Int. J. Environ. Sci. Tech., 7 (3), 435-446, Summer 2010
ISSN: 1735-1472

Assessment of heavy metal pollution in the urban stream sediments and its tributaries

[1]*K. Sekabira; [2]H. Oryem Origa; [3]T. A. Basamba; [2]G. Mutumba; [2]E. Kakudidi

[1]Department of Environment, Faculty of Science and Engineering, Kampala International University, P. O. Box 20000, Kampala, Uganda

[2]Department of Botany, Faculty of Science, Makerere University, P. O. Box 7062, Kampala, Uganda

[3]Department of Soil Science, Faculty of Agriculture, Makerere University, P. O. Box 7062, Kampala, Uganda

Received 8 March 2010; revised 15 April 2010; accepted 22 May 2010; available online 1 June 2010

ABSTRACT: Globally, aquatic ecosystems are highly polluted with heavy metals arising from anthropogenic and terrigenous sources. The objective of this study was to investigate the pollution of stream sediments and possible sources of pollutants in Nakivubo Channel Kampala, Uganda. Stream sediments were collected and analysed for heavy metal concentration using flame atomic absorption spectrophotometer. The degree of pollution in Nakivubo channelized stream sediments for lead, cadmium, copper, zinc, manganese and iron was assessed using enrichment factor, geo-accumulation index and pollution load index. The results indicated that (1) the sediments have been polluted with lead, cadmium and zinc and have high anthropogenic influences; (2) the calculation of geo-accumulation index suggest that Nakivubo stream sediments have background concentration for copper, manganese and Fe ($I_{geo} \leq 0$); (3) factor analysis results reveal three sources of pollutants as explained by three factors (75.0 %); (i) mixed origin or retention phenomena of industrial and vehicular emissions; (ii) terrigenous and (iii) dual origin of zinc (vehicular and industrial). In conclusion, the co-precipitation (inclusion, occlusion and adsorption) of lead, cadmium and zinc with manganese and iron hydroxides, scavenging ability of other metals, very low dissolved oxygen and slightly acidic to slightly alkaline pH in stream water could account for the active accumulation of heavy metals in Nakivubo stream sediments. These phenomena may pose a risk of secondary water pollution under sediment disturbance and/or changes in the geo-chemistry of sediments.

Keywords: *Anthropogenic; Channelized; Factor analysis; Geo-accumulation; Vehicular*

INTRODUCTION

Heavy metal pollution of aquatic ecosystems is becoming a potential global problem. Third world countries such as Uganda, lack for mechanisms and sensitive tools to detect and monitor water quality and are therefore exposed to heavy metal poisoning (Ochieng *et al*., 2008). Trace amounts of heavy metals are always present in fresh waters from terrigenous sources such as weathering of rocks resulting into geo-chemical recycling of heavy metal elements in these ecosystems (Muwanga, 1997; Zvinowanda *et al.,* 2009). Trace elements may be immobilised within the stream sediments and thus could be involved in absorption, co-precipitation, and complex formation (Okafor and Opuene, 2007; Mohiuddin *et al.,* 2010). Sometimes they are co-adsorbed with other elements as oxides, hydroxides of Fe, Mn, or may occur in particulate form (Awofolu *et al*., 2005; Mwiganga and Kansiime, 2005). Heavy metals may enter into aquatic ecosystems from anthropogenic sources, such as industrial wastewater discharges, sewage wastewater, fossil fuel combustion and atmospheric deposition (Linnik and Zubenko, 2000; Campbell, 2001; Lwanga *et al*., 2003; El Diwani and El Rafie, 2008; Idrees, 2009). Trace elemental concentrations in stream sediment compartments can be used to reveal the history and intensity of local and regional pollution (Nyangababo *et al*., 2005a).

Sentongo (1998); Matagi (1998) and Kansiime *et al.,* (1995) observed significant pollution load by organic and inorganic substances into the Nakivubo ecosystem. Some work on heavy metal loading of Lake Victoria wetlands, Nakivubo Channel and heavy metal pollution in and around Kampala was recognised (Nyangababo,

*Corresponding Author Email: *ssekaba@gmail.com*
Tel.: +256 772 855 348; Fax: +256 414 501 974

2003; Nyangababo *et al.*, 2005b; Muwanga and Barifaijo, 2006 and Nabulo *et al.*, 2008). The objectives of the present work were to (1) assess the geochemistry of the Nakivubo stream sediments so as to establish the possibility of secondary pollution of the sediments; (2) establish the association among heavy metals and stream physico-chemical characteristics and (3) determine the source apportionment of heavy metals using cluster and factor analyses. This study was conducted during August, 2008 to November 2009, along the Nakivubo Channelized stream, Kampala Uganda.

MATERIALS AND METHODS

Study area and sampling site

This study was conducted along the Nakivubo Channelized stream in metropolitan Kampala (0°15'N and 32°30'E). Nakivubo channel drains through Kampala City centre and the upper and lower Nakivubo swamp before discharging into the Inner Murchison Bay of Lake Victoria. The study area is located 45 km north of the equator and 8 km north of Lake Victoria , with a total area of 190 km^2 (Fig. 1). The study area has a tropical climate that is attributed to high altitude, relief, proximity to Lake Victoria and long distance from the sea (Matagi, 1998). The Lake Victoria Basin has warm temperatures ranging between 23 °C to 32 °C and a bi-modal rainfall pattern averaging approximately 1260 mm annually. The soils in the area are characterised by granites and granitoid gneisses that overly most of the Lake Victoria Basin north of Kagera River. Part of the industrial area soils are composed of shales, phillites and schists with a mixture of alluvial and lacustrine sand, silt and clay that also characterise Nakivubo swamp soils. The alluvial soils in the upper layers are composed of semi-liquid organic material, reddish ferruginous loams and clays attributed to organic decomposition and runoff (Kansiime and Nalubega, 1999). In this study, the stream was subdivided into three sections (Table 1) namely; Upstream (US01 – MD05) characterised by commercial establishments, Midstream (MD05 – DS15) characterised by commercial and industrial establishment and Downstream (DS15 and beyond), characterised by the Nakivubo wetland.

Sediment sampling and chemical analysis

Sediment samples were collected between August, 2008 to November, 2009 along the Nakivubo Channelized stream and its tributaries (Fig. 1) and Watindo stream (the control) using a hand trowel. Watindo stream was

