TOXIC METAL LEVELS IN FOOD CROPS GROWN FROM DUMP-SITES AROUND GULU MUNICIPALITY, NORTHERN UGANDA

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ABSTRACT

This study investigated heavy metal (Cu, Zn, Pb, and Cd) contamination levels of soils and crops. Soil and plant samples were collected from farms around the dump sites in Gulu Township Pece wet land and other samples from Katikamwe wet land in Bushenyi which served as a control site. The samples from both sites were well prepared, digested and the level of heavy metals (Cd, Cu, Pb and Zn) determined using Atomic Absorption Spectrophotometer. The results showed that metal levels of copper (Cu), zinc (Zn), cadmium (Cd) and lead (Pb) in Pece wet land were significantly higher than those in similar food crops from rural control sites with the exception of zinc in cocoyam. Despite the higher values of these metals than those of the control sites, its only lead (Pb) and cadmium (Cd) that exceeded the World Health Organization (WHO) maximum permissible levels. It was also observed that heavy metal uptake depend on plant species and soil quality.

Keywords:
Trace metal pollution, Food crops, Gulu Municipality

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1. INTRODUCTION

The global rise in human population is impacting negatively on the availability of land for farming, especially in the urban and peri-urban settlements where by fertile lands in these settlements are being used for building and doing other industrial activities. As a result, old dumpsites have become an ideal site for farming activities.

These dump sites are more fertile compared to the rest of the surrounding areas (Ogunyemi *et al*., 2003). This is because they are rich in soil nutrients for plant growth and developments since the decayed and composted wastes enhance soil fertility. In addition dumpsite soils are also used to fill poly-bags and nursery pots to grow seedlings in most urban areas.

Dumpsites, especially in most third world countries, comprise of a higher proportion (50–90%) of organic materials (Boateng and Murray, 1999); however, considerable proportions of plastic, paper, metal rubbish and batteries which are known to be sources of heavy metals which may be hazardous to man and his environment are also present (Alloway and Ayres 1997, Pasquini and Alexander 2004, Woodbury, 2005). These metals are not biodegradable and have toxic effects on plants and living organisms at certain level of concentration.

Industrial units located in and at the outskirts of most towns and cities and indiscriminate disposal of domestic and municipal wastes are the main sources of soil and water contamination. When it rains all these wastes are washed away through drains and lastly they find their way into wet lands and low lying areas and enrich the soils from these areas. It is in here where agriculture is normally practiced.

Trace metal accumulation in soils is of great concern in agricultural production due to the adverse effects on food quality (safety and marketability), crop growth (due to phytotoxicity) and environmental health (soil flora/fauna and terrestrial animals) (Calvert & Fergusson,1990). The mobilization of heavy metals into the biosphere by human activity has become an important process in the geochemical cycling of these metals. This is acutely evident in urban areas where various stationary and mobile sources release large quantities of heavy metals into the atmosphere and soil, exceeding the natural emission rates (Bilos *et al*., 2001).

Crops absorb whatever is present in the soil medium and therefore these hazardous metals are also absorbed and become bioaccumulated in the roots, stems, fruits, grains and leaves of the crops which may finally be transferred to man in the food chain (Fatoki, 2000). At the same time if these plants decay these toxic metals are redistributed and as a consequence their enrichment in the agricultural soils occurs. Bioaccumulation, geoaccumulation and biomagnifications may result because of entrance of these heavy metals to the eco system.

Unlike developed countries, it is difficult to estimate the level of health hazard from heavy metals in the urban environment in developing countries because urban farming is usually unregulated and soils are rarely tested (Nabulo, 2006). There tends to be little awareness among farmers or consumers about the health implications of heavy metals and pathogens, or guidance to farmers.

The level of heavy metals in urban areas of less industrialized countries is generally far lower than those in industrial countries however, there are specific areas that pose a health threat. There is very little data on the health impact of heavy metals in cities in developing countries, or the contribution of urban farming to this health problem (Nriagu, 1988). There exists a global need to identify vulnerable areas and regulate farming in these locations to ensure food safety.

Solid waste management is one of the biggest challenge facing developing countries where anything that loses value is sent to dump sites and therefore waste sorting and separation is not practiced (Odai,1997). These wastes are a composition of various elements including heavy metals. Some of these heavy metals such as As, Cd, Hg, Pb or Se are not even essential for plant growth, since they do not perform any known physiological function in plants.

Gulu district is located in Northern Uganda where there has been a lot of insurgency for the last 25 years but currently peace has been restored and the town is growing at a high rate. However waste disposal is still a problem where by anything that losses value is damped any where and when it rains all the wastes from industrial units, homes around and corroded metal particles that were left during insurgency find their way into the nearby wet land through the drains where a large number of crops are grown in various farms lying besides these drains because they are believed to be fertile. There are high chances that these heavy metals will be absorbed by these plants. Besides the leaching of these heavy metals through the soil to the crops, most of the waste water is drained to the agricultural land where this polluted water is used for irrigating these crops. Long term waste water irrigation leads to the buildup of heavy metals in soils and food crops (Khan *et al.*, 2008). So the study of metal contamination of these food crops was strongly needed

2. MATERIALS AND METHODS

Study area and sampling

Sampling sites were located in Gulu Township, in Pece wet land along the Pece stream and Katikamwe wet land in Bushenyi which was chosen because of its rural setting far away from urban industrial and domestic sources of pollution with agricultural activities similar to those of Gulu Township Pece wetland.

These areas were experiencing intensive cultivation of food crops by wet land encroachers.

In each of the study sites three locations were selected, from which soil samples and specimens of various ready crops were freshly harvested after a modest payment to the small-holding farmers.

Soil samples and crop specimens in the control wet land and in the urban wet land cultivation sites were taken at points that were at least 100m apart. Top soil samples down to a 25 cm depth were collected at each sampling site with a hand auger. The soil samples were packed in labeled plastic bags and transported in coolers to the laboratory.

Pretreatment

All glass wares and containers required for experimentations were first washed with distilled water followed by soaking in 10% nitric acid for few hours. Thus it was ensured that no contamination occurred in them. The collected vegetable samples were washed with distilled water to remove dust particles. Samples were then cut into pieces of uniform size and then air dried. Air dried samples were then placed in dehydrator for 2-3 days and then oven dried at 100^{o}c. Now these dried samples of vegetables were ground into fine powder using a blender and stored in polythene bags prior to acid digestion

Analytical procedures

In order to determine the levels of heavy metals in these food crops, from both sites, cocoyam, matooke and doodo samples were prepared according to the standard method for food crops while the sugar cane juice sample preparation was done using nitric acid digestion procedure for water and waste water. The resultant supernatant that resulted after digestion procedure was analyzed for the heavy metals.

Digestion of crops

Sugarcane

The nitric acid digestion procedure for water and waste water (American Public Health Association 1992) was used for the wet-acid digestion of the sugarcane juice.

The sugarcane stems were cut at two nodal intervals to the roots, washed, rinsed with distilled de ionized water, peeled and cut into small pieces with a stainless steel knife and their mass determined. The specimens were subsequently crushed with a stainless steel blender. The juice was filtered by pressing it through a plastic sieve.

