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Assessment of Zn, Cu, Pb and Ni contamination in wetland soils and plants in the Lake Victoria basin

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ABSTRACT: The impact of waste disposal on trace metal contamination was investigated in eleven wetlands in the Lake Victoria Basin. Samples of soil, water and plants were analysed for total Zn, Cu, Pb and Ni concentrations using flame atomic absorption spectrophotometry. The trace metal concentrations in soil were the highest in Katanga wetland with the highest mean concentrations of 387.5±86.5 mg/kg Zn, 171.5±36.2 mg/kg Pb, 51.20±6.69 mg/kg Cu and 21.33±2.23 mg/kg Ni compared to the lowest levels observed at Butabika (30.7±3.2 mg/kg Zn, 15.3±1.7 mg/kg Pb, 12.77±1.35 mg/kg Cu and 6.97±1.49 mg/kg Ni). Katanga receives waste from multiple industrial sources including a major referral city hospital while Butabika is a former solid waste dumpsite. Wetland soil near a copper smelter had a Cu concentration of 5936.3±56.2 mg/kg. Trace metal concentrations in industrial effluents were above international limits for irrigation water with the highest concentrations of 357,000 µg/L Cu and 1480 µg/L Zn at a Cu smelter and 5600 µg/L Pb at a battery assembling facility compared to the lowest of 50 µg/L Cu and 50 µg/L Zn in water discharged from Wakaliga dumpsite. Uptake of trace metals from soil differed from plant to plant and site to site. Higher levels of trace metals accumulated in the root rather than in the rhizome and the least amount was in the leaf. The study identifies industry as a potential source of trace metal contamination of water and the environment pent-up need for policy intervention in industrial waste management .

Key words: *Environment, industry, public health, risk assessment, trace metals, waste management*

INTRODUCTION

Lake Victoria is a multi functional resource shared between Uganda, Kenya and Tanzania. The lake is currently undergoing severe degradation resulting from waste disposal in the surrounding wetlands in the region. Wetlands are a potential source of livelihood for the surrounding communities in the lake region providing a wealth of ecological, social and economic functions (Mafabi, *et al*., 1998; Namakambo, 2000 and Swallow, *et al*., 2001) to the countries in the region. Industries impacting on the wetlands of the Lake Victoria basin are concentrated in Kampala and Jinja (Muwanga and Barifaijo, 2006). Kampala is one of the developing cities of the world undergoing rapid urbanization. This has resulted into densely populated settlements in the lake region. High population increase and rapid industrialisation have contributed to the degradation of the wetlands and the quality of Lake Victoria through uncontrolled human activity, waste dumping from industry and settlements in and around the wetlands. It is estimated that a half of the world's population now lives in towns or cities and many are already facing severe problems of food and nutrition insecurity and over 54% of the African population will be living in urban areas by the year 2025 (UNCHS, 1998). In Kampala city, due to rapid urbanization and growing urban unemployment, people are utilising hazardous places unsuitable for development to grow crops. Such places include road verges, banks of drainage channels, wetlands and contaminated sites such as scrap yards and dumpsites for solid and liquid wastes. The poorest groups involved in urban agriculture are most likely to utilise high-risk sites whose toxic history is unknown (Maxwell, 1994; Sawio, 1998). Hardoy and Satterwaite, (1997) observed a direct

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correlation between the level of poverty and the degree of vulnerability to health hazards. Wetlands around the city are subject to waste disposal from industry, municipality, mining and domestic sources. This poses a health risk on urban communities growing and consuming food crops and vegetables grown in the wetlands. The hazards of wastewater and solid waste use in urban and peri-urban agriculture (UPA) have been categorized into three groups: biological agents, chemical and physical hazards (Cole, *et al*., 2003). Biological agents include bacteria, helianthus, viruses, protozoa and micro-fauna. While physical hazards include sharp objects, psychosocial discrimination, insecurity and land tenure. Chemical contamination is a potential risk associated with waste reuse, notably in municipal solid waste and wastewater, especially if it is of industrial origin. Chemical hazards include chemical agents such as heavy metals, nutrients such as nitrogenous compounds, phosphorus compounds, minerals, insecticides, pesticides, fertilizers, fungicides, herbicides and organic hazards. The contamination of soils by chemicals, the potential uptake by crops, and the possible chronic and long-term toxic effects in humans are discussed by Chang, *et al*., (1995) and Birley and Lock, (1999). Plant uptake of heavy metals depends significantly on the metal as well as soil conditions, such as acidity and organic matter content. Similar metal amounts in different soils can be harmful in one and harmless in another. Metals in municipal waste come from a variety of sources. Batteries, consumer electronics, ceramics, electric light bulbs, house dust and paint chips, used motor oils, plastics and some inks and glass can all introduce metal contaminants into the solid waste stream. Several studies have indicated that crops grown on heavy metal contaminated soils have higher concentrations of heavy metals than those grown on uncontaminated soil (Dowdy and Larson, 1975; Nabulo, 2006). Wastewater containing industrial effluents poses an additional problem of chemical pollutants such as heavy metals (Cornish, *et al*., 1999). Vegetables take up heavy metals from absorbing them by contaminated soils as well as deposits on parts of the vegetables exposed to air in polluted environment. It is observed that the priority public health risks associated with wastewater use in low income developing countries are infections with soil transmitted Helminths such as hookworm and roundworm (Shuval, *et al*., 1986). The study of trace metal contamination in wetlands around the Lake Victoria region is therefore of urgent need to control and monitor environmental degradation and functioning of the dying Lake. This study seeks to assess the impact of industry on trace metal contamination of the Lake Victoria basin.

