Determination of selected heavy metals in agricultural soils in Bungoma and Kakamega Counties, Western Kenya

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ABSTRACT

A study was conducted to investigate the level of heavy metals in agricultural soils in Bungoma and Kakamega counties, Western Kenya. Copper (Cu), Lead (Pb), Cadmium (Cd), Chromium (Cr) and Zinc (Zn) were determined during the months of November 2010 (wet season) and February 2011 (dry season). Atomic Absorption Spectrophotometer was used for analysis of the samples after wet digestion and preparation of appropriate calibration standards. 11% of the soils reported to be polluted with lead, while 97% were polluted with cadmium. Soils were found to have optimum to low levels of copper and zinc. A positive correlation of wet and dry seasons was reported.

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1. Introduction

Bungoma County, located in the western region of Kenya, slopes from the foot of Mt. Elgon from the North where the altitude is over 2000 meters above sea level falling to the lower lying South and South West of altitude 1200 meters. The county has a population of 1,630,934 and an area of 2,069 km² [1]. It is evenly distributed with an average population density of 482 persons per square kilometer. There is higher population density in the main urban centers and major factories. These include Webuye town, Nzoia Sugar Company, Bungoma town and Kimilili urban centres. Mumias and Nzoia sugar companies located in Mumias and Webuye respectively serve farmers in the larger Bungoma and Kakamega counties. Cultivation of sugarcane involve application of phosphate fertilizers at the initial stage of planting and top dressing with nitrogen fertilizers at the stage of two to nine months of growth. Farmers also grow other crops (maize, beans, cassava, millet, sweet potatoes and vegetables) beside sugarcane that involve fertilizer, manure and pesticides application. Industrial effluents from the two sugar factories and the pulp industry together with the municipal effluents from Mumias and Webuye urban also characterise these study areas.

Heavy metals are persistent environmental contaminants since they cannot be degraded or destroyed [2, 3]. Heavy metals can be emitted into the environment by both natural and anthropogenic causes. Sources of anthropogenic contamination include the addition of manure, sewage sludge, fertilizers and pesticides to soils, municipal and industrial effluents, and vehicular emissions [4, 5, 6, and 7]. Whereas Zn and Cu are essential elements, Pb, Cd and Cr are chronic elements.

This study investigated the concentrations of these elements in soils in order to ascertain if they were above the recommended background values for unpolluted environment.