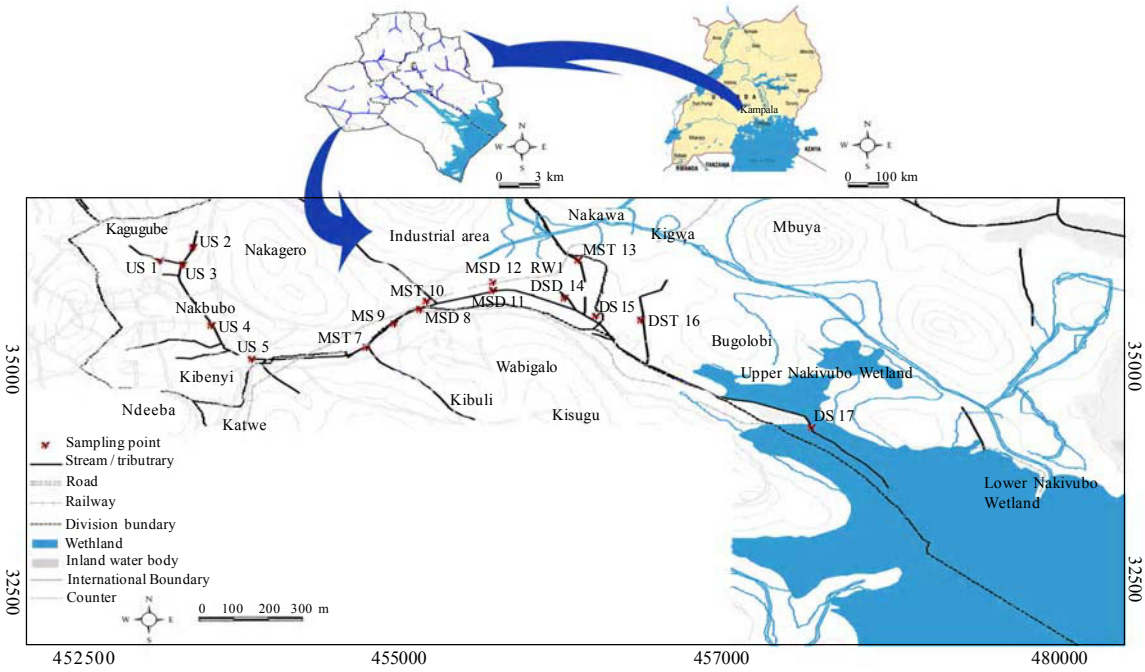

Fig. 1: Map of the sampling sites along the Nakivubo channelized stream, Kampala, Uganda

chosen to be outside the study area and therefore regarded as unpolluted. The samples were placed in Ziploc bags and transported to the laboratory.

The hand trowel was washed with a detergent, rinsed and dried before each use so as to minimize contamination. Sediment samples were dried in an oven at 105 °C overnight, sieved mechanically using a 0.5 mm sieve, homogenized and ground to 0.063 mm fine powder because metals are known to adhere to fine particles. After which, 1.25 g of each sample was digested with 20 mL aqua regia (HCl/HNO_3 3:1) in a beaker (open-beaker digestion) on a thermostatically controlled hot plate. The digest were heated to near dryness and cooled to ambient temperature. Then 5.0 mL of hydrogen peroxide was added in parts to complete the digestion and the resulting mixture heated again to near dryness in a fume cupboard. The beaker walls were washed with 10 mL of de-ionised water and 5 mL HCl were added, mixed and heated again. The resulting digest was allowed to cool and transferred into a 50 mL standard flask and made up to the mark with de-ionised water. Pb, Cd, Cu, Zn, Mn and Fe heavy metal elements were then analyzed by direct aspiration of the sample solution into a Perkin-Elmer model 2380 flame atomic absorption spectrophotometer (AAS). All metals were analysed using lean-blue air acetylene flame at wavelength 324.8 nm, slit width 0.2 nm, and sensitivity check of 5.0 mg/L Cu; wavelength 228.8 nm, slit width 0.7 and sensitivity check of 2.0 mg/L Cd; wavelength 213.9 nm, slit size 0.7 nm and sensitivity check 1.0 mg/L Zn; wavelength 217.0 nm, slit width 0.7 nm and sensitivity check 9.0 Pb and wavelength 279.5 nm, slit width 0.2 nm and sensitivity check 2.5 mg/L Mn. Sediment pH was measured in a suspension of 1:2 sediment to water ratio using a calibrated pH meter (WE-30200). Accuracy of the analytical method was evaluated by comparing the expected metal concentrations in certified reference materials with the measured values. Simultaneous performance of analytical blanks, standard reference (JG-3) (Imai *et al*., 1994) and calculation of the average recoveries of heavy metals confirmed that the accuracy of method was within acceptable limits (Table 2).

Assessment of sediment contamination

Enrichment factor (EF): As proposed by Simex and Helz (1981), EF was employed to assess the degree of contamination and to understand the distribution of the elements of anthropogenic origin from sites by individual elements in sediments. Fe was chosen as the normalizing element while determining EF-values, since in wetlands it is mainly supplied from sediments and is one of the widely used reference element (Loska *et al.,* 2003;

Table 1: Location, description of activities and sediment type

Site/Location	Code	Activity/Establishment	Sediments
Upstream			
Agakhan High School Bridge	US01	Car washing Bay, fish factory, gas/fuel station, residential, bus parking yard, seepage from walls	Sand
Bativa Hotel Bridge	US02	Car washing Bay, gas/fuel station, slum residential and commercial and seepage	Sand
Kiseka market Bridge	US03	Car washing Bay, garage, commercial and seepage	Sand
Nakivubo Stadium Bridge	US04	Recreational, commercial, market, vehicle traffic, bus park, gas/petro station, and seepage	Silty sand
Midstream			
Fire Brigade Bridge	MS05	Commercial , recreational, vehicle traffic, bus park, gas/petro station, cement stores , Katwe metal works and fabrications and seepage	Silty sand
6th Street Bridge Mukwano	MS09	Commercial, oil storage in vicinity, vehicle traffic, gas/petro station, seepage, Industries	Silty sand
Downstream			
5th Street Bridge	DS15	Industries, vehicle traffic, sewerage plant, seepage, garages, metal fabrication, petro station , residential	Sand
Luzira Culvert	DS17	Industries, cultivation, fishing, residential	Muddy sand
Tributaries			
Kayunga Stream	MT07	Solid waste dump sites, horticulture, recreational, slum and residential, vehicle traffic, gas/petro station	Sand
Kitante Stream	MT10	Horticulture, recreational, residential and commercial, vehicle traffic, gas/petro station	Sand
Lugogo Stream	MT13	Vehicle traffic, commercial, residential and industrial, electric station, horticulture, carpentry works, pole treatment and seepage	Sand
Kibira Road Stream	DT16	Battery , plastic and paper factory, industries and gas/petro station	Sand

Kothai *et al.,* 2009; Chakravarty and Patgiri, 2009; Seshan *et al.,* 2010). Other widely used reference metal elements include Al (Mn) (Nyangababo, 2005a; Kamaruzzaman *et al.,* 2008; Ong and Kamaruzzaman, 2009).

Enrichment factor = (C_n/Fe) sample/ (C_n/Fe) background, where, C_n is the concentration of element "n". The background value is that of average shale (Turekian and Wedepohl, 1961). An element qualifies as a reference one if it is of low occurrence variability and is present in the environment in trace amounts (Loska *et al.,* 2003). Elements which are naturally derived have an EF value of nearly unity, while elements of anthropogenic origin have EF values of several orders of magnitude. Six categories are recognised: ≤ 1 background concentration, 1- 2 depletion to minimal enrichment, 2 – 5 moderate enrichment, 5 – 20 significant enrichment, 20 – 40 very high enrichment and > 40 extremely high enrichment (Sutherland, 2000).

Pollution load index (PLI): Pollution load index for each site was evaluated as indicated by Tomilson *et al.* (1980).