Glass beads and 50 mls of the sugarcane juice extract were introduced into a 250 mL Pyrex conical flask and 20 mls of concentrated nitric acid added. The mixture was allowed to slowly evaporate on a hot plate just until precipitation occurred. A further 5 mls of the acid were then added slowly until the solution turned clear and digestion complete. Thereafter 1 ml of 30% hydrogen peroxide was added to the flask, swirled and reheated for 10 min. When the solution remained clear upon cooling, 25 mls of deionized distilled water were added, and the solution boiled again. After further cooling, the contents were quantitatively transferred to a 25 ml volumetric flask and made to volume. After settling for another 5 h, the contents were transferred to labeled plastic bottles, before being analyzed for heavy metal analysis using AAS.

Matooke, yams and doodo

In order to determine the total concentrations of the heavy metals in food crops and vegetables, the crops, *viz.* doodo, matooke and yams were thoroughly washed under the tap to remove all traces of soil and dirt. They were subsequently rinsed with de-ionized distilled water. The specimens were prepared according to a standard procedure given by (Okalebo and Gathua, 1993)

The vegetables were cut into small pieces using a stainless steel knife and dried in an oven at 103°C for 24 h to constant mass, taking due care to avoid charring. After cooling, they were carefully ground in a ceramic mortar and passed through a 2 mm nylon sieve. The finely ground sample (1.250g) was weighed into a clean dry 250 ml Pyrex conical flask. Concentrated nitric acid (25 ml) was added, followed by glass beads and a funnel fitted on top of the flask. The contents were heated in a fume cupboard on an electric hot-plate at medium heat until digestion was complete. A further 5 ml of the acid was added and the mixture concentrated to 10 ml.

On cooling, 4 ml of 30% hydrogen peroxide was added and the contents swirled and reheated for another 10 min. When the solution turned clear the contents were cooled, quantitatively transferred to a 25 ml volumetric flask and made up to the mark using de-ionized distilled water. After settling for 5 h the supernatant solution was carefully transferred to plastic bottles which were then sealed with plastic covers and labeled before being taken to the analytical laboratory for spectrophotometric analysis for the heavy metals using the AAS.

Wetland soils

Soil samples were spread on aluminium foil and dried to a constant mass in an oven at 103^{o}C for 24 h. After cooling, the samples were carefully ground in a ceramic mortar and subsequently sieved through a 2 mm nylon sieve. The finely ground sample (1.250 g) was weighed in a clean dry 250 ml Pyrex conical flask. Distilled de-ionized water (50 ml), glass beads and nitric acid/hydrochloric acid (50 ml; 3:1, v/v) was added and a funnel placed on top. The contents were heated in a fume cupboard on an electric hot plate at medium heat until digestion was complete. Upon cooling, 5 ml of nitric acid was added to the conical flask, followed by 4 ml of 30% hydrogen peroxide. The flask was swirled and reheated for 10 min, cooled, and a further 50 ml de-ionized distilled water added, followed by 25 ml of hydrochloric acid. The boiling mixture was cooled, quantitatively transferred to a 100 ml volumetric flask and filled to volume. The sample was thoroughly mixed and allowed to settle for 5 h. The clear supernatant was filtered through Whatman No.40 filter paper into labeled plastic bottles and sealed with plastic covers. Heavy metal analyses (Okalebo & Gathua, 1993) were carried out with an atomic absorption spectrophotometer (AAS, Model 2380; Perkin-Elmer GmbH, Uberlingen, Germany).

pH and conductivity measurements on the soil

The soil pH and electrolytic conductivity (EC) measurements were determined using soil analysis methods of Rhoades (1982). The soil sample (20.0 ± 0.1 g) was placed in a 250 ml conical flask, 50 mls of de-ionized water added. The mixture was thoroughly shaken for 10 min and subsequently allowed to settle for 30 min. Samples were shaken repeatedly for a further 2 min. The pH of the soil suspension was subsequently measured with a standard pH meter. The soil suspension was allowed to settle for 1 h, before the EC of the supernatant liquid was measured with an EC bridge.

Trace metal analyses

The clear supernatants resulting from the digestion procedures for soil and crops samples were analyzed for the heavy metals according to the standard procedure (Perkin and Elmer, 1982). Standard samples of heavy metals; lead, cadmium, zinc and copper were prepared from the stock solutions used to calibrate the atomic absorption spectrophotometer. The clear supernatants from the digestion of plant samples, soil samples and experimental blanks were analyzed for the heavy metals; lead, zinc, copper and cadmium using a flame atomic absorption spectrophotometer (Perkin-Elmer model 2380) using a slot burner head under the standard operating conditions as shown in table 3.1.

Table 3.1: Standard conditions for Atomic absorption spectrophotometer (AAS)

Elements	Wave length (nm)
Cu	324.8
Pb	217.0
Zn	228.8
Cd	248.3

Quality assurance

To test the efficiency or to obtain fortified sample recoveries of the techniques used, pure standard 1×10^{-4} M aqueous solutions of each of Cu^{2+}, Zn^{2+}, Cd^{2+} and Pb^{2+} were prepared by dissolving requisite amounts of soluble salts of the metals in de-ionized distilled water, making up to 1 litre, and diluting 100 ml of the solution ten-fold. 500 ml of this solution were subjected to a similar treatment as described in section 3.2. Further, analytical blanks were prepared by repeating the respective digestion procedures, minus the samples, and subsequently used to determine the instrument detection limits. In each case a read-out from the screen was taken as the concentration of the selected metals.

Statistical methods

After data collection from the lab, the Statistical SPSS software package was used to calculate the Frequencies, percentage distributions, mean, standard deviation, variance and correlation coefficient that were used to determine accuracy and precision of the results.

3. RESULTS AND DISCUSSION

Total trace metal levels in rural and urban wetland cultivated soils

Crop growing areas situated in or near sources of pollution have an elevated risk of potential contamination. In determining the heavy metal concentration levels, therefore, the primary aim was to highlight the contamination status of the urban wetland soils and correlate it to the metal concentrations found in the crops grown on them. Such studies may lead to the application of early measures to combat the pollution in the urban wetland, for the sake of public health. Table 4.1 shows soil properties namely soil pH and conductivity while table 4.2 shows the total heavy metal concentrations in various selected crops and soils on where they are grown.

Measurements for the physico-chemical parameters showed that whereas the control site soils had a mean pH of 5.47 ± 0.09 and EC 143 ± 3µS/cm, the urban wetland soils recorded a mean pH of 6.35 ± 0.07 and EC 167 ± 6µS/cm. Although the soils had pH and EC values within the acceptable range for agricultural soils the significantly higher EC value for the urban wetland soils, suggested a presence of more soluble ionic substances, among them basic metallic hydroxides, carbonates and hydrogen carbonates that would in turn reduce the relative acidity of the soils over that of the control site.

