing population. These products when used during crop farming could result in deposition of heavy metals to the soil environment (Aldesuquy et al., 2012; Baran et al., 2007). Uptake of heavy metals and other toxic substances by plants leads to bioaccumulation in the food chain

Heavy metals can be defined as elements having a specific density of more than 5 g/cm3 (Järup, 2003; Suciu et al., 2008). Heavy metals are those elements whose atomic mass number is more than 40 (Adelekan and Abegunde, 2011; Jennett, 1980). These include heavy metals such lead; cadmium, copper, zinc, arsenic, chromium, cobalt and mercury which are major environmental pollutant (Nagajyoti et al., 2010).

Heavy metals occur naturally in ecosystem with large variation in concentration. Human activities have continuously added a lot of heavy metal into the environment (Duffus, 2002). Although heavy metals such as Cu, Co, Fe, Mn, Mo, and Zn are considered as essential macro-elements and micro-elements especially at non-adverse effects levels, they can exert negative effects at high concentration (Dimari et al., 2008). Heavy metals are harmful because they tend to accumulate in the system.

These heavy metals are absorbed by the roots and deposited on different parts of the plants which when consumed could have health risk (Sobukola et al., 2010). Trace amount of Cd and Pb impurities can be found in compounds used to supply these elements and thus continued use of fertilizer application may significantly increase heavy metal content in the soil. Certain phosphatic fertilizer applications continuously add Cd and other toxic elements to the soil, including mercury, lead and fluorine (Raven et al., 1998).

Plants growing in a polluted environment can accumulate toxic metals at higher concentration causing serious risk to human health when consumed. High levels of Arsenic, Copper and Zinc can be contained in manures produced from animals and, if applied repeatedly to restricted areas of land, can eventually cause considerable accumulation of these metals in the soil. Health effects of heavy metals exposure is known to cause chronic illnesses such as cancer, kidney problems, damage of the nervous system and the red blood cells and affects the brain (Sanayei et al., 2009; Simeonov et al., 2010)..

The determination of levels of cobalt, zinc, lead, copper and Cd in soils of Uasin Gishu county will be used to sensitize the general population on the importance of environmental conservation. The study will also inform the authorities in environment management on the level of heavy metal pollution in the county hence providing a reference for future studies on the same. Information obtained from this study can be used by the community and other development agencies to find alternative farming practices which ensure environmental conservation..

1.1 MATERIALS AND METHODS

1.1.1. Study Area

Purposive sampling was done on the basis of agro-ecological zones done in order to capture representative areas where maize farming is practiced. Uasin Gishu County (UG) lies between longitudes 34 degrees 50‟ east and 35 degrees 37‟ West and latitudes 0 degrees 03‟ South and 0 degrees 55‟ North (Ngeno et al., 2011) and falls under the following agro-ecological zones namely, LH3- Lower highland which occupies the largest of the sub-county and covers Moiben, Kesses and Kapseret where maize and wheat are grown. UH4-Upper midland covering turbo (Tapsagoi and Sugoi area) and is a maize zone UH2-Upper midland covering Timboroa wheat, pyrethrum and maize are grown. (Authority, 2009; UGIDP, 2013). The wards in each agro-ecological zone were picked at random to arrive at homogeneity. In LH3, UH4 and UH2 Moiben, Tapsagoi and Anabkoi ward were randomly picked respectively. One location was purposively selected in each ward, being the ones that intensively practice maize farming. Two sub-locations within the selected locations were randomly selected. The sub locations were Moiben and Merewet in Moiben ward, Kapkong and Turbo in Tapsagoi ward as well as Kapkeno and Burnt Forest in Ainabkoi ward. Soil sampling was done in farms in the six wards which were randomly picked.

1.1.2. Soil Sampling Design

Three farms in each sub-location were purposively sampled to obtain farmers that practice small, medium and large scale type of agriculture. For each farm, samples were taken using random sampling design where farms in the area were picked randomly. This was done twice during the dry season before planting and the long rainy season after planting. Individual samples were collected from two locations in each farm using a line transect. Soil samples were collected into plastic containers which had all been pre-cleaned with concentrated nitric acid to avoid contamination at all stages. The reason was to remove any traces of heavy metal contaminant (Brigden et al., 2008). Plastic spades was used to collect soil samples from two depths; these are 0-10cm and 11-20cm and stored in labeled polythene bags, Geographic Positioning System (GPS) was used to generate the polar co-ordinates and the altitude of the site where samples were obtained. A total of seventy two samples were obtained from the three agro-ecological zones at Uasin Gishu County. The samples were transported to Tea Research Institute labs in Kericho for analysis. In the laboratory, the concentration of Zn, Pb, Co, Cd and Cu for each sample were ascertained using ICPE-900 Shimadzu inductive coupled plasma using the standard procedure stipulated by Melaku et al., (2005). Data was presented using tables. The student statistical t-test was used for significant different at ($P<0.05$).