MATERIALS AND METHODS

The study was carried out in wetlands around the Kampala city and Jinja districts; these are the most industrialized areas in the Lake Victoria region in Uganda. The Kampala city is situated between 32ºE and 33º E and between 0ºN and 1ºN (Atlas of Uganda, 1967). Kampala, as a city district, is divided into five administrative divisions of Nakawa, Makindye, Rubaga, Kawempe and Central covering approx. 189 km^2 of land (Fig. 1). The district has a resident population of 1,208,544 persons with a population density of 7378 persons per km^2. (UBOS, 2003). The study sites included Banda, Kinawataka, Busega, Namuwongo, Munyonyo, Bukasa, Murchison Bay, Butabika, Katanga, Kyebando, the industrial area in Bugolobi, Wakaliga and Bwaise. These sites were selected considering that they are subject to either industrial waste discharge, municipal, sewage, toxic waste disposal and wastewater irrigation activities taking place. Soil and water samples were collected from each one of the six plots measuring 25 m^2 randomly selected, using a 5 m x 5 m quadrant. The plots were located 20 m apart along a line transect cut across the wetland. Soil samples were collected from a depth of 20 cm at various locations in each quadrant to form a composite sample using a soil auger. The soils were placed in polythene bags, stored in cooled boxes and transported to the research laboratory in the Department of Botany at Makerere University. Water samples were taken from the same locations as soil. Six replicate water samples were collected in sample bottles from pits dug along with soil auger 30 cm deep from each of the six quadrants. The samples were transported to the research laboratory and filtered through a 0.2 µm filter. The water samples were acidified to a $pH<2$ using concentrated HNO_3. Effluents from various industries were also sampled at the point source before their discharge into the wetlands. Plants of different species growing at each quadrant were all collected from various locations within each quadrant. Where several plants of the same species existed in one quadrant, three plants were randomly selected and combined to form a composite sample for each plot. The plant

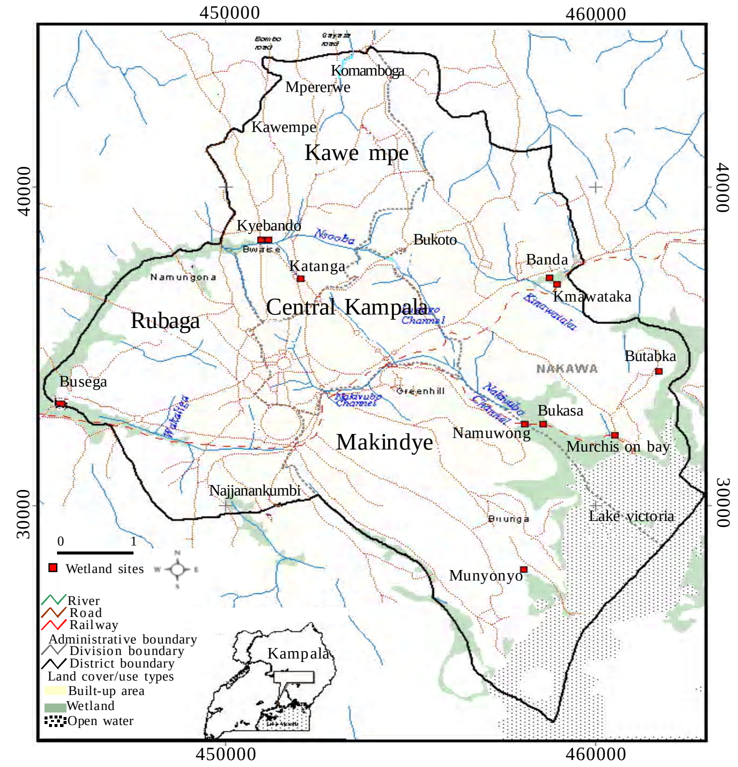

Fig. 1: Distribution of wetlands and selected solid waste dumping sites in Kampala city