Table 4.1: Soils pH and Electric Conductivity (EC)

Gulu township Pece wet land (n=3)		
Month	**Soil pH**	**Electric conductivity(µS/cm)**
April 2011	6.34 ± 0.07	160 ± 6
December 2011	6.36 ± 0.07	172 ± 6
April 2012	6.33 ± 0.07	162 ± 6
December 2012	6.37 ± 0.07	174 ± 6
Average	**6.35± 0.07**	**167 ± 6**
Control site (n= 3)		
July 2011	5.46±0.09	137 ± 3
December 2011	5.48±0.09	148 ± 3
July 2012	5.45±0.09	139 ± 3
December 2012	5.49±0.09	148 ± 3
Average	**5.47±0.09**	**143 ± 3**

Table 4.2: the mean concentration levels of heavy metals in food crops and soil samples in Gulu Township

Matrix	period	**Mean total concentration levels in mg/kg (n=3)**			
		Zn	Cu	Cd	Pb
doodo (leaves)	April 2011	140.27±05.21	17.10±1.40	0.81±0.31	9.90±1.10
	Dec 2011	150.47±15.21	17.16±1.44	0.83±0.39	9.89±1.18
	April 2012	142.30±10.20	17.15±1.46	0.92±0.25	9.81±1.19
	Dec 2012	148.44±10.22	17.01±1.38	0.72±0.45	9.80±1.09
	Mean average	**145.37±10.21**	**17.13 ± 1.42**	**0.82 ± 0.35**	**9.85 ± 1.14**
Matooke (fruit)	April 2011	120.30±21.20	15.11 ±1.40	0.22±0.01	5.39±1.40
	Dec 2011	120.38±21.28	15.15±1.44	0.20±0.05	5.38±1.56
	April 2012	110.20±22.20	15.20±1.32	0.23±0.02	5.30±1.44
	Dec 2012	130.48±20.28	15.06±1.52	0.19±0.04	5.29±1.52
	Mean average	**120.34 ± 21.24**	**15.13 ± 1.42**	**0.21 ± 0.03**	**5.34 ± 1.48**
Sugar cane	April 2011	68.44±12.44	14.80±16.20	0.76±0.02	3.98±1.40
	Dec 2011	60.24±10.24	14.94±16.22	0.72±0.03	3.95±1.48
	April 2012	54.20±06.30	14.84±16.17	0.78±0.05	3.93±1.42
	Dec 2012	74.48±16.38	14.90±16.25	0.70±0.01	3.90±1.46
	Mean average	**64.34 ± 11.34**	**14.87±16.21**	**0.74 ± 0.03**	**3.94 ± 1.44**
Coco Yam (corms)	April 2011	115.57±20.01	6.00±11.50	0.25±0.02	4.90±0.80
	Dec 2011	105.67±22.01	6.05±11.52	0.25±0.00	4.92±0.96
	April 2012	118.40±10.01	6.02±11.55	0.27±0.05	4.81±0.81
	Dec 2012	102.54±32.01	5.97±11.47	0.23±0.01	5.01±0.95
	Mean average	**110.47±21.01**	**12.32±1.62**	**0.25 ± 0.02**	**4.91 ± 0.88**
soil	April 2011	151.55±2.52	36.20±4.00	1.35±0.44	50.14±2.24
	Dec 2011	153.23±1.45	36.26±4.08	1.31±0.41	46.35±2.13
	April 2012	149.42±1.65	36.25±4.01	1.39±0.39	42.33±0.21
	Dec 2012	151.25±3.25	36.21±4.07	1.34±0.52	42.11±2.14
	Mean average	**151.36 ± 2.22**	**36.23 ± 4.04**	**1.35 ± 0.44**	**46.23 ± 1.68**

Table 4.3: the mean concentration levels of heavy metals in food crops and soil samples Bushenyi wetland (control site)

Matrix	Period	**Mean total concentration levels in mg/kg (n=3)**			
		Zn	Cu	Cd	Pb
doodo	July 2011	12.05±0.41	6.72±1.50	0.08±0.03	3.36±0.50
	Dec 2011	16.09±0.41	6.72±1.52	0.10±0.05	3.48±0.58
	July 2012	10.02±0.31	6.80±1.55	0.07±0.07	3.40±051
	Dec 2012	18.12±0.51	6.68±1.47	0.11±0.01	3.44±0.57
	Mean average	**14.07 ±0.41**	**6.74 ± 1.51**	**0.09 ± 0.04**	**3.42 ± 0.54**
matooke	July 2011	6.90±0.18	5.70±1.50	0.10±0.00	2.40±0.32
	Dec 2011	6.94±0.54	5.78±1.52	0.06±0.00	2.50±0.36
	July 2012	6.00±0.30	5.80±1.48	0.09±0.02	2.41±0.30
	Dec 2012	7.84±0.42	5.68±1.54	0.07±0.01	2.49±0.38
	Mean average	**6.92 ± 0.36**	**5.74 ± 1.51**	**0.08 ± 0.01**	**2.45 ± 0.34**
Sugar cane	July 2011	40.84±3.26	6.42±1.50	0.12±0.06	2.41±0.30
	Dec 2011	40.86±5.46	6.46±1.52	0.14±0.07	2.39±0.34
	July 2012	35.80±2.36	6.36±1.48	0.15±0.05	2.20±0.36
	Dec 2012	45.90±6.36	6.52±1.54	0.11±0.11	2.60±0.28
	Mean average	**40.85 ± 4.36**	**6.44 ± 1.51**	**0.13 ± 0.07**	**2.40 ± 0.32**
Cocoyam corms	July 2011	114.10±20.51	6.00±11.50	0.03±0.04	1.20±0.40
	Dec 2011	116.26±02.51	6.02±11.52	0.01±0.06	1.24±0.50
	July 2012	110.36±05.30	6.05±11.55	0.03±0.03	1.26±0.41
	Dec 2012	120.00±17.72	5.97±11.47	0.01±0.07	1.18±0.49
	Mean average	**115.18±11.51**	**6.01 ±11.51**	**0.02 ± 0.05**	**1.22 ± 0.45**
soil	July 2011	7.40±1.61	18.26±3.20	0.65±0.02	12.56±3.11
	Dec 2011	7.50±2.62	18.18±3.24	0.64±0.04	10.46±3.33
	July 2012	7.50±6.12	18.16±3.18	0.67±0.01	14.67±2.11
	Dec 2012	7.60±1.21	18.28±3.26	0.63±0.05	12.54±4.89
	Mean average	**7.50 ± 2.76**	**18.22 ± 3.22**	**0.65 ± 0.01**	**12.56 ± 3.36**

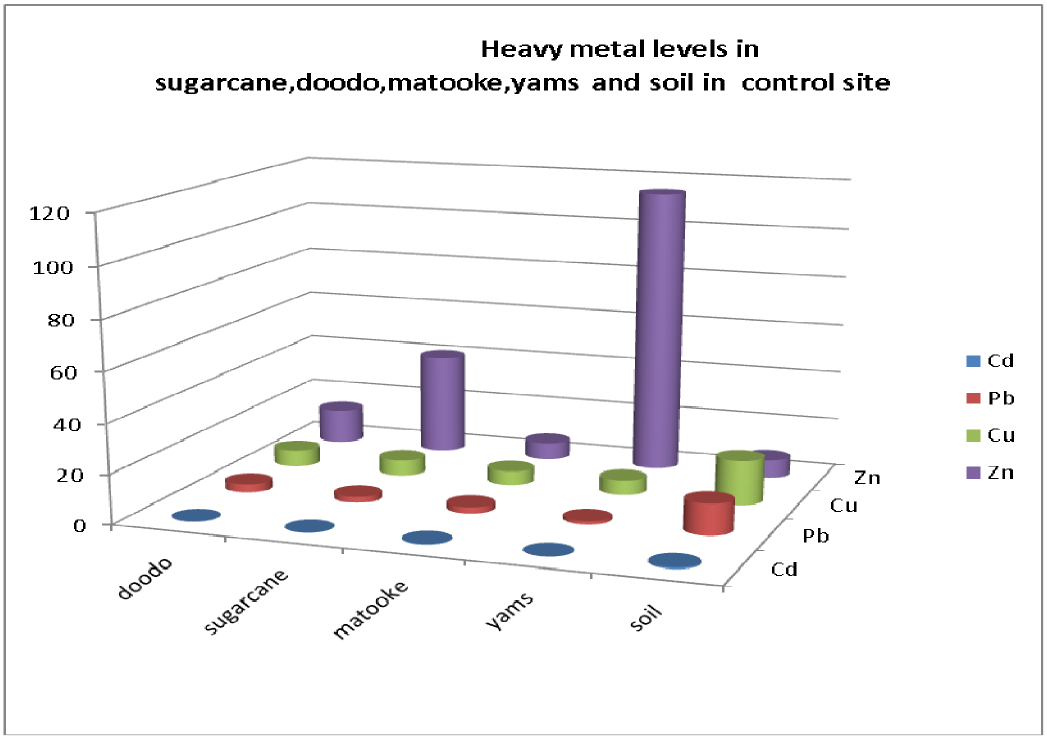

Figure 4.1: A bar chart showing mean heavy metal contents in cocoyam, doodo, matooke, sugar cane and soils from the control site.