1.2. RESULTS AND DISCUSSION

1.2.1. Mean concentration of heavy metals in soils

Table 1: Heavy metals in soils (Dry season and Wet season) in different agro-ecological zones in UGC

			Season 1 (Dry)	Season 2 (Wet season)
Agro-ecological zones	Soil Dept	Heavy metal	Concentration (ppm)	Concentration (ppm)
UH2				
	0-10 cm	Pb	12.0±0.35	15.3±0.33
		Cd	4.1 ±0.38	4.5±0.34
		Co	9.5±1.86	2.5±1.67
		Zn	2.3±0.31	4.0±0.30
		Cu	8.0±0.30	16.3±0.32
	10-20 cm	Pb	13±0.51	15.5±0.32
		Cd	4.7±0.27	2.8±0.28
		Co	8.2±0.14	4.0±0.15
		Zn	3.5±0.18	3.16±0.14
		Cu	10.3±0.50	8.7±0.45
LH3				
	0-10 cm	Pb	13.0±0.82	10.0±0.81
		Cd	4.8±0.23	4.0±0.20
		Co	9.0±0.00	2.3±0.00
		Zn	12.5±0.33	17.3±0.28
		Cu	7.87±0.19	8.0±0.19
	10-20 cm	Pb	10.0±0.86	18.6±0.87
		Cd	2.3±0.35	1.8±0.41
		Co	10.0±0.67	4.2±0.65
		Zn	2.0±0.00	2.0±0.00
		Cu	8.0±0.45	17.3±0.49
UH 4				
	0-10 cm	Pb	12.2±0.68	10.7±0.78
		Cd	4.3±0.13	1.7±0.19
		Co	8.5±0.65	4.0±0.67
		Zn	2.5±0.02	2.0±0.00
		Cu	8.7±1.56	7.7±1.45
	10-20cm	Pb	13.0±0.52	10.3±0.51
		Cd	4.3±0.15	1.8±0.14
		Co	8.5±0.58	4.0±0.48
		Zn	2.5±0.00	2.5±0.00
		Cu	8.0±1.92	16.5±1.90

The results obtained showed that the mean concentration of Pb, Cd, Co, Zn and Cu in UH2 ranged between 12.0 –15.5ppm, 2.8–4.7 ppm, 2.5–9.5 ppm, 2.3–4.0 ppm, 8.0–16.3 ppm respectively, while in LH3 the concentration range between10.0 –18.6 ppm, 1.8–4.8 ppm, 2.3–10.0 ppm, 2.0–17.3 ppm, 7.9–17.3 ppm respectively and finally in UH4, the mean concentrations of the five metals ranged between 10.3 –13.0ppm, 1.7–4.3 ppm, 4.0–8.5 ppm, 2.0–2.5 ppm, 7.7–16.5 ppm respectively at the two depths of 0-10cm and 10-20cm as shown in table 1 above. The level of Cd concentrations was found to exceed the WHO standard of 3mg/l in the study area. This findings was in line with those of Yahaya et al., (2009) who assessed the seasonal variations of heavy metals concentration in Abattoir dumping site soil in Nigeria and found out the concentration of Pb, Co and Zn in soil, during wet season were 16.20–28.11mg/l, 49.96– 89.46mg/l and 50.91- 89.10mg/l respectively at the depth of 0-15cm. The difference in soil depth could be to the leaching process that occurs with increase in rainfall during the wet season, which transported these metals down the depth of the soil. Similar pattern of increase in heavy metal levels with soil depth was done byUsman and Kolo, (2015) who assess of some pollutants in soils of Sakwa, Thila and Marama in Hawul local government area, Borno state, Nigeria. Cadmium concentration reported in the soil samples exceeded the recommended concentration in the soils of 3 mg/l (Adelekan and Abegunde, 2011; Chiroma et al., 2014). The levels of Cd were in line with concentration levels reported by (Salano, 2014). This may have been due to the intensive application of phosphatic fertilizers such as Di-Ammonium Phosphate which adds Cadmium and lead (Raven et al., 1998; Wuana and Okieimen, 2011). Despite the low mean concentration of Pb, few samples exceeded the WHO standard of 100 mg/l. The high level of the lead in some areas could be due to heavy use of herbicide and fertilizers that could contain some traces of Pb as pointed out by Wuana and Okieimen, (2011).