samples were packed in polythene bags and transported in cool boxes to the research laboratory. Soil samples were air-dried and any clods and crumbs were removed. The dried soil was passed through a 2 mm sieve to remove coarse particles; the soil was then sub-sampled and ground to a fine powder in a mortar in preparation for chemical analysis. A sample of 1.250 g of air-dried ground soil was digested in *aqua regia*: a mixture of 25% of HNO_3 and 75% of HCl (Fisher Scientific, UK). The resulting solution was analyzed for total Cu, Pb, Ni and Zn using flame atomic absorption spectrophotometer (Perkin Elmer, model 2380). Soil pH was determined in a soil/ water suspension of 10 g in 25 mL of deionised water using a pH-meter (Aqualytica, Model pH 17). Soil organic matter content was measured by titration using Walkley-Black potassium dichromate wet oxidation (Nelson and Sommer, 1982). The soil organic matter content was expressed as percent carbon (w/w). All physico-chemical parameters of the wetlands including pH, electrical conductivity and temperature were measured in-situ using portable wissenschaftlich-technishe werkstatten (WTW) microprocessor probes and meters. The total nitrogen content was determined using persulphate method to determine the total nitrogen by converting organic and inorganic nitrogen to nitrate through alkaline oxidation of all nitrogenous compounds at 100-110 ºC. The total nitrogen was determined by analyzing the nitrate in the digested sample and nitrate was measured by cadmium reduction method. NH_4-N was analyzed following direct Nesslerization method (APHA, 1992). Total reactive phosphate (TRP) was analyzed following the ascorbic acid method (APHA, 1992). All colorimetric determinations were made using A HACH DR-4000 spectrophotometer. Individual plants were divided into root, leaves, fruit, tuber and peel. Each leaf sample was further divided into two parts: One portion was washed under tap water to remove dust particles and then in distilled water and finally rinsed carefully in deionised water. Excessive water was removed from the washed samples using Kim wipes. The other portion was not washed. The samples were weighed to determine the fresh weight and then dried in an oven at 80 ºC for 72 h. to determine their dry weight. The dry samples were ground in a grinding mill and about 1.250 g of the resulting powder added to a 250 mL conical flask and digested in concentrated HNO_3 (Fisher Scientific, UK). The plant digests were filtered and made up to the mark in a 25 mL volumetric flask using deionised water. The resultant supernatant was analysed for total Zn, Cu, Pb and Ni using flame atomic absorption spectrophotometer (Perkin-Elmer model, 2380). For quality control, each site constituted six replicate samples of each soil, plant and water taken from six quadrants to ensure maximum representation of the site. Laboratory blanks were analysed for the same elements to control for heavy metal contamination during the digestion process. Reagent blanks were prepared in the same manner as the samples and the blanks were used to correct instrument readings. The extraction and analytical efficiency of the AAS was validated using a standard reference material like tomato leaf (SRM 1573a, National Institute of Standards and Technology, NIST). The percentage recoveries from the analysis of the standard reference material by the procedures used in this study were 92% Zn, 97% Cu, 92% Ni and 90% Pb.

RESULTS AND DISCUSSION

The total heavy metal contents in the Kampala wetland soils ranged from 30.7±3.2 to 387.5±86.5 mg/kg Zn; 10.33±0.99 to 51.20±8.69 mg/kg Cu and 5.50±1.30 to 21.87±3.36 mg/kg Ni. Katanga was the most contaminated by Zn and Cu followed by Bukasa and Namuwongo. The Butabika and Busega wetlands were the least contaminated by heavy metals (Table 1). Significant differences were observed in heavy metal concentrations in all the sites ($P< 0.05$, DF = 10, ANOVA). Additionally, there were significant correlations among all the metals ($P < 0.05$, DF = 33, *t*-test). This implies that the heavy metals shared the same source of contamination. In Jinja, trace metal concentrations in soil at the Masese wetland situated on the shores of Lake Victoria showed high trace metal concentrations of Cu up to 5936±56.2 mg/kg, 2414±51.7 mg/kg Zn, 70.9±8.3 mg/kg Pb and 62.5±7.7 mg/kg Ni. The elevated trace metal levels originate from a former Cu smelter in Jinja that discharged its effluents directly down the hill into Lake Victoria through the Masese wetland. This study found that industry was the major source of heavy metal contamination of the wetlands in Uganda. Analysis of variance reveals significant differences in heavy metal contents in soils across the Kampala city. The mean differences in Zn, Ni and Cu in the wetland soils were significant ($P < 0.05$, DF = 10, ANOVA). Significant differences were observed in the soil characteristics of the wetlands with the pH of the soils ranging from 4.9±0.1 to 7.7±0.2% at Munyonyo and Namuwongo, respectively. While organic matter content ranged from 3.0±2.3% to 45.8±2.0% at Namuwongo and Busega, respectively. The heavy metal concentrations in the wetland waters ranged from 20-900 µg/L for Zn, 5-80 µg/L for Cu and 20-100 µg/L for Ni with the lowest concentrations observed at Munyonyo (Table 2). Lower concentrations of Cu and Ni below 5 µg/L and 50 µg/L were not respectively detected by the flame atomic absorption spectrophotometer used in this analysis. The wetlands were mainly contaminated by Zn and Cu and in some cases Ni was not detected by the AAS equipment in most of the habitats. The highest level of Zn was observed in wetland water sampled from Kyebando and the lowest