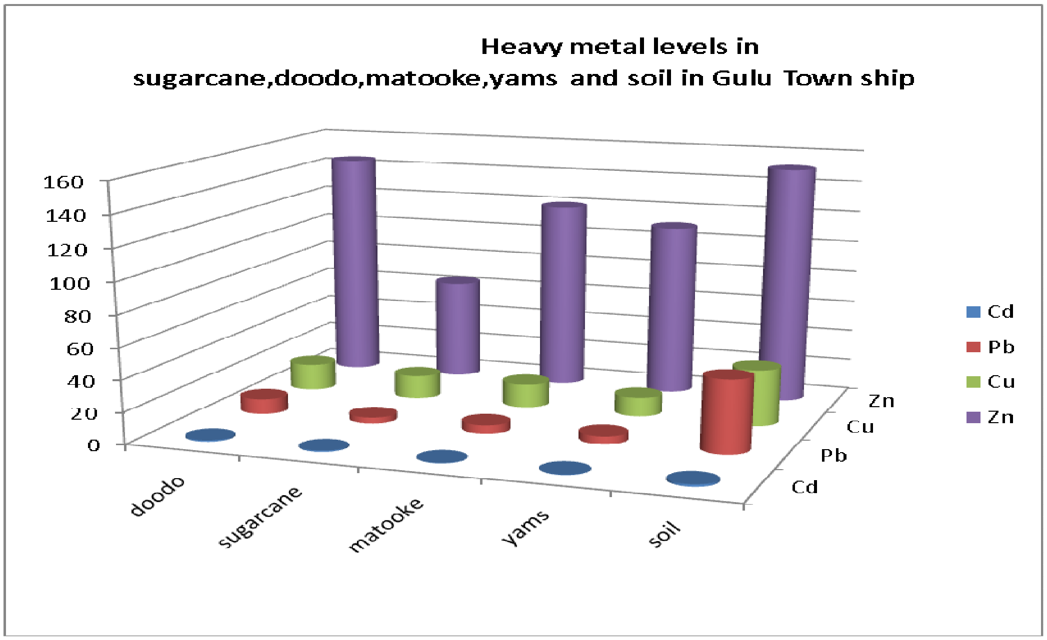

Figure 4.2**:** A bar chart showing mean heavy metal contents in cocoyam corms, doodo, matooke, sugar cane and soils from Gulu Township.

Trace metal levels in the soil

Zinc: An average Zn concentration of up to 40 mg/kg was reported for non-contaminated soils (Adriano 1986). The comparatively low mean Zn levels in the soils from the wetland control site 7.50 ± 2.76 mg/kg d.w. were found to be well within the levels of uncontaminated soils 0-250 by ICRCL. The observed mean total Zn levels of 151.36 ± 2.22 mg/kg d.w. in the soils from the urban wetland drainage system (Table 4.2) were far above those from uncontaminated soils, even though they were still within the optimal concentration of 0–250 mg/kg recommended by the ICRCL, Interdepartmental Committee for the Redevelopment of Contaminated Land (1987) for soils used for agriculture. This finding suggested significant Zn pollution of the urban wetland soils, which is perhaps not too surprising, considering that the main roofing material in Gulu municipality for over a century has been, and continues to be, galvanized iron. Corrosion of such zinc-coated corrugated iron sheets releases considerable quantities of zinc into the soil (Suciu et al., 2008), the leaching of which concentrates it in the wetland water catchment areas. The critical total soil Zn concentration, above which toxicity is considered possible, has been put at 70–400 mg/kg (Kabata & Pendias, 1984)

Cadimium: While the mean Cd concentrations of 0.65 ± 0.01 mg/kg d.w. measured in the soils from the control sampling site were incomparable to those in the earth's crust, quoted as 0.1 mg/kg (Bowen, 1979; WHO, 1992), they remain within the mean Cd levels of 0.01–1.00 mg/kg in non-volcanic soils, as reported by Korte (1983). The mean total Cd level of 1.35 ± 0.44 mg/kg d.w. (Table 4.2) measured in the soil samples from the urban wetland cultivation site was above the recommended concentrations (ICRCL 1987) of 0–1.0 mg/kg for soils used for agriculture. Thus, it may be concluded that the soils from Pece wet land Gulu town ship were contaminated with cadmium, relative to those from the control site. Cadmium is widely used in paints and plastics. The traces of cadmium embedded in scrap metal (Moors & Dijkema, 2006) processed by small-scale industries littered all over the outskirts of the town center and their untreated effluents, therefore could be blamed for its relative increase in the urban wetland soils. Furthermore, increasing chemical usage, as well as organic fertilizers, especially in vegetable growing activities on the urban wetland, could also be another source.

Lead: The mean total Pb concentration levels of 12.56 ± 3.36 mg/kg d.w. in the soil samples from the rural control site were comparable to those in the earth's crust, reported as 13 mg/kg (WHO 1989), and to those in soils from areas remote from human activity, estimated to be in the range of 5–25 mg/kg (Swaine, 1955). The soils from the urban wetland cultivation site exhibited a mean total Pb level of 46.23 ± 1.68 mg/kg d.w. and were apparently relatively more contaminated with this heavy metal than those from the control site by a factor of four (Table 4.3). This relatively elevated Pb level in the urban wetland soils may be attributed to continued use of lead paints, and to prolonged car-washing and emptying of dead lead-acid accumulators being conducted by unknowing car washers directly along the streams and channels leading to the wetland (Yoon et al., 2006).

Copper: The mean total Cu concentration levels of copper in soils from the control site was found to be 18.22 ± 3.22 mg/kg d.w. while that from the urban wetland cultivation site exhibited a mean total Cu concentration level of 36.23 ± 4.04 mg/kg d.w. and were apparently relatively more contaminated with this heavy metal than those from the control site by a factor of two.

Cadmium (Cd) levels in food crops

Cocoyarm:The Cd concentration levels in cocoyam from the urban wetland was 0.25 ± 0.02 mg/kg d.w., while that from the control site was 0.02 ± 0.05 mg/kg d.w. (Table 4.3).The maximum permissible Cd limit for such crops is 0.1 mg/kg (Codex Alimentarius Commission, 2001). The cocoyam crop grown on the urban wetland soils evidently contains Cd levels that distinctly exceed this maximum tolerable limit. Cd has been blamed for large-scale poisoning incidents (Wendelaar-Bonga & Lock 2003). The comparatively higher Cd levels in the soils of the urban wetland drainage system over those from the control site also are reflected in the cocoyam crops grown on the Pece wetland. The provisional recommended tolerable weekly intake (PTWI) for cadmium is 7µg/kg body weight (FAO ⁄WHO 1993). Thus, if a 60 kg person consumes an average of 0.6 kg of cocoyam in a week, the Cd intake from the urban wetland yams would be 2.42 µg/kg body weight, and 0.16 µg/kg body weight from the control site.