Pollution load index= $(CF_1 * CF_2 * ..... * CF_n)^{1/n}$

Where, n is the number of metals (six in the present study) and CF is the contamination factor. The contamination can be calculated from;

Contamination factor (CF) = metal concentration in sediments/Background values of the metal. The PLI value > 1 is polluted whereas PLI value < 1 indicates no pollution (Chakravarty and Patgiri, 2009; Seshan *et al.,* 2010). (I_{geo}): Geo-accumulation index was used to assess heavy metal accumulation in sediments as introduced by Muller (1969) to measure the degree of metal pollution in aquatic sediments studies (Praveena *et al.,* 2007; Praveena *et al.,* 2008; Chakravarty and Patgiri, 2009).

$$I_{geo} = \text{Log}_2 (C_n/1.5B_n)$$

Where, C_n is the measured concentration of a heavy metal in stream sediments, B_n is the geochemical background value in average shale of element n and 1.5 is the background matrix correction due to Terrigenous effects. The geo-accumulation index classification consists of seven classes (0-6), ranging from background concentration to very heavily polluted: < 0 (class 0) background concentration, 0-1 (class 1) unpolluted, 1-2 (class 2) moderately polluted, 2-3 (class 3) moderate to high pollution, 3-4 (Class 4) heavily polluted, 4-5 (Class 5) highly to very highly polluted, 5-6 (Class 6) very heavily polluted (Kumar and Edward, 2009).

Analysis of variance (ANOVA): ANOVA was employed to determine whether groups of variables have the same means on data that are continuous or normally distributed and with homogeneous variance. Additionally, it was employed to assess the relationship between heavy metal concentrations and their elemental interaction between sections of the stream. Correlation analysis: Pearson correlation's correlation analysis was adopted to analyse and establish inter-metal relationship and physico-chemical characteristics of the stream water. Cluster analysis (CA) and factor analysis (FA): CA was performed to classify elements of different sources on the basis of their similarities using dendrograms and to identify relatively homogeneous groups of variables with similar properties. FA was employed on the variables that are correlated to isolate or determine specific factors that are associated with such groupings of metal concentration so as to establish their origin. The data was standardised to give a normal distribution with a mean of 0 and a variance of 1. Sample means were standardised by subtracting the mean of their distribution and dividing by standard error (SE) or square root of the variance.

RESULTS AND DISCUSSION

Heavy metal distribution in the sediments

Average contents of heavy metals and physico-chemical parameters of individual elements along the Nakivubo drainage system are given in Table 3. The mean pH ranged between 5.71 ± 0.88 and 7.25 ± 0.45, which was neutral or slightly acidic but at Watindo stream, the mean pH of the sediments ranged from highly acidic (4.53 ± 0.76) to acidic (5.40 ± 0.94), Table 3. Mean heavy metal contents in the Nakivubo Channelized stream sediments ranged from 64.05 ± 6.16 to 147.40 ± 17.98 mg/kg Pb; 0.88 ± 0.14 to 1.62 ± 0.24 mg/kg Cd; 63.75 ± 10.02 to 27.15±2.68 mg/kg Cu; 177.89 ± 16.37 to 442.40 ± 57.62 mg/kg Zn; 363.47 ± 18.34 mg/

Table 2: Quality control (mean ± SD) (mg/kg trace and % for elements)

Heavy metals	Pb	Cd	Cu	Zn	Mn (%)	Fe (%)
Reference material	11.7	0.054	6.81	46.5	0.055	2.58
Measured values	10±0.981	0.05±0.002	6.75±0.131	48.25±1.041	0.048±0.003	2.35±0.139
Percentage Recovery	85.5	92.6	99.1	103.8	87.3	91.1

kg Mn and 30085.33±7216.63 to 5835.00 ± 17154.67 mg/kg Fe. Pb, Cd and Zn concentrations were highest at Luzira Culvert, Cu was highest at Fire Brigade Bridge, Mn was highest at Kiseka market and Fe at Mukwano round about bridge. Generally, there is marked increase in mean heavy metal concentration upstream as well as downstream. The total mean concentration ranged from 79 ± 18.49 to 298.41 ± 138.18 mg/kg Pb; 0.84±0.78 to 1.04 ± 0.79 mg/kg Cd; 28.84 ± 14.4 to 38.01 ± 9.56 mg/kg Cu and 124.99 ± 30.97 mg/kg Zn. The mean concentrations of Cd and Cu in sediments were highest along Kitante stream and lowest along Kibira stream. However, the concentration of Zn and Pb were highest along Kibira Road stream and lowest along Kitante stream (Table 2). Elemental concentration of Fe was highest in stream sediments followed by Zn, Pb, Cu and Cd i.e. Fe > Mn > Zn > Pb > Cu > Cd. The sediments from industrial discharge sites have the highest concentrations of Cd, Cu and Zn (Table 4). Mean Pb concentration was highest in the sludge at National Water and Sewerage Corporation (NWSC) followed Sadoline factory and City Abattoir wastewater discharge. The mean content in the industrial discharge sediments ranged from 92.03 ± 6.45 to 178.16 ± 13.43 mg/kg Pb; 2.03 ± 0.20 to 4.81 ± 1.19 mg/kg Cd; 25.46 ± 3.89 to 226.20 ± 24.31 mg/kg Cu; 341.28 ± 60.74 to 1968.43±252.55 mg/kg Zn; 371.47±137.42 to 588.80±194.37 mg/kg Mn and 23552.00± to 98928.00±64928.00. The concentrations of all heavy metal elements were highest in the sludge from NWSC plant in the order Fe > Zn > Mn > Pb > Cu > Cd. Mean cadmium concentrations were the least occurring heavy metal in all the sites sampled and the results are consistent with those of Seshan *et al.*, (2010).

Heavy metals pollution

The results showed that heavy metal pollution can be assessed with respect to world surface rock averages (Chakravarty and Patgiri, 2009) or the widely used average shale (Shyamalendu *et al.*, 2001; Karageorgis and Hatzianestis, 2003; Harikumar *et al.*, 2009; Ong and Kamaruzzaman, 2009) with reference to the degree of contamination. The source of pollution is therefore determined through the normalization of geo-accumulation values to the reference element. The degree of pollution in sediments can be assessed by determining the enrichment factor and indices such as the Pollution load index and Geo-accumulation index. Variations of EF, *Igeo* and PLI along the stream are shown in Figs. 2 a-c.

Enrichment factor; enrichment factor values are shown in Fig. 2a. Lead showed a fairly high (> 3) to a very high value (> 5). Generally, enrichment factor for Pb, Cd and Zn increase downstream, indicating increasing contamination (Fig. 2a). Nakivubo channel tributary sediments are moderately enriched with Pb, Cd and Zn (EF > 2), except the EF of Pb in Lugogo stream and Kibira Road stream sediments which showed significant enrichment (> 5) (Muwanga and Balfaijo, 2006). Most industrial discharge outfall sediments are significantly enriched by Pb, Cd and Zn (> 5) and moderately enriched by Pb and Zn (> 2) at Peacock paint factory, Cd at Sadorin paint factory and Zn at Mukwano industries. Sludge at Nation Water and Sewerage Corporation was very highly enriched with Cd and Zn (> 20). The heavy metal EF in sludge follows the order Zn > Cd > Pb > Cu > Mn. EF values for Pb and Mn in Watindo stream sediments were about normal but Cu and Zn show background concentration. The EF value of Cd was fairly high (> 2).