2. Materials and methods

2.1 Sample collection and storage

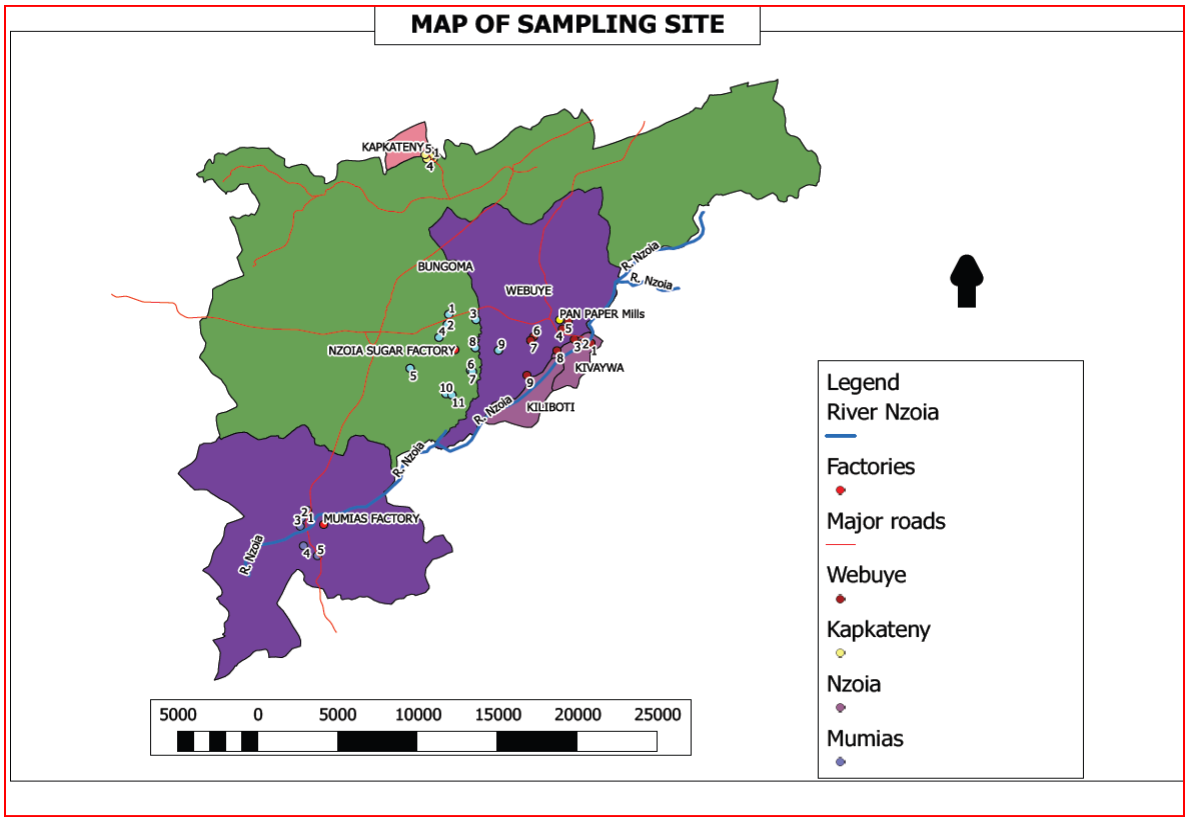

Figure 1: Site map of the sampled area

The study was carried out during the months of November 2010 (wet season) and February 2011 (dry season). Soil samples were collected from 25 sites within the agricultural and industrial areas of Webuye and Mumias. There were 5 sites sampled around Mumias town, 11 around Nzoia sugar factory, and 9 around Webuye town. The sites represented commercial vegetable farms and private residential vegetable gardens. Five sites were sampled around Kapkateny. Sampling was done using a stainless steel scoop. Soil was collected over a surface area of 10 cm by 10 cm and a depth of 20 cm. A square cardboard template measuring 10cm by 10cm was used to mark sampling areas. A total of 50 soil samples were collected during both seasons. The samples were stored in clean polythene bags that had been rinsed with distilled water and transported to the laboratory for storage, preparation and analysis. Fig.1, is a map showing sampling areas while Table 1 shows the coordinates of sampling points.

Table 1. Coordinates of sampling points

Sampling site	Easting	Northing	Site number
Mumias site	665632.33m	42209.18m	1
	664853.31m	41187.88m	2
	664720.49m	40144.56m	3
	665117.42m	37585.45m	4
	666866.24m	36285.12m	5
Nzoia site	683308.02m	67863.90m	1
	683135.51m	66567.09m	2
	686726.43m	67183.42m	3
	682079.74M	64857.63m	4
	678469.28M	60819.96m	5
	686048.19m	60555.49m	6
	686270.45m	60373.45m	7
	686635.55m	63516.35m	8
	689534.13m	63172.74m	9
	682950.03m	57482.16m	10
	683709.62m	57326.04m	11
Webuye site	701115.99m	64109.98m	1
	700054.17m	64085.77m	2
	699027.27m	64594.48m	3
	697533.04m	65988.06m	4
	698265.09m	67024.34m	5
	693932.33m	64955.08m	6
	693563.41m	64476m	7
	696858.71m	63131.04m	8
	693095.66m	59912.64m	9

2.2 Sample preparation and analysis

Soil samples were air dried at room temperature for 3 days. The dry soils were disaggregated with a porcelain pestle and mortar and passed through a 2 mm sieve. The samples were then oven dried at 105 degrees centigrade for 1 hour, and stored in a dry environment for further analysis.2.500±0.002g each of the samples was accurately weighed and placed into 100 ml beakers to which 20 ml of a mixture of HCl and HNO_3 in a ratio of 3:1 (V/V) was added. The mixture was then digested in a hot plate to a transparent liquid digest. The digest were separately cooled, filtered and diluted to 50 ml using deionised water for analysis of Cu, Zn, Cd, Pb and Cr using atomic absorption spectrometer.