Table 1: Mean heavy metal contents and SE for soils from selected wetlands and international limits of heavy metals in agricultural soil

Site	Pb (mg/kg)	Ni (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
Katanga	171.5±36.2	21.87±3.36	1.20 ± 6.69	387.5 ± 86.5
Bukasa	105.5±2.7	22.33±2.23	51.13 ± 1.72	318.4 ± 5.9
Namuwongo	98.2±4.3	19.07±1.38	42.13 ± 0.64	260.3 ± 0.6
Bwaise	67.3±2.1	19.63±1.47	34.50 ± 1.22	237.7 ± 7.2
Murchison Bay	54.1±9.1	15.23±1.64	28.70 ± 4.90	230.1 ± 40.3
Kinawataka	49.2±4.6	25.93±2.67	42.47 ± 2.28	225.6 ± 18.7
Kyebando	30.1±7.0	6.83±2.58	12.03 ± 2.86	67.9 ± 26.4
Munyonyo	27.2±3.4	12.17±2.09	19.77 ± 3.80	53.3 ± 11.5
Banda	27.2±2.0	12.87±0.35	14.00 ± 2.35	58.8 ± 6.2
Busega	18.0±1.6	5.50±1.30	10.33 ± 0.99	40.4 ± 2.8
Butabika	15.3±1.7	6.97±1.49	12.77 ± 1.35	30.7 ± 3.2
Ewers (1991)*	100	100	-	100
ICRCL (1997)**	50	20	10	25
Ewers (1991)***	50	50	50	200

* Recommended guideline value for maximum limit of heavy metal levels in irrigation soil

** Mean of heavy metal limits in soil used for agriculture and recreation recommended by Interdepartmental Committee for Redevelopment of Contaminated Land (ICRCL)

*** Guideline values for tolerable total metal concentrations in agricultural soil recommended by the Swiss Ordinance

Table 2: Mean Cu, Ni and Zn concentrations in wetland water samples

Site	Pb (µg/L)	Cu (µg/L)	Ni (µg/L)	Zn (µg/L)
Katanga	250	80	ND	560
Kyebando	150	5	50	900
Banda	50	10	50	250
Busega	50	5	100	280
Bwaise	50	25	100	220
Murchison Bay	50	ND	ND	50
Namuwongo	50	20	ND	160
Bukasa	50	ND	ND	20
Butabika	10	20	ND	110
Munyonyo	ND	5	ND	20
Kinawataka	ND	40	ND	160
USEPA (2001)*	65	17	1400	2000

* Recommended maximum levels of heavy metals in irrigation water

ND: Heavy metal concentrations below detection limit

Table 3: Cd, Pb, Zn and Cu concentrations in effluent released from various industries and dumping sites into the wetlands

Source	Cd (µg/L)	Pb (µg/L)	Zn (µg/L)	Cu (µg/L)
Kilembe copper smelter (Jinja)	20	100	1480	357000
Uganda Batteries Ltd.	10	5600	390	800
Pea Cock Paints Ltd.	10	200	170	140
Kiteezi current dumping site	50	800	820	150
Wakaliga former dumping site	10	100	50	50
EC Council Directive, 1980*	1	50	-	-
US PHS, 1997; ATSDR, 1997**	10	15	-	-
WHO, 1993***	5	10	-	-

* Maximum permissible concentration in water intended for human consumption

** Maximum permissible concentration for drinking water

*** Recommended limit in drinking water

from Munyonyo where no visible waste disposal was observed. Analytical results of the water samples from the selected industries and dumpsites showed high concentrations of heavy metals especially in the industrial effluents (Table 3). The results show high Cu concentration in the run-off from a former copper smelting industry. These concentrations are above the internationally acceptable limits for heavy metals in usable water. The results show that the wastewaters released by some of the Ugandan industries into agricultural land have heavy metal concentrations above those recommended for use and this poses a health risk to consumers. The study showed that Murchison Bay had the highest pH while the lowest pH value was observed at Kinawataka (Table 4). This was attributed to the discharge of industrial and chemical waste at the Kinawataka wetland, whereas Murchison Bay received waste mainly from untreated sewage from Luzira Prisons. Electrical conductivity ranged from 145±1.4 S/m to 878.0±1.2 S/m at Butabika and Bwaise, respectively. The total reactive phosphate ranged from 0.48±0.25 mg/L to 11.33±8.89 mg/L at Kyebando and Murchison Bay, respectively. Conversely, the TRP/TN ratio ranged from 0.65 to 18.02 at Munyonyo and Kyebando, respectively. Kyebando was characterised by low phosphate but ranked as the highest in total nitrogen, followed by Busega, Bukasa, Munyonyo and Kinawataka, respectively. Kyebando is a seasonal wetland whose wetland properties have changed over time by human activity and waste dumping. The mean electrical conductivity (EC) of the water in the wetlands was significantly different at 0.05 significance level with the highest EC recorded at Katanga. The Katanga wetland also had the highest trace metal concentrations in soil. However, Bukasa and Namuwongo did not show a significant difference in EC because the two sites receive wastewater from the same channel. Conversely, there was no significant difference in EC between the wastewater sampled from the channel and that from the wetlands ($P>0.05$, DF = 10, *t*-test) indicating a possibility of cross contamination of the wetlands with wastewater from the channels. The heavy metal contents in the leaves of the wetland plants varied from one species to another with Cu levels ranging from 6.5 to 18.9 mg/kg in Ferns and *Commelina*. Besides, Ni concentrations ranged from 5.1 to 23.6 mg/kg in *Cyperus papyrus* and *Eichhornia crassipes* (water hyacinth), respectively. The highest Zn concentrations accumulated in water hyacinth (Table 5). There were significant differences in Ni and