Some researchers use numerical sediment quality guidelines as predictors of contaminants in aquatic sediments (Muwanga, 1997). Comparison of the mean concentration of heavy metals in the core sediments (Table 1) and sediment quality guidelines (SQGs) of USEPA (Pedersen *et al.*, 1998) indicate that all sites studied were heavily polluted with Pb (> 60) and Zn (> 200) and moderately polluted with Cu (25 – 500), except the Watindo stream sediments that were unpolluted with Cu and Zn. Pollution load index; The PLI values calculated for each site were shown in Fig. 2c. All the studied sites therefore, were found to be polluted (PLI > 1), suggesting inputs from anthropogenic sources. Pollution load indices were found to increase in sediments down stream along Nakivubo Channelized stream (Fig. 2c). This is attributed to vehicular emission, and industrial emissions and inflows Katwe metal works and commercial establishments in the upstream, vehicular emission, industrial effluents such as paint factories, sewage plant and in inflows from the tributaries in the midstream and Kibira road stream loaded with wastewater from Uganda batteries limited, Nice House of plastics (Table 1). Sludge from NWSC was the most polluted, followed by Industrial discharge effluent sediments, tributaries and Nakivubo Channelized stream sediments. Contaminants are transported from the upstream, industrial outfall and tributaries in solution and particulate form and are subsequently deposited into the Nakivubo sediments and Lake Victoria. Geo-

Table 3: Mean values of heavy metal contents in the Nakivubo Channelized stream sediments and their average shale

Sites	Soil	Heavy metal (mg/kg)					
Nakivubo stream	pH	Pb	Cd	Cu	Zn	Mn	Fe
US01	6.99	68.44	0.96	27.15	177.89	446.13	33818.67
US02	7.13	64.05	1.00	32.25	223.80	540.80	38885.33
US03	7.25	77.24	0.88	33.54	179.57	1467.47	30085.33
US04	6.75	147.40	0.97	54.76	255.27	459.20	53928.00
MS05	7.11	140.48	0.91	63.75	331.60	498.13	58085.33
MS09	6.93	95.51	0.99	37.69	304.60	610.13	58352.00
DS15	6.91	116.23	1.22	52.40	294.53	363.47	35018.67
DS17	5.71	138.64	1.62	59.62	442.40	872.80	40485.33
Tributaries							
MST07	7.07	103.97	1.01	37.16	320.00	683.20	52528.00
MST10	6.94	70.75	1.14	37.98	194.84	422.13	38485.33
MST13	6.55	142.31	1.07	35.88	573.18	483.47	51018.67
DST16	6.89	339.96	0.93	28.05	349.77	273.33	40885.33
Industrial effluent							
MSD08	6.82	97.09	1.26	48.99	341.28	588.80	37418.67
MSD11	6.92	92.03	3.67	25.46	643.64	2603.20	98928.00
MSD12	7.08	164.60	0.97	64.30	369.90	371.47	32752.00
MSD14 i	6.84	178.16	3.81	226.20	1968.43	474.13	23552.00
MSD14 ii		83.77	1.03	56.02	615.14	515.47	26885.33
Watindo stream (control)							
CTL1	5.09	44.19	1.31	18.55	89.21	1112.80	84618.67
CTL2	4.53	31.31	1.00	12.35	44.27	1559.47	71018.67
CTL3	5.4	43.14	0.81	16.54	63.16	871.47	52485.33
*USEPA; SQGs	Unpolluted	< 40	-	< 25	< 90	-	-
	Moderate	40 – 60	-	25 – 50	90 – 200	-	-
	Heavily polluted	> 60	-	> 50	> 200	-	-
**Average shale		20.00	0.30	45.00	95.00	850.00	46000.00

*USEPA sediment quality guidelines (Pedersen *et al.*, 1998) **World geochemical background value in average shale (Turekian and Wedepohl, 1961)

accumulation index; calculated I_{geo} values based on the average shale are presented in Table 5 and variations along the Nakivubo Channelized stream are shown in Fig. 2 b. The I_{geo} value for Cu, Mn and Fe fall in class '0', indicating background concentration in all the sites except for Cu which falls in class 2 in the sludge, indicating moderate pollution, Mn and Fe are in class 1 at Peacock paint factory, indicating uncontaminated to moderately contaminated sediments. The I_{geo} values of Cd fall in the range 1 – 2, while Pb falls into four classes namely 1, 2, 3 and 4, indicating varying sediment quality and local contamination. Kibira Road stream was heavily polluted with Pb (class 4), which is attributed to the wastewater discharge from Uganda Batteries Limited factory, a petrol station and Nice House of plastics factory. The I_{geo} values for Zn fall in class 1 in the upstream of Nakivubo channelized stream, indicating no pollution while the midstream and downstream fall in the range of 1 – 2, suggesting moderate pollution (Fig. 2b). Elemental concentration of Pb, Cd and Zn along the Nakivubo Channelized stream increased downstream (Fig. 2b). The increased EF, PLI and I_{geo} downstream were attributed principally to anthropogenic activities such as industrial effluents, vehicular emissions and terrigenous influx from upstream and Kampala city centre.

The sediments were unpolluted with Cu, Mn and Fe along the Nakivubo channellized stream (Fig. 2b) and Watindo stream. I_{geo} values of Cd in Watindo stream sediments fall in the range 1 – 2, indicating moderately polluted sediments that could be attributed to terrigenous sources, whereas Pb has I_{geo} values ranging from 0 – 1, indicating unpolluted sediments (Table 4). This shows that the sources of heavy metals in Watindo stream sediments are natural (coming from the earth's surface), considering the calculated EF and I_{geo} values.

Analysis of variance; Analysis of variance was employed to determine whether groups of variables have the same mean on data that are continuous or normally distributed and with homogeneous variance.

SS- Sum of Squares; MS- Mean square; DF- degree of freedom; F- ratio of variation between groups/within groups; P- value P. Sites show no significant effect on variation between group means of the heavy metals at

Table 4: Geo-accumulation index and pollution load index of heavy metals in sediments of the Nakivubo tributaries, industrial discharge outfall and Watindo stream

Sites	Pb	Cd	Cu	Zn	Mn	Fe	PLI
Nakivubo tributaries							
MT07	1.79	1.16	-0.86	1.17	-0.90	-0.39	1.88
MT10	1.24	1.34	-0.83	0.45	-1.59	-0.84	1.46
MT13	2.25	1.25	-0.91	2.01	-1.40	-0.44	2.06
DT16	3.50	1.05	-1.27	1.30	-2.22	-0.76	1.81
Industrial discharge outfall							
MD08	1.69	1.49	-0.46	1.26	-1.11	-0.88	1.89
MD11	1.62	3.03	-1.41	2.18	1.03	0.52	3.35
MD12	2.46	1.11	-0.07	1.38	-1.78	-1.08	1.89
MD14 i	2.57	3.08	1.74	3.79	-1.43	-1.55	3.87
MS14 ii	1.48	1.20	-0.27	2.11	-1.31	-1.36	1.86
Watindo stream							
CTL1	0.56	1.54	-1.86	-0.68	-0.20	0.29	1.44
CTL2	0.06	1.15	-2.45	-1.69	0.29	0.04	1.11
CTL3	0.52	0.85	-2.03	-1.17	-0.55	-0.39	1.09

different stream sections; upstream; $F_{3,15} = 1.69$, $P > 0.212$ and midstream $F_{1,5} = 1.22$, $P > 0.320$ except the down stream ($F_{1,5} = 7.00$, $P < 0.046$ (Table 5a). However, the mean concentrations of elements within sites differ significantly in the upstream ($F_{3,15} = 443.35$, $P < 0.001$), midstream ($F_{1,5} = 598.29$, $P < 0.001$) and, as well as downstream($F_{1,5} = 467.6$, $P < 0.001$).