2.3 Quality assurance

Quality assurance procedures and precautions were taken to ensure the reliability of the results by minimizing contamination. Glassware were washed thoroughly in alkaline detergent, soaked in 3M nitric acid for 48 hours and rinsed thoroughly in distilled deionised water before use to leach out any trace metal contamination. Plastics were soaked in detergent and rinsed thoroughly in deionised water. Reagents were of analytical grade. Chemicals were obtained from Sigma, Kobian and Aldrich Chemical Company. Deionised water was used for all dissolutions and dilutions.

2.4 Statistical analysis

Mean concentrations of elements in soils and their standard deviations for different sites were calculated using data from individual farms. Outlier values from some farms were noted and filtered when calculating the mean of a site. The recorded data were subjected to two-way analysis of variance to assess the influence of different variables on the concentrations of heavy metals. All the statistical analyses were computed using SPSS software version 12.

3. Results and discussions

3.1 Heavy metal levels in geospatial area during wet season

Soil samples collected at Mumias, Webuye and Nzoia during wet season were analysed for Cu, Pb, Cr, Cd and Zn. Fig. 2, shows the mean heavy metal levels in soils at Webuye, Mumias and Nzoia during wet season.

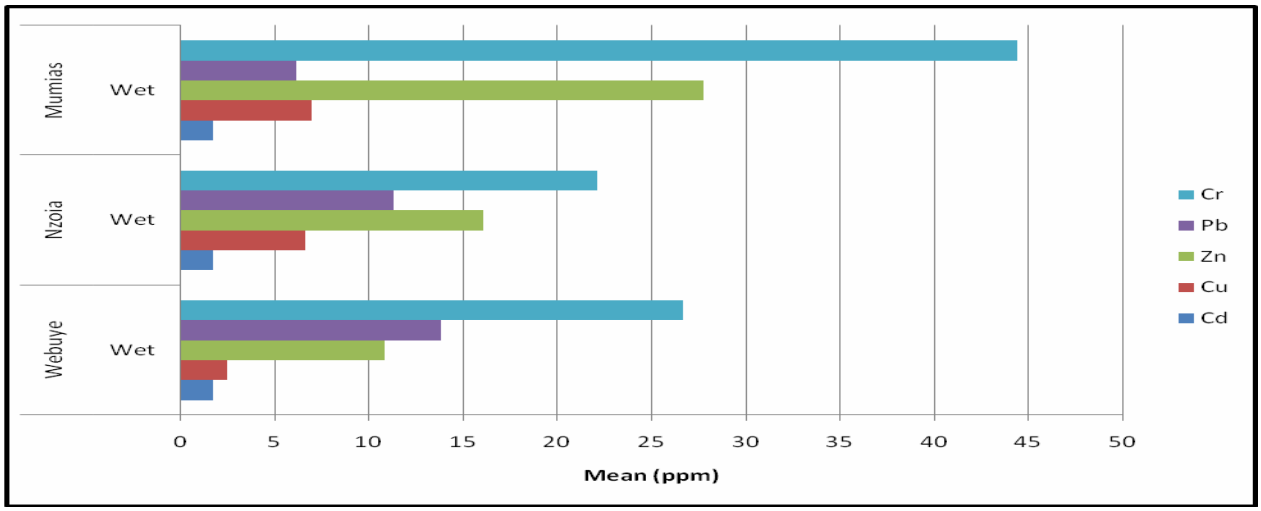

Figure 2. Mean levels in soils at Mumias, Webuye and Nzoia (wet season)

Soils at Webuye had lower copper level (2.52 ppm) compared to Nzoia (6.67 ppm) and Mumias (6.97 ppm), while zinc in soils at Mumias was higher (6.97 ppm) compared to Webuye (2.52 ppm) and Nzoia (6.67 ppm). Lead in soils at Webuye (13.85 ppm) was higher compared to Nzoia (11.36 ppm) and Mumias (6.17 ppm). Cadmium in soils at Webuye (1.74 ppm), Nzoia (1.77 ppm) and Mumias (1.76 ppm) was similar, while chromium was higher at Mumias (44.4 ppm) and lower at Nzoia (22.01 ppm). Copper and zinc at all the sites were within the recommended background levels of 100 ppm and 250 respectively.