Thus, overconsumption of cocoyam grown on the urban wetland might in time pose a human health threat associated with exposure to cadmium.

Sugarcane: The Cd concentration in the sugarcane juice extracts from the stems cut from the control site was 0.13 ± 0.07 mg/kg of juice, while that in the food crop from the urban cultivation site was 0.74 ± 0.03 mg/kg juice (Table 4.3). The Cd concentration in all the sugarcane juice extract samples in this study was above the maximum permissible limit of 0.1 mg/ kg. Considering that the Cd level in the urban wetland soil was1.35 ± 0.42 mg/kg d.w. as opposed to 0.65 ± 0.01 mg/kg d.w. for the rural control setting (Table 4.2), it would appear that the sugarcane stem absorbs this toxic heavy metal to a larger extent.

Doodo: The Cd concentration in doodo from the control site was 0.09 ± 0.04 mg/kg, while that from the urban cultivation site was 0.82 ± 0.35 mg/kg (Table 4.2). The Cd concentration in the urban wet land was above the maximum permissible limit of 0.1 mg/ kg. The relatively high accumulation of Cd in doodo from the urban wetland cultivation sites may be linked to the mildly acidic nature of the soil (6.35± 0.07) resulting in greater Cd availability Singh, B., (2001). The uptake of aerial deposited Cd by vegetable leaves may also be a contributory factor Mbabazi.J.et al., (2010)

Matooke:The Cd concentration levels in matooke from the urban wetland was 0.21 ± 0.03 mg/kg d.w., while that from the control site was 0.08 ± 0.01 mg/kg d.w. (Table 4.3).The matooke grown on the urban wetland soils evidently contains Cd levels that distinctly exceed the maximum tolerable limit of 0.1 mg/kg according to Codex Alimentarius Commission (2001). The comparatively higher Cd levels in the soils of the urban wetland drainage system over those from the control site also are reflected in the banana crop grown on the wetland. The provisional recommended tolerable weekly intake (PTWI) for cadmium is 7µg/kg body weight (FAO ⁄WHO 1993). Thus, if a 60 kg person consumes an average of 0.6 kg of cocoyam in a week, the Cd intake from the urban wetland corms would be 2.1 µg/kg body weight, and 0.14 µg/kg body weight from the control site

Zinc levels in food crops

Cocoyam: The Zn concentration levels in plants are a function of various soil and climatic factors (Kiekens 1995), including pH, organic matter content, microbial activity and the soil moisture regime. Plants absorb zinc as Zn^{2+}, and the normal range in plants is 1–400 mg/kg (Bowen 1979). The cocoyam corms from the urban wetland sampling site had a concentration of 110.47±21.01 mg/kg d.w., while those from the control site had a concentration of 143.18 ±11.51 mg/kg d.w. (Table 4.3). This finding contrasts with the expectations from the rather low Zn level in the rural wetland setting (7.50 ± 1.62 mg /kg d.w.), compared with that in the urban wetland cultivated soils (151.54 ± 9.22 mg/ kg d.w); Thus, it would appear that, in spite of the relative Zn pollution in the urban wetland soils, the cocoyam plant is able to shield most of it from its corms. This may be attributable to soil Zn geochemical barriers and also cocoyam trying to optimize Zn absorption in zinc-deficient soils. The daily dietary Zn intake proposed as being adequate for adults is in the range of 12–15 and 15–35 mg/day for pregnant or lactating females (National Academy of Sciences, 1989).

Sugarcane: The extracts from the sugarcane stems grown on the control site yielded a Zn concentration level of 40.85 ± 4.36 mg/kg of juice, while that from the urban wetland stems yielded 64.34 ± 11.34 mg/kg juice. Although these levels were significantly lower than those observed in cocoyam, the sugarcane stems yielded juice extracts with Zn concentration levels roughly consistent with those in the soils on which they were grown. The Zn pollution in the urban wetland soils also was reflected in the Zn level in the juice extracts from the sugarcane stems. Nevertheless, the observed Zn concentrations in the juice extracts were still within the normal range of 1–400 mg/kg for plants, as described by Bowen (1979).

Doodo: As already mentioned Zn levels in plants are a function of various soil and climatic factors (Kiekens, 1995), including pH, organic matter content, plant species, microbial activity and the soil moisture regime. The doodo from the urban wetland sampling site had a concentration of 145.37±10.21 mg/kg d.w., while those from the control site had a concentration of 14.07 ±0.41 mg/kg d.w. (Table 4.3). This is in agreement with the study made by Davies and White (1981) who reported Zn concentrations of 39.0 to 710 $mgkg^{-1}$*d.w.* in vegetables grown on Zn contaminated soils. From these results it is also observed that the concentration of Zn in doodo leaves from the control site is higher than that from the soil where it is absorbed this may be attributed to Ariel deposition of zinc and the fact that some plant species try to optimize Zn^{2+} in Zn deficient soils Mbabazi et al.,(2010). Zinc levels were also high in vegetables grown on the urban wetland. This might have been due to some aerial deposition of various modifications of the combined element Jinadasa et al., (1997) in addition to zinc absorbed from the soil. Despite these elevated levels of zinc in doodo leaves, it had not reached such alarming levels and was still within the normal range of 1–400 mg/kg for plants as described by Bowen (1979

Matooke: The extracts of matooke from the control site yielded a Zn concentration level of 6.92 ± 0.36 mg/kg, while that from the urban wetland yielded 120.34 ± 21.24 mg/kg. These levels were lower than those observed in cocoyam and doodo extracts but greater than those observed in sugar cane and roughly consistent with those in the soils on which they were grown Nevertheless, the observed Zn concentrations in the matooke extracts were still within the normal range of 1–400 mg/kg for plants, as described by Bowen (1979)

Lead levels in food crops

Sugarcane: The mean Pb level concentration in the sugarcane juice extracts from the stems grown on the urban wetland drainage system soils was 3.94 ± 1.44 mg/kg of juice, while those from the stems from the rural control site was 2.40 ± 0.32 mg/kg. The Pb concentrations in the sugarcane from the urban wetland cultivation were significantly higher than the maximum permissible limit of 2.5 mg/kg recommended by Indian Legislation (1954).

The sugarcane stems grown on the rural wetland soils with normal Pb contents did not exhibit such relatively high levels in sugarcane. This shows that there is Pb pollution in the urban wetland soils (Table 4.2). This might affect nutritional quality of the sugarcane crop grown there. It appears, therefore, that excessive consumption of sugarcane is likely to pose health risks related to Pb poisoning. There is a possibility that plants may absorb Pb and other metals, not only by translocation from roots to leaves, but also directly through the leaves (Kabata-Pendias & Pendias 1992; Jinadasa et al. 1997). It is also likely, therefore, that the Pb from vehicles could influence Pb levels on crop grown along the roadside, especially in urban sites (Nyangababo 1987). Such realities also may be reflected with the elevated Pb levels in both cocoyam and sugarcane grown on the urban wetland, resulting from its aerial deposition onto the plant leaves.