SS- Sum of Squares; MS- Mean square; DF- degree of freedom; F- ratio of variation between groups/within groups; P- value P.

Sections (Table 5b) have significant effect on the mean heavy metal concentrations at the upstream, midstream and downstream sections ($F_{2,30} = 3.76$, $P < 0.035$). Additionally, there was a significant difference among heavy metal concentrations between sections of the stream ($F_{2,30} = 856.21$, $P < 0.001$). The effects of interaction between sections and mean heavy metal concentration show no significant variations ($F_{2,30} = 0.88$, $P > 0.563$), suggesting minimum mobility of heavy metals in Nakivubo stream sediments.

Correlation coefficient; interelemental association has also been evaluated by pearson correlation coefficient (r) and the results are presented in Table 6. Table 6 shows that elemental pairs Pb/Zn, ($r = 0.641$, d.f $= 15$, $P < 0.01$); Cd/Zn, ($r = 0.641$, d.f $= 15$, $P < 0.01$) and Cu/Zn ($r = 0.558$, d.f $= 15$, $P < 0.05$) are significantly correlated with each other, whereas the rest of elemental pairs show no significant correlation with each other. Elemental association may signify that each paired elements has identical source or common sink in the stream sediments (Singh *et al.,* 2002; Nyangababo *et al.,* 2005b). Metal and physico-chemical associations show pairs Pb/EC, Pb/DO, Cd/pHs, Cu/pHw, Cu/pHs, Cu/EC, Zn/pHs and Fe/pHw are correlated with each other, whereas the rest are not significantly correlated.

Cluster analysis; cluster analysis was performed on the data using Ward linkage and absolute correlation coefficient distance. Results of CA are shown in Fig. 3. Elements and physicochemical parameters were fused into clusters because sediments samples contain similar heavy metal elements. On this basis, three clusters (groups) of elemental associations were identified (Fig. 3). The dendrogram clarifies the influence and association of the clusters or groupings by their relative elemental concentrations at each site (Fig. 3).Therefore, on the basis of similarity coefficients, Pb, Zn and Cu originated from mixed sources or a retention phenomenon. CA showed the association of pH with heavy metal elements in the first cluster. pH values in water are one of the most important factors that regulate the dissolved metals (Muwanga, 1997). Elements in the cluster III (Mn and Fe) originated from terrigenous source. Biplot of sites and elemental concentrations (Fig. 4) identifies NWSC effluent as a point source of Zn and Mn, Mukwano industries effluent a point source of Mn, Zn, Cu and Pb and Kayunga stream inflows are loaded with Pb and Cu attributed to solid waste piles along the tributary and petro station. These results are consistent with those of Muwanga and Balifaijo., (2006).

Factor analysis : Factor analysis was performed to establish the possible factors that contribute to heavy metal concentration and source apportionment (Table 7). Three axes with eigenvalues > 1 were extracted in the analysis and explain the data and corresponds to the cluster analysis. The first three factors account for

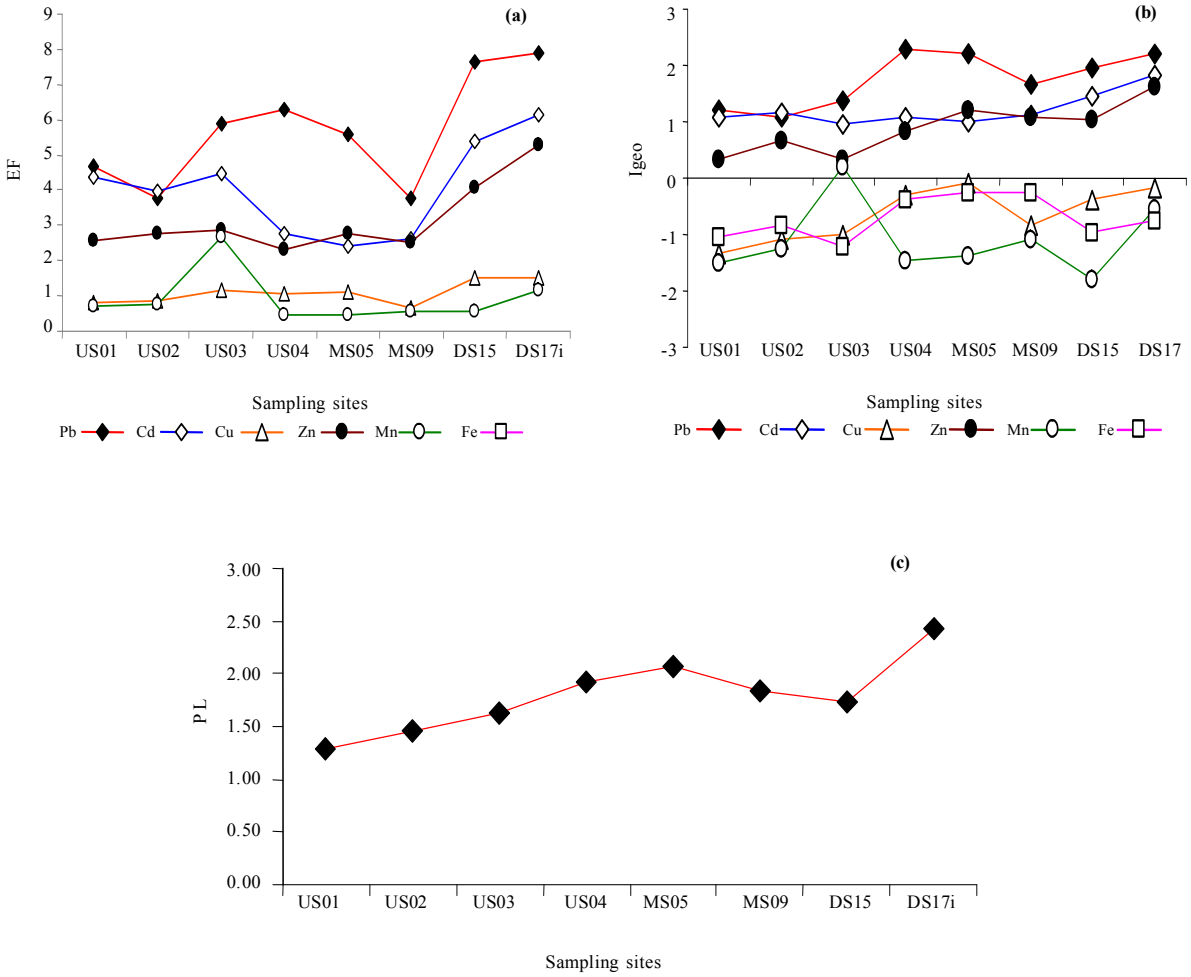

Fig. 2: Variation of enrichment factor, geo-accumulation index and pollution load index in sediments along Nakivubo channelized stream

over 75 % of the total inertia or variance in the data set, indicating that the remaining 25 % were not explained by these axes. The rotated factor matrix is explained by three factors with high communalities of elements except Pb. The first factor accounts for 29.5 % of the total variance and contains Pb, Cu and Zn, as well as electric conductivity and water pH with high variable loadings on this factor and corresponds to group I of the cluster analysis. This indicates flocculation or co-precipitation which is influenced by salinity and pH (Balachandran *et al.,* 2006). Aprile and Bouvy (2008) have recently shown that limnological processes are natural factors controlling such spatial variations of the heavy metals in sediments. The presence of EC and pH in this cluster is most likely due to its association with Pb and Cu, respectively (Table 6). This factor may suggest a source of mixed origins or retention phenomena of industrial and vehicular emissions or/and terrigenous influx from the upstream areas in run-off. The association of Pb, Cu and Zn is controlled by the pH in the stream water. The second Factor accounts for 27.0 % of the variance and contains Cd and Zn, as well as sediment pH with high variable loadings and corresponds to group II of the cluster analysis. This association of Zn and Cd may be attributed to their geo-chemistry,