Table 4: The physico-chemical characteristics of the wetland waters

Site	pH	EC (S/m)	Temp.(ºC)	TRP (mg/L)	TN (mg/L)	TN/TRP
Banda	6.91±0.03	380.7±2.1	22.4±0.3	2.19 ± 0.47	7.53±0.17	3.44
Kinawataka	5.85±0.04	187.3±1.2	28.3±0.1	0.76 ± 0.58	8.25±0.16	10.86
Butabika	6.63±0.02	145.6±1.4	30.4±0.2	2.03 ± 1.17	6.87±0.07	3.38
Murchison Bay	8.86±0.34	585.0±2.6	28.2±0.1	11.33 ± 8.98	7.34±0.02	0.65
Bukasa	7.17±0.02	561.7±0.9	30.5±0.2	0.61 ± 0.19	7.56±0.05	12.39
Namuwongo	7.15±0.02	566.7±0.9	30.7±0.1	2.21 ± 2.05	7.28±0. 39	3.29
Munyonyo	7.34±0.03	258.7±1.5	28.7±0.1	0.66 ± 0.38	7.28±0.13	11.03
Katanga	6.97±0.04	354.0±2.1	25.4±0.2	2.95 ± 0.34	6.35±0.00	2.15
Kyebando	6.93±0.03	665.3±2.9	24.8±0.2	0.48 ± 0.25	8.67±0.06	18.02
Bwaise	6.78±0.04	878.0±1.2	24.8±0.1	1.07 ± 0.47	7.96±0.15	7.44
Busega	6.67±0.01	405.7±0.9	27.7±0.0	0.51 ± 0.17	6.87±0.00	13.47

Table 5: Average heavy metal contents and SE in leaves and roots of wetland plants (mg/kg)

Plant species	Cu in leaf (mg/kg DW)	Cu in root (mg/kg DW)	Ni in leaf (mg/kg DW)	Ni in root (mg/kg DW)	Zn in leaf (mg/kg DW)	Zn in root (mg/kg DW)
C. papyrus	13.5±4.7	13.9±1.9	5.1±0.9	14.8±3.7	53.5 ± 11.7	90.2±11.2
Fern	6.5±0.8	8.1±1.8	6.5±0.9	10.5±4.7	32.1 ± 3.6	65.0±5.7
C. benghalensis	18.9±3.6	27.2±2.3	16.3±5.2	195.3±61.4	114.9 ± 23.7	204.7±66.2
E. crassipes	12.2±2.3	22.3±5.1	23.6±9.3	25.1±11.8	126.0 ± 58.9	239.1±46.4
P. clandestum	9.7±1.2	23.1±5.7	6.1±1.1	17.5±8.1	41.9 ± 3.5	266.3±109.3
C. esculenta	11.3±1.8	7.7±0.0	9.9±0.0	6.4±0.0	31.2 ± 0.0	47.1±0.0