Cocoyam: The Pb concentration in the cocoyam corms from the urban wetland drainage system site was 4.91 ± 0.88 mg/kg, while that from the control site soils was 1.22 ± 0.45 mg/kg) d.w. (Table 4.3). The mean Pb levels in the cocoyams grown in the urban wetland were higher than the maximum permissible limit of 2.5 mg/kg established by Indian Legislation (1954). Thus, it would appear that consumption of the coco yam grown on the urban wetland over a period of time poses a human health risk. The elevated Pb level in the cocoyam crop is consistent with that observed in the urban wetland soils. Thus, it is also reasonable to conclude that the Pb pollution observed in the urban wetland soils is evidently reflected in the cocoyam crop grown in them. The relatively unpolluted rural wetland soils (Table 4.2) results in mean Pb levels in cocoyam well within the maximum permissible limits.

Matooke: The mean Pb concentration level in the matooke extracts from the urban wetland drainage system soils was 5.34 ± 1.48 mg/kg, while that from the rural control site was 2.45 ± 0.34 mg/kg. The Pb concentrations in matooke from the urban wetland cultivation were significantly higher than the maximum permissible limit of 2.5 mg/kg recommended by Indian Legislation (1954).

Doodo: The mean Pb concentration level in the doodo extracts from the urban wetland drainage system was 9.85 ± 1.14 mg/kg, while that from the rural control site was 3.42 ± 0.54 mg/kg. The Pb concentrations in doodo from the urban wetland cultivation were significantly higher than the maximum permissible limit of 2.5 mg/kg recommended by Indian Legislation (1954) and about three times higher than the one from control site (Bushenyi wet land)

From these results it is clear that Pb pollution observed in the urban wetland soils is evidently reflected in the doodo grown in them. The relatively unpolluted rural wetland soils resulted in mean Pb levels in doodo though high but not far much beyond the maximum permissible limits.

Copper levels in food crops

Cocoyam: The Cu concentration levels in plants are a function of various soil and climatic factors (Kiekens, 1995), including pH, organic matter content, microbial activity and the soil moisture regime. Plants absorb copper as Cu^{2+}.The cocoyam corms from the urban wetland sampling site had a concentration of 12.32 ± 1.62 mg/kg d.w., while those from the control site had a concentration of 6.01±11.51 mg/kg d.w. (Table 4.3). The recommended levels of Cu in food crops are $40mgkg^{-1}$ from Codex Alimentarius commission 1984. The comparatively higher Cu levels in the soils of the urban wetland drainage system over those from the control site also are reflected in the cocoyam crop grown.

Sugarcane: As already mentioned the Cu levels in plants are a function of various soil and climatic factors (Kiekens 1995), including pH, organic matter content, microbial activity and the soil moisture regime. Plants absorb copper as Cu^{2+}.The sugar cane from the urban wetland sampling site had a concentration of 14.87 ± 16.21 mg/kg d.w., while those from the control site had a concentration of 6.44 ± 1.51 mg/kg d.w. (Table 4.3). Cu concentrations in sugar cane from the urban wetland cultivation were significantly higher than that from the control site. From these results it is clear that Cu pollution observed in the urban wetland soils is evidently reflected in the sugar cane grown in them but still within the limits of the recommended levels of Cu in food crops (40 mg kg^{-1}) Codex Alimentarius commission 1984

Doodo: The doodo from the urban wetland sampling site had a concentration of 17.13 ± 1.42 mg/kg d.w., while those from the control site had a concentration of 6.74 ± 1.51 mg/kg d.w. Cu concentrations in doodo from the urban wetland cultivation were significantly higher than that from the control site. From these results it is clear that Cu pollution observed in the urban wetland soils is evidently reflected in the doodo grown on them but still within the limits of the recommended levels of Cu in food crops ($40mgkg^{-1}$) Codex Alimentarius commission 1984.

Matooke: Matooke from the urban wetland sampling site had a concentration of 15.13 ± 1.42 mg/kg d.w., while those from the control site had a concentration of 5.74 ± 1.51 mg/kg) d.w. (Table 4.3). Cu concentrations in matooke from the urban wetland cultivation were significantly higher than that from the control site. From these results it is clear that Cu pollution observed in the urban wetland soils is evidently reflected in the matooke grown on them but still within the limits of the recommended levels of Cu in food crops (40mgkg^{-1}) Codex Alimentarius commission 1984.

Table 4.4: Recommended heavy metal levels in plants

Heavy metals	**levels(mg/kg)**	**Recommended bodies**
Cu	40	Codex Alimetarius Commission (2001)
Zn	1-400	Bowen (1979)
Pb	2.5	Indian legislation(1954)
Cd	0.1	Codex Alimetarius Commission 2001

Generally crops harvested from the soils of refuse dump sites presented higher values of metals when compared to those crops from the control sites. This is interpreted to mean that if the level of these metals in the soil is significantly increased, the test crops have the potential of showing increased up take of these metals. Alloy and Davies (1971) and Grant and Dobbs (1977) reported that plants grown on soils possessing enhanced metal concentrations have increased metal ion content. The uptake of metal ions have been found out to be influenced by a number of factors including metal and plant species (Juste and Mench, 1962) on the basis of this the transfer ratio of each plant species was calculated using the method of Oyedele et al., (1995). This is the ratio of the concentration of metals in plants to the total concentration in the soil. The transfer factors for the same metal were significantly different from those of the control site and were varying according to the type of crops.

Plants are known to take up and accumulate trace metals from contaminated soil (Abdul et al., 1999). Hence detection in crop samples was not a surprise. Also the variation in values obtained for these heavy metals in the soil and crop plant samples as against those from control sites is an indication of their mobility from the dumpsites to the farmlands around particularly through leaching and runoffs. This is in agreement with the report of Oluyemi *et al.*, (2008).

The TF is one of the key components of human exposure to metals through the food chain. In all the four crops, the rate of heavy metal up take by the plant(transfer factors) was generally in the order Zn>Cu>Cd>Pb. The mobility of metals from soil to plant is a function of the physical and chemical properties of the soil and of vegetable species, and is altered by innumerable environmental and human factors (Zurera *et al.,* 1987).

Generally the trend of heavy metal transfer ratios was in line with their levels of concentration in the soil with little variation in lead and cadmium.

Comparing cadmium and lead, cadmium is less concentrated in the soil but on the other hand it has high TF than lead. This might be due to higher mobility of Cd with a natural occurrence in soil (Alam *et al.,* 2003), and the low retention of Cd in the soil than other toxic cations (Lokeshwari and Chandrappa, 2006). The result also supports the findings that accumulation of Pb is comparatively less than that of Cd in plants (Olaniya *et al.,* 1998).

The transfer ratios of Zn, in cocoyam, doodo and sugar cane from the control soils with lower concentrations of these metals were higher than those from the refuse dump soils with higher metal loads. This indicates that some soil factors apart from the total soil content of the metals also may have influenced heavy metal up take by plants. Mench et al. 1994, Chen and Lee 1997 also attributed this to some materials such as dolomite, phosphates or organic matter and exchangeable cations. These were found to be higher in refuse dump soils and good at reducing the concentration of metals by precipitation, adsorption, or complexation and thereby making them unavailable to plants.

Another crucial factor which affects metal availability in the soil is soil pH. Smith (1996), metal mobility decreases with increasing soil pH due to precipitation of hydroxides, carbonates or formation of insoluble organic complexes. All the refuse dump soils recorded higher pH values (6.28–6.42) than their background soils which were in the range of (5.38-5.56). These high pH values might have decreased the mobility of the metals in the soil as stated by Smith (1996) and consequently contributing to the lower transfer ratios of the metals in the refuse dump soils.