1.2.2. Comparisons between seasons, depth and agro-ecological zone

Comparison between two sampling depth

Season 1

To determine whether there existed significant differences in the concentration of heavy metals in the two sampling depths, a t-test was conducted. The results are presented below:

Table 2: T- test results comparing the two sampling depths in UG County for dry season

	T	Df	Significance (2-tailed)	Mean Difference
Pb	0.64	24	0.528	0.308
Cd	0.00	24	1.000	0.000
Co	0.17	24	0.866	0.385
Zn	0.22	24	0.828	0.077
Cu	0.00	24	1.000	0.000

According to the t-test results above, the p values of Pb, Cd, Co, Zn and Cu were 0.528, 1.000, 0.866, 0.828 and 1.000 respectively. All these values were above the 0.05 significance level indicating that the concentration of heavy metals for the two sampling depths (0 – 10 cm and 10 – 20 cm) for season 1 was not significant at 95% confidence level. This was attributed to the leaching process that occurs with increase in rainfall, which transported these metals down the depth of the soil. These findings are in line with those of Buccolieri et al., (201) and Usman and Kolo, (2015) who assessed heavy metals concentration in Italy and Nigeria respectively.

Season 2

To determine whether there existed significant differences in the concentration of heavy metals in the two sampling depths, a t-test was conducted. The results are presented below:

Table 3: T- test results comparing the two sampling depths in UG County for wet season

	T	Df	Significance (2-tailed)	Mean Difference
Pb	0.31	34	0.758	0.389
Cd	0.00	34	1.000	0.000
Co	0.00	34	1.000	0.000
Zn	0.37	34	0.714	0.167
Cu	1.28	34	1.000	0.209

According to the t-test results above, the p values of Pb, Cd, Co, Zn and Cu were 0.528, 1.000, 0.866, 0.828 and

1.000 respectively. All these values were above the 0.05 significance level indicating that the concentration of heavy metals for the two sampling depths (0 – 10 cm and 10 – 20 cm) for season 1 was not significant at 95% confidence level. This is attributed to the fact that Pb, Cd, Co, Zn and Cu have high leaching capacity and rainfall during the wet season facilitated leaching. In addition, heavy metals are not biodegradable hence persist longer in the soil. These findings are in line with those of Guo et al., (2013); Moore, (2000); Nazir et al., (2015) who assessed heavy metal contamination in soils in USA, China and Austria respectively

Comparison of seasons
Season 1 and Season 2 (0 – 10cm)
To determine whether there existed significant differences in the concentration of heavy metals for the two seasons, a t-test was conducted. The results are presented below:

Table 4: T- test results comparing dry and wet inUG for 0-10 cm depth

	t	Df	Significance (2-tailed)	Mean Difference
Pb	0.24	34	0.812	0.2222
Cd	5.32	34	0.001	2.0556
Co	3.35	34	0.002	4.5556
Zn	0.88	34	0.385	0.3889
Cu	1.23	34	0.227	2.3333

According to the t-test results above, the p values of Pb, Cd, Co, Zn and Cu were 0.812, 0.001, 0.002, 0.385 and 0.227 respectively. All these values were above the 0.05 significance level except for Cd and Co indicating that the difference in concentration of Pb, Zn and Cu for the two seasons was not significant at 95% confidence level. The Cd and Co p-values were below the 0.05 significance level implying that the difference in concentration of Cd and Co in the sampling points for the two seasons was significant at 95% confidence level. This could be attributed to use of fertilizers during the wet season and cadmium are present as an impurity in phosphate fertilizers (Wuana and Okieimen, 2011) which are used in planting. These findings are in line with those of Kiende et al., (2012); Oluyemi et al., (2008); Tanner, (2006) who assessed concentrations of heavy metals in agricultural fields in USA, Nigeria and Kenya respectively.

Season 1 and Season 2 (10 – 20cm)
To determine whether there existed significant differences in the concentration of heavy metals for the two seasons, a t-test was conducted. The results are presented below:

Table 5: T- test results comparing dry and wet inUG for 10-20 cm depth

	t	df	Significance (2-tailed)	Mean Difference
Pb	0.06	34	0.953	0.0556
Cd	6.65	34	0.001	2.1667
Co	4.69	34	0.001	5.2778
Zn	0.84	34	0.407	0.3333
Cu	2.75	34	0.009	5.6667

According to the t-test results above, the p values of Pb, Cd, Co, Zn and Cu were 0.953, 0.001, 0.001, 0.407 and 0.009 respectively. All these values were above the 0.05 significance level except for Cd, Co and Cu indicating that the difference in concentration of Pb and Zn for the two seasons was not significant at 95% confidence level. The Cd, Co and Cu p-values were below the 0.05 significance level implying that the difference in concentration of Cd, Cu and Co in the sampling points for the two seasons was significant at 95% confidence level. These findings are similar to the 0 – 10 cm depth above and thus attributable to the same causal factors. The findings are in line with those of Kananu et al., (2014) and Sharma et al., (2007) who assessed concentrations of heavy metals in agricultural fields for two different seasons in India and Kenya respectively.