Zn levels in the leaves of different plant species ($P<0.05$, DF = 5, ANOVA). *Commelina benghalensis* accumulated the highest concentrations of Cu in both the shoots and roots. The study found that Commelina and water hyacinth were capable of bioaccumulating heavy metals in their tissues. Considering trace metal accumulation in different sites, it was observed that *Cyperus papyrus* accumulated the highest trace metal concentrations from Murchison Bay followed by Banda, Kinawataka, Munyonyo and Busega sites, respectively (Fig. 2). The highest levels of trace metal accumulation at all the sites were observed in roots and followed the order "root > rhizome > leaves", respectively. Hence, the below ground parts of *C. papyrus* effectively accumulated trace metal pollutants from soil, with the lowest concentrations transported to the leaves. Significant differences were observed in Cu and Zn contents in leaf, rhizome and root of *C. papyrus* from Banda ($p<0.05$, DF = 5, ANOVA). Multiple comparisons show significant differences in Cu levels between the leaf and root and between rhizome and root while a significant difference in Zn partitioning was observed between leaf and root of *C. papyrus* ($p<0.05$, LSD). Similarly, significant differences were observed in Zn accumulation in leaf, rhizome and root of fern from Banda and Munyonyo sites ($p<0.05$, DF = 5, ANOVA). Multiple comparisons show significant differences in Zn levels between the leaf and root and between rhizome and root ($p<0.05$, LSD) at both sites. Water hyacinth from Bukasa and Munyonyo showed significant differences in all the elements Cu, Ni and Zn between leaf, rhizome and root ($p<0.05$, DF = 5, ANOVA). Multiple comparisons found significant differences in Cu, Ni and Zn between the leaf and root ($p<0.05$, LSD). Wetland plants therefore tend to accumulate heavy metals in roots with lower concentrations in the leaves. Generally, heavy metal accumulation followed the trend: leaf < rhizome < root. Comparison of the total trace metal levels in various plants from the same site revealed different uptakes by different plants. Concentrations of trace metals in a common wetland root crop *colocasia esculenta* (cocoyam) differed in different plant parts with the highest concentrations in the root (Fig. 3). This study found that Cu, Ni and Zn were accumulated in cocoyam following the order: root > leaf > peel > tuber. This order followed the general trend observed for trace metal accumulation in wetland plants: root > rhizome > leaf (when the peel and tuber are not separated). This study also found that heavy metal concentrations in cocoyam differed from site to site with the highest levels of Cu from Namuwongo, Zn from industrial area in Bugolobi and Ni from Lugogo waste dump. Significant differences were also found in Zn content in pumpkin leaves with concentrations in a descending range: Namuwongo>Bugolobi sewage works > Wakaliga (Fig.4). Pumpkin leaves from Wakaliga site were found to accumulate the lowest levels of Zn, Cu

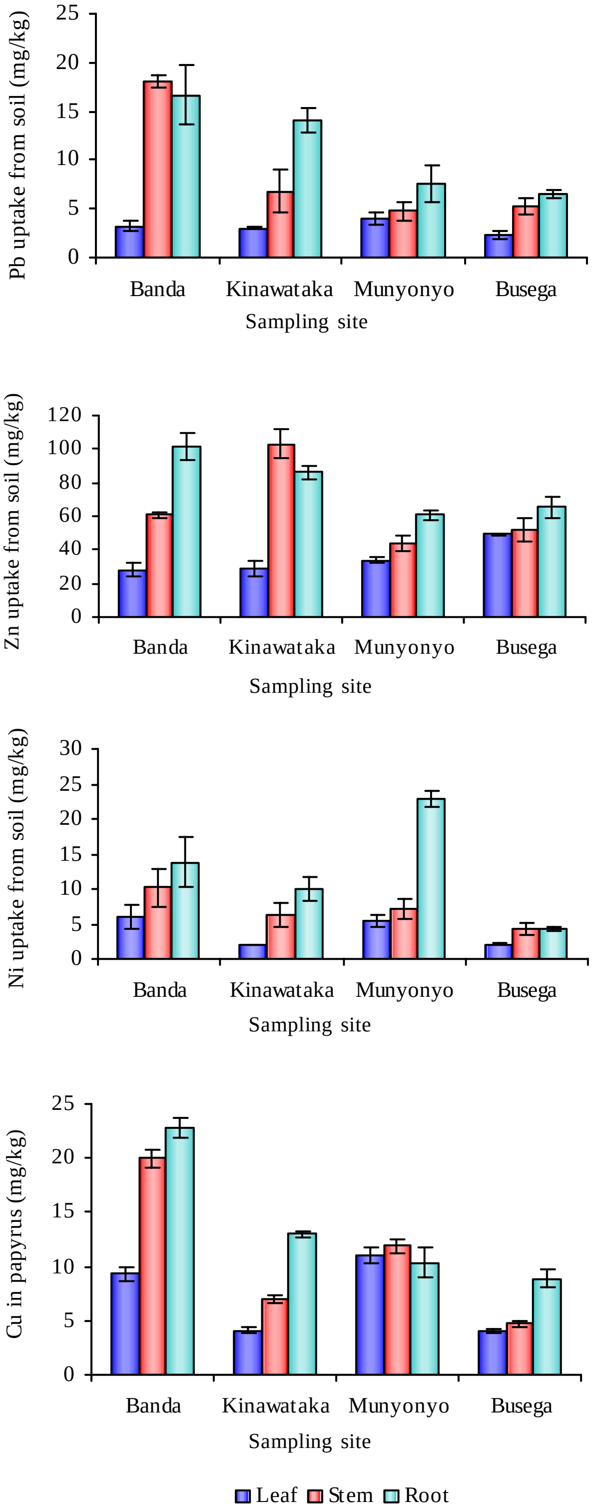

Fig. 2: Zn, Cu, Pb and Ni accumulation and partitioning in *Cyperus papyrus* leaves

and Ni. Namuwongo site is contaminated by effluent discharge from industrial area in Bugolobi, while Wakaliga is a former solid waste dumping ground for Kampala City Council. This suggests that uptake of heavy metals is higher when plants are grown in soil contaminated by industrial effluents than those grown on municipal solid waste dumps. This illustrates the need for industries to manage toxic waste and effluents at point source to reduce trace metal levels to the acceptable limits before being discharged into the main stream water channels, wetlands and water bodies.