With exceptional of zinc in cocoyam, doodo and sugar cane for the control site the levels of heavy metals in soils were higher than those in plants. This is in agreement with Demi˙rezen and Aksoy (2006) also who reported that the levels of heavy metals in vegetables were generally lower than those in soil samples. According to Davies et al., (1981), such results might have been attributed to root activity, which seems to act as a barrier for translocation of metals. High levels of heavy metals in soils do not always indicate similar high concentrations in plants. The extent of accumulation and toxic level depend on the plant and heavy metal species (Alloway, 1996).

Table 4.5: Transfer ratios of heavy metal from the soil to crop species

Metal type	**Dump site**				**Control site**			
	cocoyam	Sugar cane	Matooke	doodo	cocoyam	Sugar cane	Matooke	doodo
Zn	0.730	0.425	0.795	0.960	15.357	5.447	0.794	1.876
Cd	0.185	0.548	0.156	0.607	0.025	0.200	0.138	0.138
Pb	0.106	0.085	0.115	0.213	0.097	0.191	0.195	0.273
Cu	0.340	0.410	0.418	0.473	0.330	0.353	0.315	0.370

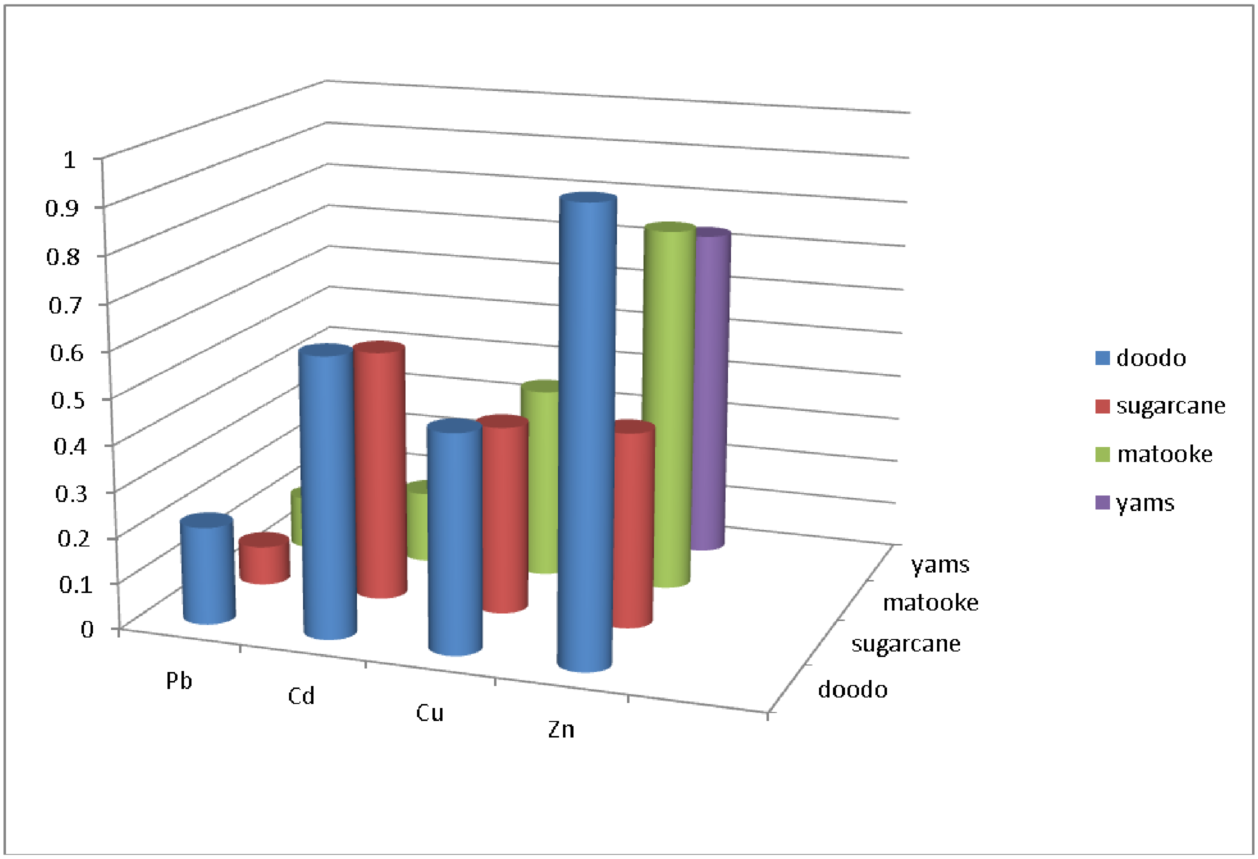

Figure 4.3: A bar chart showing heavy metal transfer ratios in food crops from the Gulu Township.

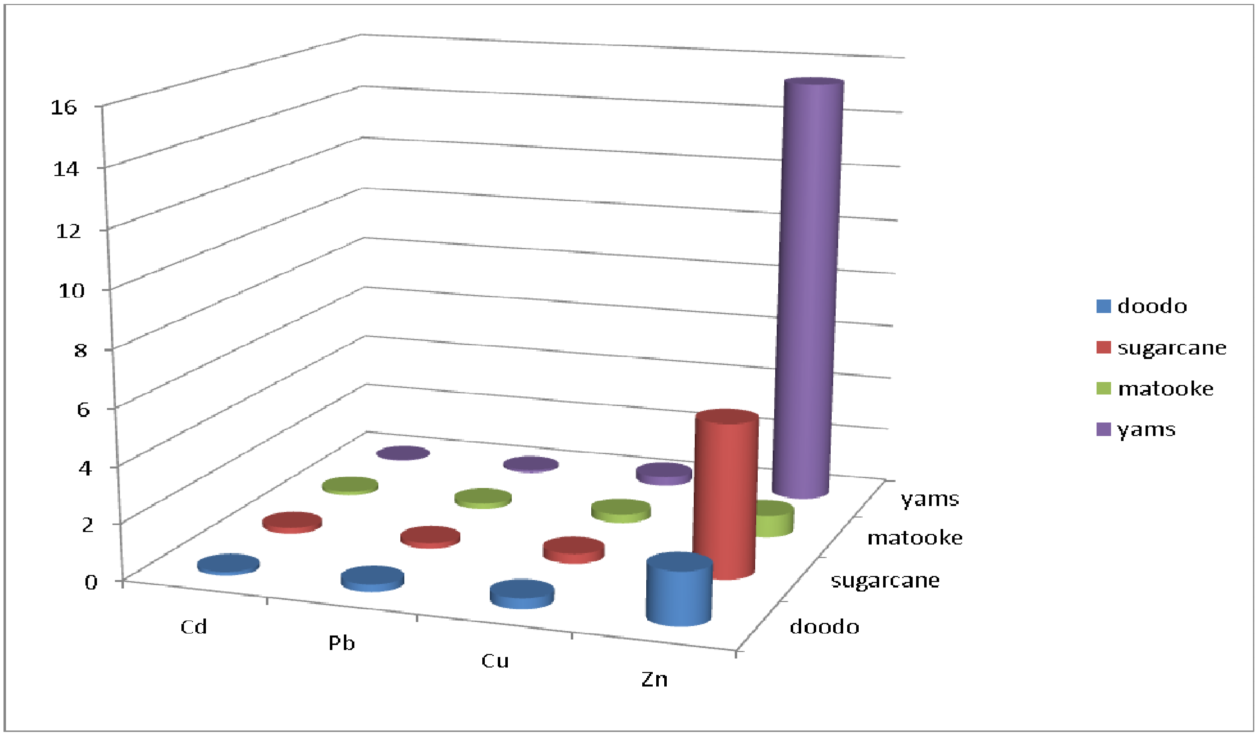

Figure 4.4: A bar chart showing heavy metal transfer ratios in food crops from the control site.