Table 5a: Two-way ANOVA results for sites and heavy metal concentration variables (dependant variables were log-normal transformed)

Stream sections	Source of variation	DF	SS	MS	F	P
Upstream	Sites	3	0.093	0.031	1.69	0.212
	Metal content	5	40.7294	8.1459	443.35	0.000
Midstream	Sites	1	0.0088	0.0088	1.22	0.320
	Metal content	5	21.5469	4.3094	598.29	0.000
Downstream	Sites	1	0.0566	0.0566	7.00	0.046
	Metal content	5	18.9036	3.7807	467.6	0.000

Table 5b: Two-way ANOVA results for stream sections and mean heavy metal concentration variables (dependant variables were log-normal transformed)

Source of variation	DF	SS	MS	F	P
Sections	2	0.000	0.0639	3.76	0.035
Metal content	5	81.000	14.5676	856.21	0.000
Sections*Metal	10	0.000	0.0149	0.88	0.563

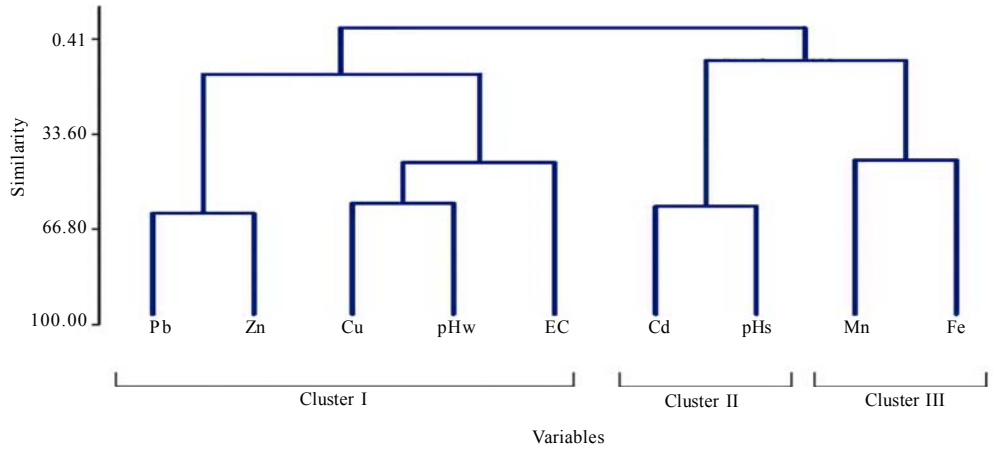

Fig. 3: Dendrogram of stream sediment samples along the Nakivubo drainage system and discharge outlets

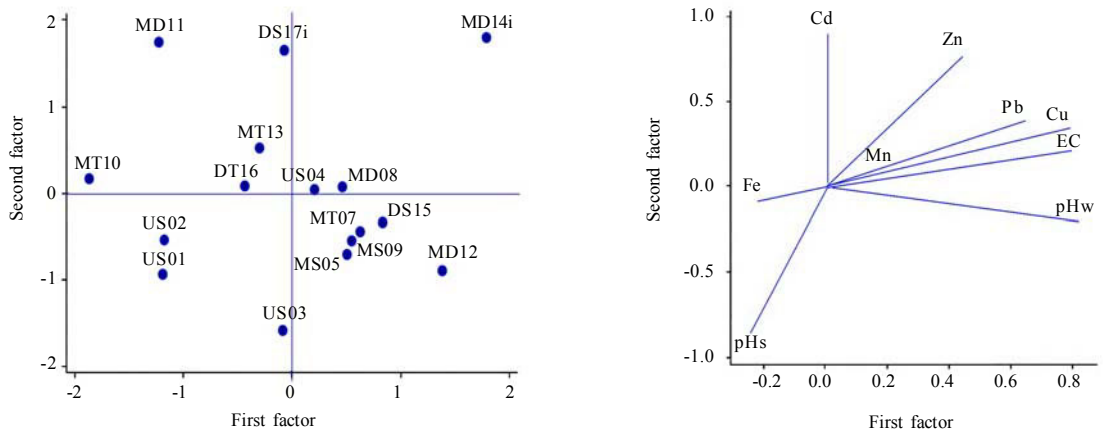

Fig. 4: Biplot of elemental concentrations (a) and sites (b) in stream sediments

Table 6: Pearson correletion coefficient matrix for heavy metals and physico-chemical characteristics in Nakivubo channelized stream sediments (n = 16)

	Pb	Cd	Cu	Zn	Mn	Fe	pHw	pHs	EC
Pb	1								
Cd	0.141	1							
Cu	0.508*	0.266	1						
Zn	0.647**	0.641**	0.558*	1					
Mn	-0.160	0.127	0.185	0.172	1				
Fe	-0.004	-0.187	-0.336	0.110	0.463	1			
pHw	0.272	-0.059	0.611*	0.162	-0.113	-0.498*	1		
pHs	-0.495	-0.624**	-0.542*	-0.616*	-0.115	0.229	-0.053	1	
EC	0.606*	0.306	0.519*	0.442	0.244	-0.094	0.470	-0.281	1
DO	-0.524*	-0.099	-0.593*	-0.246	0.118	0.262	-0.459	0.170	-0.711**

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed); pHw- water pH; pHs- soil pH

Table 7: Varimax rotated factor loadings and communalities of Nakivubo stream sediments, tributaries and industrial outfall sediments

Variable	Factor 1	Factor 2	Factor 3	Communality
Pb	0.644	0.387	0.038	0.566
Cd	0.006	0.881	-0.038	0.778
Cu	0.796	0.341	-0.092	0.757
Zn	0.431	0.758	0.228	0.812
Mn	0.143	0.072	0.793	0.655
Fe	-0.233	-0.101	0.884	0.845
pHw	0.811	-0.192	-0.378	0.837
pHs	-0.244	-0.849	0.079	0.786
EC	0.796	0.203	0.186	0.709
Variance	2.6594	2.4292	1.6570	6.7456
% Var	0.295	0.270	1.6570	0.750

retention phenomena or/and identical source which is pH controlled (acidic to near neutral), indicating both specific and non-specific adsorption of Cd in solid phase (Muwanga, 1997). Cadmium is negatively correlated with sediment pH ($r = -0.624$, d.f = 15, $p < 0.01$). Zinc has been distributed between the first and second factor indicating dual sources that contribute to Zn concentrations. The third factor accounts for 18.4 % of the variance and contains Mn and Fe. This association may be due to their common occurrence in the basic rock, since the concentrations of these elements were lower than background values (I_{geo} d" 0). Stream sediments showed an anomaly in spatial separation of the depositions of Fe and Mn, possibly a result of their flocculation properties attributed to pH and salinity (Balachandran *et al.*, 2005; 2006).