Disposal of industrial waste in the wetlands is a potential source of elevated trace metal concentrations in the environment making urban wetlands a potential source of food chain transfer of trace metals in the urban ecosystems. Elevated trace metal concentrations in the wetlands within the Lake Victoria basin pose a potential threat to the quality of water in the lake. In this study, the Katanga soil was found to be the most contaminated by Zn and Cu followed by Bukasa and Namuwongo. The Katanga wetland receives wastewater from Mulago Hospital, Makerere University, Bwaise and Kawempe industries. Similarly, the Namuwongo and Bukasa wetlands are sinks for effluents and chemical wastes from the industrial area. Butabika and Busega wetlands were least contaminated by trace metals because of their remoteness from areas of industrial activities. Previous studies show high Pb values in the sediments associated with battery and metal fabricating industry and high Cu, Pb and Ni in the sediments from former Cu smelter (Muwanga and Barifaijo, 2006). It was observed that the wetland soils of Katanga, Bukasa, Namuwongo, Bwaise and Murchison Bay were not suitable for agriculture because their trace metal levels were above the recommended limits in agricultural soils (Ewers, 1991; ICRCL, 1997). Analysis of wetland waters showed that they contain higher concentrations of Cu than the recommended levels in water used for irrigation (ICRCL, 1997). The highest Cu concentration of 357,000 µg/L was found in effluents from Jinja former copper smelter with further Zn and Pb concentrations of 1480 µg/L and 100 µg/L, respectively. Cu is easily mobilised and transported in solution to downstream locations including the Lake (Lwanga, *et al*., 2003). In the lake, metals are likely to enter into the food chain and enter the fish tissues (Denny, *et al*., 1995). In Kampala, Pb concentration in the effluents from a battery manufacturing industry was 5600 µg/L with

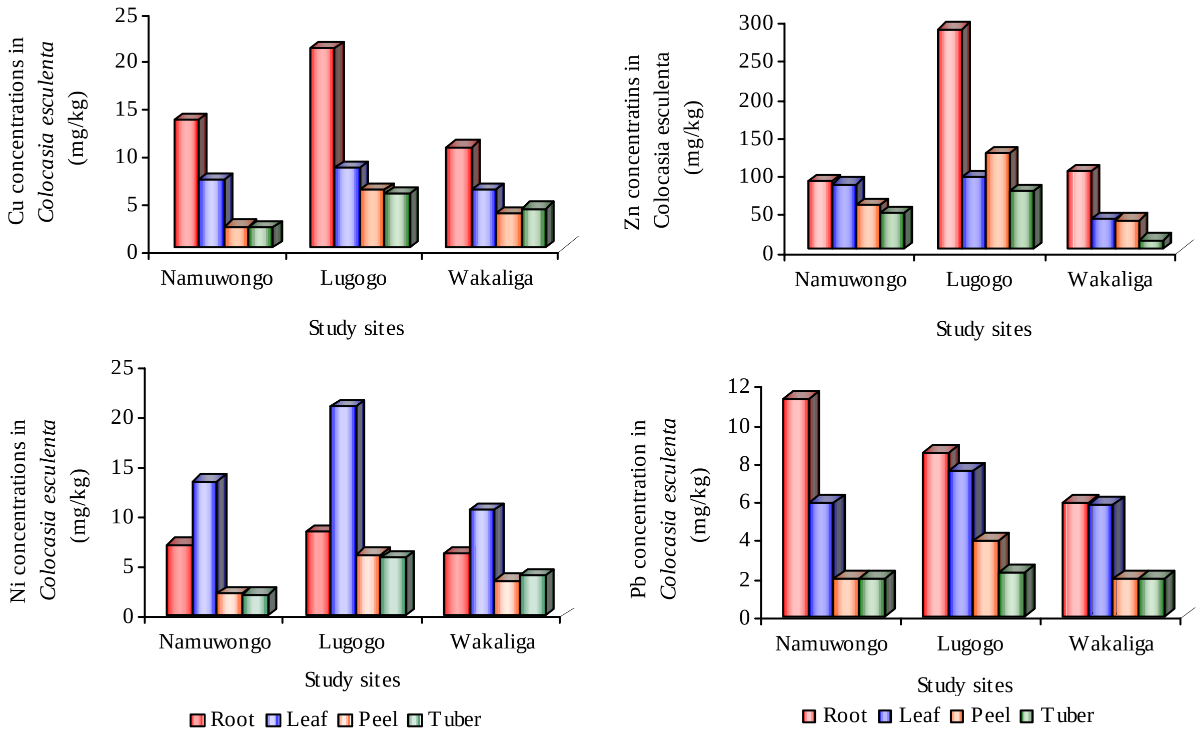

Fig. 3: Zn, Cu, Pb and Ni accumulation in *Colocassia esculenta* (cocoyam)