3.2 Pb and Cd distribution on individual farms at Nzoia (wet season)

Cadmium level on individual farms at Nzoia ranged between 1.67 and 2.67 ppm (Table 2.0), with 100% of the samples above the recommended background value of 0.5 ppm for the unpolluted environment. Lead ranged between 7.47 and 19.8 ppm and was within the recommended level of 20 ppm for the unpolluted environment (Table 2).

Table 2. Concentrations in soils around Nzoia

Sample No.	Nsb	Nsc	Nsd	Nse	Nsf	Nsh	Nsi	Nsj	Nsk	Mean	Std. Dev.
Cd (ppm)	2.00	2.00	2.50	2.00	2.00	2.27	2.67	1.67	1.80	1.77	±0.79
Pb (ppm)	12.00	19.80	8.00	7.47	8.67	15.20	8.37	8.80	10.33	11.36	±4.01

3.4 Pb and Cd distribution on individual farms at Webuye during wet season

Table 3, shows the elemental concentrations in samples around Webuye. All the samples had cadmium levels above the recommended background value of 0.5 ppm. Pb ranged between 4.53 and 21.6 ppm, Cu (1.00 and 3.86 ppm), zinc (4.80 and 19.00 ppm) and chromium (16.40 and 37.40 ppm).

Table 3. Concentrations in soils around Webuye

Sample No.	Wsa	Wsb	Wsc	Wse	Wsf	Wsj	Wsp	Mean	Std. Dev.
Cd (ppm)	1.80	2.50	2.40	0.40	2.00	2.20	2.20	1.77	±0.79
Pb (ppm)	4.53	14.50	15.80	16.06	10.33	21.60	14.60	11.36	±4.01

3.5 Pb and Cd distribution on individual farms at Mumias during wet season

Elemental concentrations of samples from farms around Mumias are presented on Table 4. Sample Msc had a higher lead level (28.46 ppm), which is above the background recommended limit of 20 ppm. All the samples except sample MSa had cadmium levels above the recommended limit of 0.5 ppm.

Table 4. Concentrations in Soils around Mumias during Wet Season

Sample No.	Msa	Msb	Msd	Mse	Msc	Mean	Std. Dev.
Cd (ppm)	bdl	2.20	2.20	2.20	2.20	1.77	±0.79
Pb (ppm)	4.47	5.40	6.00	8.80	28.46	11.36	±4.01

3.6 Heavy Metal Levels in Geospatial Area during Dry Season

Soil samples collected at Mumias, Webuye, Nzoia and Kapkateny during dry season were analysed for Cu, Pb, Cr, Cd and Zn. Figure 3, shows the level of heavy metals in soils at various sites during dry season.