CONCLUSION

Sediments in the Nakivubo drainage system and surrounding environment actively accumulate heavy metals, improving the quality of the aquatic ecosystem. These observations are in agreement with those of Parizanganeh *et al.*, (2007); Durán and González, (2009). However, this phenomenon poses a risk of secondary water pollution by heavy metals under sediment disturbance and/or changes in sediment chemistry. EF, PLI and I_{geo} values indicated widespread pollution by Pb, Cd and Zn in the Nakivubo channelized stream sediments. The sources of heavy metals in Watindo stream sediments (control) are natural (coming from the earth's surface) and are classified as unpolluted (class = 1) considering the calculated I_{geo} values except Cd. Cadmium fall in class 2 indicating moderately polluted sediments for the element. Co-precipitation of Pb, Cd and Zn with Mn and Fe hydroxides along with scavenging of other metals could account for the accumulation of heavy metals in the Nakivubo stream sediments. Factor analysis generated three sources of pollutants in the Nakivubo channelized stream sediments: (1) mixed origin or retention phenomena of vehicular and industrial emissions characterised by Pb, Cu, and Zn; (2) Terrigenous fractions in the runoff, characterised by Mn, Fe and Cu; and (3) dual source of vehicular and industrial emissions, characterised by Zn. The I_{geo} value of heavy metals showed that stream sediments have background concentration for Mn, Fe and Cu at most of the sites.

ACKNOWLEDGEMENTS

The authors are thankful to Kampala International University for the financial support in form of PhD research project and Department of Geology, Faculty of Science, Makerere University, for geochemical analyses.

REFERENCES

Aprile, F. M.; Bouvy, M., (2008). Distribution and enrichment of heavy metals in sediments at the Tapacura River Basin, North eastern Brazil. Braz. J. Aqua. Sci. Tech., 12 (1), 1-8 **(8 pages)**.

Awofolu, O. R.; Mbolekwa, Z., Mtshemla, V.; Fatoki, O. S., (2005). Levels of trace metals in water and sediments from Tyume River and its effects on an irrigated farmland. Water SA., 31 (1), 87-94 **(8 pages)**.

Balachandran, K. K.; Lalu R. C. M.; Nair, M.; Joseph, T.; Sheeba, P.; Venugopal, P., (2005). Heavy metal accumulation in a flow restricted, tropical estuary, Estuarine. Coast. Shelf Sci., 65 (1-2), 361-370 **(10 pages)**.

Balachandran, K. K.; Lalu raj. C. M.; Martin, G. D.; Srinivas, K.; Venugopal, P., (2006). Environmental analysis of heavy metal deposition in a flow-restricted tropical estuary and its adjacent shelf. Environ. Forensics, 7 (4), 345-351 **(7 pages)**.

Campbell, L. M., (2001). Mercury in Lake Victoria (East Africa): Another emerging issue for a Beleaguered Lake? Ph.D. dissertation, Waterloo, Ontario, Canada.

Chakravarty, M.; Patgiri, A. D., (2009). Metal pollution assessment in sediments of the Dikrong River, NE India. J. Hum. Ecol., 27 (1), 63-67 **(5 pages)**.

Durán, A. C.; González, A., (2009). Determination of lead, naphthalene, phenanthrene, anthracene and pyrene in street dust. Int. J. Environ. Sci. Tech., 6 (4), 663-670 **(8 pages)**.

El Diwani, G.; El Rafie, Sh., (2008). Modification of thermal and oxidative properties of biodiesel produced from vegetable oils. Int. J. Environ. Sci. Tech., 5 (3), 391-400 **(10 pages)**.

Harkumar, P. S.; Nasir ,U. P.; Mujeebu Rahman, M. P., (2009). Distribution of heavy metals in the core sediments of a tropical wetland system. Int. J. Environ. Sci. Tech., 6 (2), 225-232 **(8 pages)**.

Imai, N.; Terashina, S.; Itoh, S.; Ando, A., (1994). Compilation of analytical data for minor and trace elements in seventeen GSJ Geochemical reference samples "Igneous rock series", Geo-standard Newsletter, 19 (2), 135-213 **(79 pages)**

Idrees, F. A., (2009). Assessment of trace metal distribution and contamination in surface soils of Amman. Jordan J. Chem., 4 (1), 77-87 **(10 pages)**.

Kamaruzzaman, M. C.; Ong, M. S.; Noor, A.; Shahbudin, S.; Jalal, K. C. A., (2008). Geochemistry of sediment in the major estuarine mangrove forest of Terengganu Region, Malaysia. Am. J. Appl. Sci., 5 (12), 1707-1712 **(6 pages)**.

Kansiime, F.; Nalubega, M., (1999). Wastewater treatment by a natural wetland: the Nakivubo swamp, Uganda. Processes and implementations, Ph.D. dissertation, Wageningen Agricultural University, Netherlands.

Kansiime, F.; Kateyo, E.; Okot-okumu, J., (1995). Effects of pollution on Inner Murchison bay (Lake Victoria- Uganda) on the distribution and abundance of plankton. A report of makerere institute of environment and natural resources.

Karageorgis, A. P.; Hatzianestis, I., (2003). Surface sediment chemistry in the Olympic Games 2004 sailing center (Saronikos gulf). Mediterranean Mar. Sci., 4 (1), 5-22 **(18 pages)**.

Kothai, P.; Prathibha, P.; Saradhi, I. V.; Pandit, G. G.; Puranik, V. D., (2009). Characterization of atmospheric particulate matter using pixe technique. Int. J. Environ. Sci. Eng., 1 (1), 27 - 30 **(4 pages)**.

Kumar, S. P.; Edward, J. K. P., (2009). Assessment of metal concentration in the sediment cores of Manakudy estuary, south west coastal of India. Indian J. Mar. Sci., 38 (2), 235-248 **(14 pages)**.

Linnik, P. M.; Zubenko, I. B., (2000). Role of bottom sediments in the secondary pollution of aquatic environments by heavy metal compounds, lakes and reservoirs. Res. Manage., 5 (1), 11 – 21 **(11 pages)**.

Loska, K.; Wiechula, D.; Barska, B.; Cebula, E.; Chojnecka, A., (2003). Assessment of arsenic enrichment of cultivated soils in Southern Poland. Pol. J. Environ. Stud., 12 (2), 187 – 192 **(6 pages)**.

Lwanga, M. S.; Kansiime, F.; Denny, P.; Scullion, J., (2003). Heavy metals in Lake George, Uganda with relation to metal concentrations in tissues of common fish specie. Hydrobiologia, 499 (1-3), 83-93 **(10 pages)**.

Matagi, S. V.; Swai, D.; Mugabe, R., (1998). A review of heavy metal removal mechanisms in wetlands. Afr. J. Trap. Hydrobiologia Fish, 8 (1), 23-35 **(13 pages)**.

Mohiuddin, K. M.; Zakir, H. M.; Otomo, K.; Sharmin, S.; Shikazono, N., (2010). Geochemical distribution of trace metal pollutants in water and sediments of downstream of an urban river. Int. J. Environ. Sci. Tech., 7 (1), 17-28 **(12 pages)**.

Muller, G., (1969). Index of geo-accumulation in sediments of the Rhine River. Geo. J., 2 (3), 108-118 **(11 pages)**.

Muwanga, A., (1997). Environmental impacts of copper mining at Kilembe, Uganda: A geochemical investigation of heavy metal pollution of drainage waters, stream, sediments and soils in the Kilembe valley in relation to mine waste disposal. Ph.D. dissertation. Universitat Braunschweig, Germany.