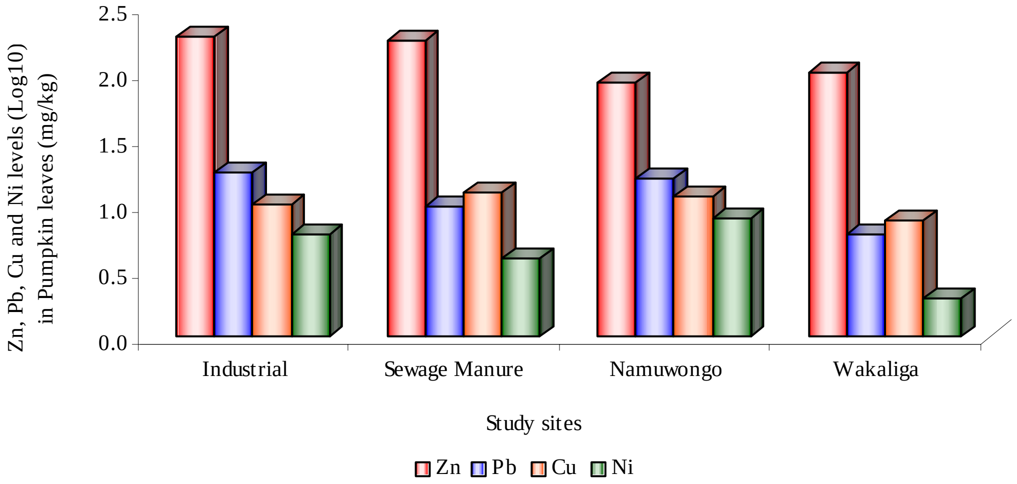

Fig. 4: Zn, Cu, Pb and Ni accumulation in *Cucurbita maxima* (pumpkin) leaves

corresponding Zn and Cu concentrations of 390 µg/L and 800 µg/L, respectively. These concentrations far exceed those reported by Muwanga and Barifaijo, (2006) for the same industry. Different industries will discharge different chemicals into the environment. Therefore, soil properties and plant uptake of trace metals will differ from site to site. This study showed that the root tissue in wetland plants accumulated the highest concentrations of trace metals. Significant differences existed in heavy metal accumulation in the leaf and root of wetland plants. Significant differences were observed between Cu and Zn in *C. papyrus* and fern, Cu, Ni and Zn in *P. clandestum* and Cu between the leaf and root of water hyacinth. The tendency for Zn to remain concentrated in the root tissues was previously demonstrated by Blake, *et al*., (1987). Significant differences were observed in Ni between the rhizome and the root of water hyacinth, Cu and Zn between the rhizome and root of fern and Zn and Cu between the stem and leaf of *P. clandestum*. Ellis, *et al*., (1994) reported that *Typha latifolia* under controlled laboratory and *in-situ* field conditions exhibited the highest metal concentrations in the root tissue with Cd and Zn demonstrating exponential increases. Other studies on *Typha latifolia* showed a progressive decrease in Cu and Zn concentrations from sediment to root and from root to leaf (Taylor and Crowder, 1983). Dunbabin and Bowmer, (1992) reported that under contaminated conditions, the greater proportion of heavy metals taken up by plants was retained in the roots with metal concentrations decreasing in the following order: roots > rhizomes > non-green leaves > green leaves. Water hyacinth has been reported to have heavy metal cleansing potential due to its rapid growth in wastewater and the capacity to absorb heavy metals. Blake, *et al*., (1987) demonstrated the tendency for Water hyacinth roots to exhibit a high affinity for Cd. Considering different vegetable types grown in the wetlands, trace metal concentrations differed in different plant types and parts. Vegetables are reported to take up heavy metals from contaminated soil as well as from aerial deposits on the above-ground parts of the vegetables that are exposed to polluted air. In a related study in Lagos Nigeria, Yusuf, *et al*., (2003) observed a higher degree of contamination in soils of industrial areas compared to the residential areas. Concentrations of Ni in vegetables from industrial areas were higher than those from the residential area with the highest concentrations in *Corchorus* than in other vegetable types. In this study, vegetables were found to accumulate higher levels of trace metals in the leaves than in the fruits. Pumpkin leaves accumulated the highest levels of trace elements from Namuwongo wastewater irrigated site which receives effluents from industry. Significant differences were observed in Cu and Ni concentrations from Namuwongo, Bugolobi Sewerage works and Wakaliga former dumpsite. Leafy vegetables grown in contaminated wetlands could therefore pose health risks to consumers. There is a general view that the wetlands in the Lake Victoria region are at risk of chemical contamination resulting from waste disposal from industrial, municipal, domestic, agricultural and mining activities. Kampala wetlands have been the main recipients of elevated levels of toxic chemicals such as Zn, Cu, Pb and Ni due to the rather poor waste management and careless disposal practices. This has led to an expression of concern about the safety of water and food crops grown in wetlands around the city. This calls for the need for environmental monitoring strategies to identify potentially toxic and elevated trace metal concentrations in the environment and to implement appropriate mitigation measures to minimize possible food contamination and transfer into the Lake Victoria basin.

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