1.2.3. Comparison among Sampling Zones

Season 1

In order to determine whether there existed significant differences in the concentration of the 5 heavy metals for the first season among the 3 sampling zones LH3 (Lower highland) covers Moiben, UH4(Upper midland) covering turbo, UH2 (Upper midland) covering Timboroa, an ANOVA was done.

Table 6: ANOVA results comparing UH2, LH3 and UH4 Agro-ecological zones in dry season

Element	MS	F	P
Pb	31.60	102.29	0.037
Cd	2.97	23.25	0.001
Co	1.88	0.30	0.073
Zn	75.14	274.86	0.001
Cu	68.49	68.25	0.051

According to the ANOVA results above, the p values of Co and Cu were above the 0.05 significance level indicating that the difference in concentration of these three metals in the three sampling zones was not statistically significant at 95% confidence level. However, the p-values of Pb, Cd and Zn p-values were below the 0.05 significance level implying that the difference in concentration of these three metals in the three sampling zones for season one was significant at 95% confidence level. This is attributed to the different agricultural activities in the different sampling zones which lead to different concentrations of different heavy metals. These findings are in line with those of Manta et al., (2002) and Tam and Wong, (2000) who assessed the concentration of heavy metals in different sampling zones in Hong Kong and Italy respectively.

Season 2

In order to determine whether there existed significant differences in the concentration of the 5 heavy metals for the second season among the 3 sampling zones LH3 (Lower highland) covers Moiben, UH4(Upper midland) covering turbo, UH2 (Upper midland) covering Timboroa an ANOVA was done.

Table 7: ANOVA results comparing UH2, LH3 and UH4 Agro-ecological zones in et season

Element	MS	F	P
Pb	1.91	6.37	0.00686
Cd	3.42	11.2	0.00211
Co	0.89	8.25	0.00929
Zn	1.12	8.67	0.00741
Cu	28.46	54.95	0.00001

According to the ANOVA results, the p values of the five metals were the 0.05 significance level implying that the difference in concentration of all the metals in the three sampling zones for seasons two was significant at 95% confidence level. This is attributed to the different agricultural practices in the different sampling zones which lead to different concentrations of different heavy metals. The results are further attributable to the fact that in the second season, there was elevated use of agrochemical during the planting season. These findings are in line with those of Manta et al., (2002); Murray et al., (2004); Nabulo et al., (2008) who assessed the concentration of heavy metals in different sampling zones in Hong Kong Kenya, , Michigan USA and Italy respectively.

1.4. CONCLUSION AND RECOMMENDATION

1.4.1. Conclusion and Recommendations

The results of this study revealed that the three agricultural zones of LH3 (Lower highland), UH4 (Upper midland) and UH2 (Upper midland) contained variable levels of heavy metals (Pb, Zn, Cu, Cd and Co). This may be indicative of the level of pollution activity among the three locations. It also appeared that the metal levels were generally higher in LH3 than UH4 and UH2. This was attributed to intensive farming in Moiben than other regions, hence fertilizers/agrochemicals application was higher in LH3 is higher than the other regions. The difference in heavy concentrations in respect with season was attributed to the different activities in the different sampling zones which lead to different concentrations of different heavy metals.

Zinc (Zn), lead (Pb), Cadmium (Cd), copper (Cu) all except Cd were below their WHO standard values. Cadmium (Cd) concentrations exceeded the WHO values of 3mg/l mg/L. The presence of the heavy metals above the natural levels in the study area can also be attributed to other sources such intensive agricultural activities and natural causes.

The concentration of heavy metals increases with soil depth and it indicate that high level of these pollutants are likely to result in bioaccumulation in the food chain. It is recommended therefore that effective agrochemicals management is vital in addressing problem soil pollution in the study area. It is therefore recommended that farmers should use agro-chemicals for crop nutrition, pest and weed control that are easily degradable and have less environmental and human impacts. Also mechanisms for an integrated approach should be encouraged between the agricultural officers, farmers and the agrochemical distributors. Continuous monitoring of the soil pollution should be carried out and appropriate monitoring protocols should be established. Health screening should be carried out periodically on the workers and inhabitants to check for some symptoms of heavy metals poisoning and further epidemiological studies to be done on the association between agrochemical and cancer occurrences in the study area. More studies are needed especially on the presence of heavy metals in the food chain so as to sensitize the community on possible health risks associated with the heavy metal contamination.

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