Muwanga, A.; Barifaijo, E., (2006). Impact of industrial activities on heavy metal loading and their physico-chemical effects on wetlands of Lake Victoria basin (Uganda). Afri. J. Tech. Sci. Eng., 7 (1), 51-63 **(13 pages)**.

Mwiganga, M.; Kansiime, F., (2005). Impact of Mpererwe Landfill in Kampala Uganda, on the surrounding environment. Phys. Chem. Earth, 30 (11-16) 744-750 **(7 pages)**.

Nabulo, G.; Oryem-origa, H.; Nasinyama, G.; Cole, D., (2008). Assessment of Zn, Cu, Pb and Ni contamination in wetland soils and plants in the Lake Victoria basin. Int. J. Environ. Sci. Tech., 5 (1), 65-74 **(10 pages)**.

Nyangababo, J. T., (2003). Heavy metal in the contour feathers of marabou stork *(Leptoptilos crumeniferus)* from Kampala City and its surrounding areas. Bull. Environ. Contam. Toxicol., 70 , 792-799 **(8 pages)**.

Nyangababo, J. T.; Henry, E.; Omutange, E., (2005a). Lead, cadmium, copper, manganese and zinc in wetland waters of Victoria Lake Basin, East Africa. Bull. Environ. Contam. Toxicol., 74 (5), 1003-1010 **(8 pages)**.

Nyangababo, J. T.; Henry, I.; Omutunge, E., (2005b). Heavy metal contamination in plants, sediments and air precipitation of Katonga, Simiyu and Nyando wetlands of Lake Victoria Basin, East Africa. Bull. Environ., Contam. Toxicol., 75 (1), 189-196 **(8 pages)**.

Ochieng, H.; Steveninck, E. S.; Wanda, F. M., (2008). Mouthparts deformities in chironomides (dipteral) as indicators of heavy metal pollution in northern Lake Victoria, Uganda. Afr. J. Aqua. Sci., 33 (2), 135-142 **(8 pages)**.

Okafor, E. Ch., Opuene, K., (2007). Preliminary assessment of trace metals and polycyclic aromatic hydrocarbons in the sediments. Int. J. Environ. Sci. Tech., 4 (2), 233-240.

Ong, M. C.; Kamaruzzaman, B. Y., (2009). An assessment of metal (Pb and Cu) contamination in bottom sediments from South China Sea coastal waters, Malaysia. Am. J. Appl. Sci., 6 (7), 1418-1423 **(6 pages)**.

Parizanganeh, A.; Lakhan, V. C.; Jalalian, H., (2007). A geochemical and statistical approaches for assessing heavy metal pollution in sediments from the Southern Caspian coast. Int. J. Sci. Tech., 4 (3), 351-358 **(8 pages)**.

Pedersen, F.; Bjorestad, E.; Anderson, H. V.; Kjolholt, J.; Poll, C., (1998). Characterization of sediments from Copenhagen harbour by use of biotests. Water Sci. Tech., 37 (6-7), 233-240 **(8 pages)**.

Praveena, S. M.; Ahmed, A.; Radojevic, M.; Abdullah, M. H.; Aris, A. Z., (2007). Factor-cluster analysis and enrichment study of mangrove sediments-an example from Mengkabong, Sabah. Malaysian J. Anal. Sci., 11 (2), 421-430 **(10 pages)**.

Praveena, S. M.; Ahmed, A.; Radojevic, M.; Abdullah, M. H.; ris, A. Z., (2008). Heavy metals in mangrove surface sediment of Mengkabong lagoon, Sabah: Multivariate and eo-accumulation index approaches. Int. J. Environ. Res., 2 (2), 139-148 **(10 pages)**.

Sentongo, J., (1998). Assessment of pollution to Lake Victoria by industrial and municipal activities around Lake Victoria in Uganda. M.Sc. thesis, Makerere University, Uganda.

Seshan, B. R. R.; Natesan, U.; Deepthi, K., (2010). Geochemical and statistical approach for evaluation of heavy metal pollution in core sediments in southeast coast of India. Int. J. Environ. Sci. Tech., 7 (2), 291-306 **(16 pages)**.

Shyamalendu, B. S.; Abhijit, M.; Bhattacharyya, S. B.; Amalesh, C., (2001). Status of sediment with special reference to heavy metal pollution of a blackish water tidal ecosystem in northern Sundarbans of west Bengal. Trop. Eco., 42(1), 127-132 **(6 pages)**.

Simex, S. A.; Helz, G. R., (1981). Regional geochemistry of trace elements in Chesapeake Bay. Environ. Geo., 3 , 315-323 **(9 pages)**.

Singh, M.; Muller, G,; Singh, I. B., (2002). Heavy metals in Freshly deposited stream sediments of rivers associated with urbanization of the Ganga plain, India. Water Air Soil Pollut., 141 (1-4), 35-54 **(20 pages)**.

Sutherland, R. A., (2000). Bed sediment associated trace metals in an urban stream Oahu. Hawaii. Environ. Geo., 39 (6), 611-627 **(17 pages)**.

Turekian, K. K.; Wedepohl, K. H., (1961). Distribution of the elements in some major units of the earth's crust. Geo. Soc. Am. Bull., 72 (2), 175-192 **(13 pages).**

Tomilson, D. C.; Wilson, D. J.; Harris, C. R.; Jeffrey, D. W., (1980). Problem in assessment of heavy metals in estuaries and the formation of pollution index. Helgol. Wiss. Meeresunlter, 33 (1-4), 566-575 **(10 pages)**.

Zvinowanda, C. M.; Okonkwo, J. O.; Shabalala, P. N.; Agyei, N. M., (2009). A novel adsorbent for heavy metal remediation in aqueous environments. Int. J. Environ. Sci. Tech., 6 (3), 425-434 **(10 pages)**.

AUTHOR (S) BIOSKETCHES

Sekabira, K., Ph.D. Candidate, Lecturer, Department of Environment, Faculty of Science and Engineering, Kampala International University, P. O. Box 20000, Kampala, Uganda. Email: *ssekaba@gmail.com*

Oryem Origa, H., Ph.D., Full Professor, Department of Botany, Faculty of Science, Makerere University, P. O. Box 7062, Kampala, Uganda. Email: *horyem_origa@botany.mak.ac.ug*

Basamba, T. A., Ph.D., Deputy Dean and a lecturer, Department of Soil Science, Faculty of Agriculture, Makerere University, P. O. Box 7062, Kampala, Uganda. Email: *ateenyitwaha@hotmail.com*

Mutumba, G., Ph.D., Assisstant Professor, Department of Botany, Faculty of Science, Makerere University, P. O. Box 7062, Kampala, Uganda. Email: *gmutumba@botany.mak.ac.ug*

Kakudidi, E., Ph.D., Head of Department and a lecturer, Department of Botany, Faculty of Science, Makerere University, P. O. Box 7062, Kampala, Uganda. Email: *ekakudidi@sci.mak.ac.ug*

How to cite this article: (Harvard style)

Sekabira, K.; Oryem Origa, H.; Basamba, T. A.; Mutumba, G.; Kakudidi, E., (2010). Assessment of heavy metal pollution in the urban stream sediments and its tributaries. Int. J. Environ. Sci. Tech., 7 (3), 435-446.