In order to ascertain probable relationship between Pb, Cd, Zn, and Cu content of soils and crops, correlations were calculated.

Table 4. 6: Correlation between heavy metal content in soils and food crops
($* = p<0.05$, ns= non significant)

Food crop	Heavy metal			
	Zn	**Cu**	**Cd**	**Pb**
doodo	0.623ns	0.760ns	**0.971***	0.782ns
matooke	0.477ns	0.857ns	0.939ns	0.782ns
Sugarcane	0.608ns	**0.983***	0.939ns	**0.970***
Cocoyam corms	0.647ns	0.841ns	**0.988***	**0.995***

The results showed positive correlation between metal concentration in soils and crops, and the correlation varied widely. The correlation between soil-plant was found to be in the order Pb>Cd>Cu>Zn. The relationship between heavy metals in the soil and plant depend on available forms of metal ions in soil

Cataldo and Wildung, (1978) pointed it out that for root uptake to occur; a soluble species must exist adjacent to the root membrane for some finite period. Once metal-containing materials are deposited, they are subjected to chemical and microbial modification with metal solubility ultimately approaching thermodynamic equilibrium with nature soil mineral and organic matter. The rate and extent of solubilisation are governed by the physicochemical properties of the deposited material, soil processes and soil properties; therefore solubility might be responsible for the different levels of heavy metal uptake by the plants hence variation in correlation.

The study established no significant correlations of heavy metals in matooke. This implies that the heavy metals in matooke do not entirely originate from the soil but from various sources like aerial deposition.

CONCLUSION AND RECOMMENDATIONS

CONCLUSIONS

From the results of this study, the following conclusions have been drawn

- Heavy metal pollution in the Pece wet land Gulu municipality may eventually reach the dining table through the food crops grown directly on these soils.
- All the vegetable samples drawn from the urban wetland drainage system in this study were polluted with cadmium and lead that is the lead and cadmium values were above the recommended permissible levels.
- Individual crops were found to differ in their uptake and accumulation of the heavy metal pollutants.
- There were relatively high levels of soil heavy metal contamination in the Gulu town ship (pece wet land) compared to the control site.

RECOMMENDATIONS

- Wetlands exposed to heavy metal pollutants should not be used for agricultural activities
- Further studies need to be carried out in Gulu town ship pece wet land dumping site to determine the levels of heavy metals in other food crops grown in the wet land such as beans, cassava etc and to consider also other heavy metals like aluminium, iron which were not covered in this study because of little funds.
- Studies need to be carried out to establish the relationship between the seasonal changes and the levels of heavy metals in Gulu town ship.

- Research should be done to quantify the levels of heavy metals present in the urban atmosphere, the difference in mechanism between vegetable uptake from soil and through leaves, and the variations in uptake among different vegetable species.

REFFERENCES

Abdul. K, B. Singh., (1999). Heavy metal contamination of soil and vegetation in the vicinity of industries in Bangladesh - Water, Air and Soil Pollution. Contamination of Vegetables in Delhi Executive Summary of Technical Report.

Adriano, D.C., (1986). Zinc, in: Trace Elements in the Terrestrial Environment (New York: Springer), pp. 426–469.

Alloway, B. J. (1990). Heavy Metal in Soils. 2nd Edition, Glasgow: Blackie Publishers, p.50.

Alloway, B. J. (1996). Heavy Metal in Soils. London: John Wiley and Sons Incorporated, pp.149-159.

Alloway, B.J and Ayres D.C (1997) Chemical Principles of Environmental Pollution, 2nd ed. Blackie Academic and Professional Chapman and Hall, London.

Bowen, H. J. M. (1979) Environmental Chemistry of the Elements. Academic Press, New York.

Davies, B.E. and White, H.M., (1981. Trace elements in vegetables grown on soils contaminated by base metal mining. Journal of Plant Nutrition, **2,** 387–395.

Fatoki, O.S. (2000). *Int. L. Environmental Studies.*

Indian Legislation (1954) Prevention of Food Adulteration Act. Government of India.

Jinadasa, K.B.P.N., Milham, P.J., Hawkins, C.A., Cornish, P.S.D., Williams, P.A., Kaldor, C.J. and Conroy,J.P., (1997). Survey of cadmium levels in vegetables and soils of greater Sydney, Australia. Journal of Environmental Quality, 26, 924–933.

Kabata-Pendias A. and Pendias H. (1984) Trace Elements in Soils and Plants. CRC Press, Baton Rouge.

Khan D.H and Frankland B. (1983). Effects of cadmium and lead on radish plants with particular reference to movement of metals through soil profile and plant.

Khan,S.,Q.Cao,Y.M.Zheng,Y.Z.Huang and Y.G.Zhu,2008. Health risks of heavy metals in contaminated soils and food crops irrigated with waste water in Beijing.

Kiekens L. (1995) Zinc. In: Heavy Metals in Soils, pp.284–305.

Korte F. (1983). Ecotoxicology of cadmium.

Mbabazi. J, Wasswa J., Kwetegyeka J. and Bokyaita,G.K, 2010. Heavy metal contamination in vegetables cultivated on a major urban wet land inlet drainage system of Lake Victoria, Uganda.

Moors E. H. M. and Dijkema G. P. J. (2006) Embedded industrial production systems: lessons from waste management in zinc production.

Nabulo G. (2004) Assessment of Heavy Metal Contamination of Food Crops and Vegetables from Motor Vehicle Emissions in Kampala City, Uganda. PhD Thesis, Makerere University.

Nabulo, G. (2009). Assessing risks to human health from peri-urban agriculture in Uganda. PhD thesis, University of Nottingham.

National Academy of Science (1989) Recommended Dietary Allowances. National Academy of Sciences Press, Washington, DC.

Nriagu J.O., (1988). A silent killer of environmental metal poisoning.

Nriagu, J.O., and Pacyna, J. M., (1988). "Quantitative Assessment of World-wide Contamination of Air, Water and Soils by Trace Metals"

Ogunyemi, S, Awodoyin. R. and Opadeji,.T**,** (2003). *Journal of Agric Science.*

Olaniya, M.S., Sur, M.S., Bhide, A.D.and Swarnakar, S.N., (1998). Heavy metal pollution of agricultural soil and vegetation due to application of municipal solid waste – A case study. Indian Journal of Environment & Health 40: 160–168.

Oluyemi E.A., Feuyit G., Oyekunle J.A.O., Ogunfowokan A.O.(2008) Int. J. Environmental Science and Technology

Singh, B., (2001). Heavy metals in soils: sources, chemical reactions and forms, in: D. Smith, S. Fityus and M. Allman (Eds) GeoEnvironment: Proceedings of the 2nd Australia and New Zealand Conference on Environmental Geotechnics (Newcastle, New South Wales: Australian Geochemical Society), pp. 77–93.

Suciu I., Cosma C., Todica M., Bolboaca S. D. and Ja¨ntschi L. (2008) Analysis of Soil Heavy Metal Pollution and Pattern in Central Transylvania.

WHO (1989) Environmental Health Criteria for Lead. World Health Organization, Geneva.

Yoon J., Cao X., Zhou Q. and Ma L. Q. (2006) Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. Sci. Total Environ. 368, 456–64.

Zurera, G., Estrada, B., Rincon, F. and Pozo, R., 1987. Lead and cadmium contamination levels in edible vegetables. Bull. Environmental Contamination and Toxicology.