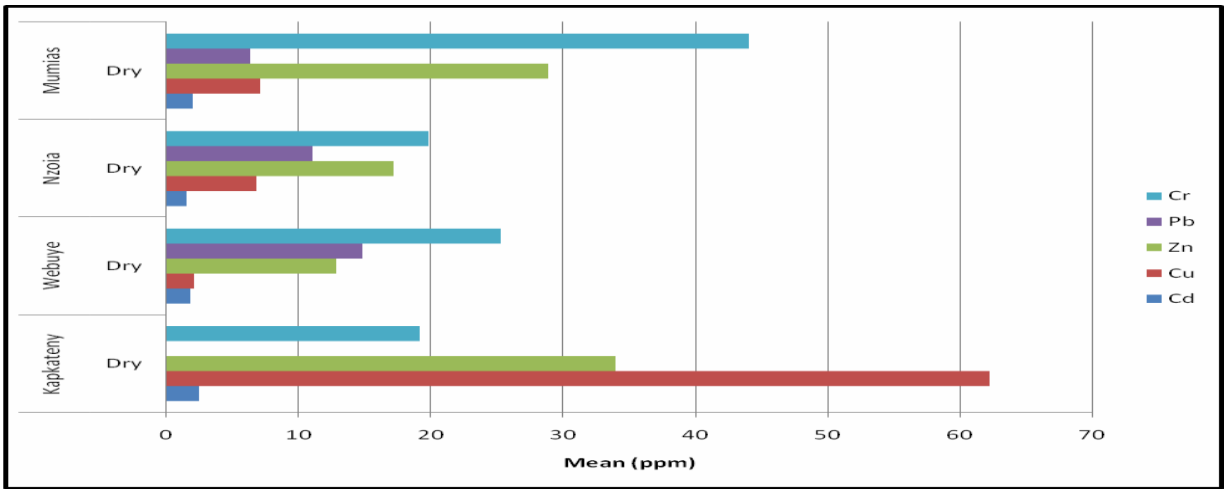

Figure 3. Level of heavy metals in soils at various sites during the dry season

Soils at Webuye had the highest level of lead (14.80 ppm) compared to Nzoia (11.05 ppm) and Mumias (6.34 ppm). Chromium was higher at Mumias (44.0 ppm) and lower at Nzoia (19.80 ppm). Both lead and chromium were not detected in soils at Kapkateny, while copper (62.22 ppm), Zinc (33.94 ppm) and Cd (2.47 ppm) were higher in soils at Kapkateny compared to Webuye, Mumias and Nzoia.

3.7 Pb and Cd distribution on individual farms at Nzoia (dry season)

Table 5, shows elemental concentrations in soils on at Nzoia. Apart from sample nsa-d and nsg-d, all other samples had cadmium levels above the background recommended limit of 0.5 ppm for the unpolluted environment. Pb concentrations fell within the range of background values for the unpolluted environment.

Table 5. Concentrations in soils around Nzoia

Sample No.	nsb-d	nsc-d	nsd-d	nse-d	nsf-d	nsg-d	nsh-d	nsi-d	nsj-d	nsk-d	Mean	Std. dev.
Cd (ppm)	1.7	2.2	2.1	2.2	1.4	0.3	1.6	2.3	1.8	1.2	1.75	±0.68
Pb (ppm)	14.2	17.1	5.6	8.6	6.5	19.1	13.2	7.5	12.2	11.05	11.05	±4.78

3.8 Pb and Cd distribution on individual farms at Webuye (dry season)

At Webuye, lead in soils ranged between 5.1 and 41.3 ppm and Cd (0.6 to 2.9 ppm), as presented in Table 6.

Table 6. Concentrations in soils around Webuye

Sample No.	Wsa-d	Wsb-b	Wsc-d	wse-d	wsd-d	wsf-d	wsj-d	wsp-d	Mean	Std.dev.
Cd (ppm)	0.90	1.40	2.10	0.60	1.80	2.90	2.80	1.50	1.75	±0.82
Pb (ppm)	5.10	16.30	12.30	18.20	41.30	13.50	23.40	14.20	17.74	±10.09

3.9 Pb and Cd distribution on individual farms at Mumias (dry season)

Table 7 shows concentrations of elements in soils at Mumias. All samples had cadmium above the recommended limit of 0.5 ppm, while only sample MSC-D had lead level above the recommended limit of 20 ppm.

Table 7. Concentrations in Soils around Mumias

Sample No.	MSA-D	MSB-D	MSD-D	MSE-D	MSC-D	Mean	Std. dev.
Cd (ppm)	0.90	1.40	2.10	0.60	1.80	1.95	±0.647
Pb (ppm)	5.10	16.30	12.30	18.20	41.30	11.64	±11.63

4. Conclusions

Lead in eleven percent of soil samples exceeded the range for unpolluted soils of 0.1 to 20 ppm while 97% of samples had cadmium level exceeding the range for unpolluted environment of 0.5 ppm. Industrial effluents from the sugar factories and the paper mill and municipal effluents from the urban centers is a source for the high concentration of cadmium and lead.

Pesticides, manure and fertilizer application on farms and vehicular emissions is also a possible source. Copper and zinc were within the recommended limit of 100 ppm and 250 respectively. There was positive correlation (p>5) between the wet and dry seasons, indicating insignificant seasonal variations in heavy metal concentrations.

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