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IMPACT OF INDUSTRIAL ACTIVITIES ON HEAVY METAL LOADING AND THEIR PHYSICO-CHEMICAL EFFECTS ON WETLANDS OF LAKE VICTORIA BASIN (UGANDA)

Muwanga, A. and Barifaijo, E.

Department of Geology, Makerere University,
P.O. Box 7062, Kampala, UGANDA

ABSTRACT: *The diverse functions of wetlands are being adversely affected by human activities. This paper discusses the impact of these activities on heavy metal loading in different media within the wetlands. Water and sediment/soil samples were taken from areas with active industrial activities and from an area where there is no industrial activity. Sources of water pollution include effluents from a brewery (high pH) and areas associated with tanning activities, sewage treatment plant and former copper smelter (high electric conductivity values). Effluents from a battery assembly plant, water treatment plant, pharmaceutical industry and former copper smelter have relatively high Pb values (up to 1.4 ppm) otherwise most heavy metal concentrations are below maximum acceptable limits for water. This calls for mitigation measures. In sediments, high heavy metal values were associated with battery and metal fabricating industry (Pb), operations involving Zn scrap (Cd), former Cu smelter (Cu, Pb, Ni and Co), tannery and pharmaceutical industry (Cr), and soap and cosmetics industry (Hg). Fish have low levels of Hg. However, fish is known to bioaccumulate Hg through methylation, may cause increase in the Hg in the food chain. Industries which release effluents with high heavy metal contents should treat them before discharge.*

Key words: *Wetlands, Lake Victoria basin, heavy metals, physico-chemical parameters, toxicity, bioaccumulation.*

INTRODUCTION

Wetlands provide an ecological, social and economic status which contribute to the GNP (Gross National Product) of a nation thus becoming “wealthlands” (Namakambo, 2000; Mafabi et al; 1998, Swallow et al., 2001 and Haskoning - CMS, 2001a & b). They serve both direct and indirect functions. Direct functions include fishing, fuel wood, wild foods, medicinal plants, agriculture, pasture, transport, recreation (green corridors) etc. The indirect or ecosystem functions include; maintenance of water quality (Kansiime et al., 1995, 2003; Okurut et al., 2000) and flow, water storage, water recharge, flood control, reproduction area for fish, climate control and shore stability. Other functions include cultural, biodiversity of flora and fauna, aesthetic, heritage bequest values and nesting site for birds.

The catchment area of Lake Victoria basin is very densely populated. The functions of the wetlands mentioned above are being adversely affected by the high population and associated increase in human activities including mining and industries. These human activities around Lake Victoria are likely to impact on the water quality and the quality of wetland resources such as fish and food derived from the area.

The industries impacting on the wetlands of the Lake Victoria basin are concentrated in Kampala and Jinja. The operations and effluent management of these industries plus other municipal wastes and urban run-off were found to be negatively impacting on the wetlands in both towns (Mott Macdonald, 2001). The industrial activities include factories of batteries, soap, paint, metal fabrication, plastics, corrugated iron sheets, pharmaceuticals, breweries, tanneries, former copper smelting plant as well as municipal waste disposal. Mining activities are minimal and they are not likely to have a significant effect on the wetlands.

For sustainable development of the natural resources of the wetlands in the basin, it is necessary to study the how the industrial activities impact on them. These activities are sources of toxic metals and other chemicals which pollute the wetland ecosystem. This ongoing interdisciplinary study has identified some of the impacted areas and evaluated the heavy metal loads in the different media within the wetlands.

SAMPLING

The sampling was done during the dry season in the months of December, 2003 to February, 2004 starting in the wetlands around Kampala, Jinja and Busia. The wetlands around Kampala and Jinja are impacted on by industrial activities while those in Busia are considered pristine. The sampled areas are shown in Fig. 1.

The GPS co-ordinates in UTM were recorded for each sampling station followed by measurement of the physical parameters which included acidity (pH), electrical

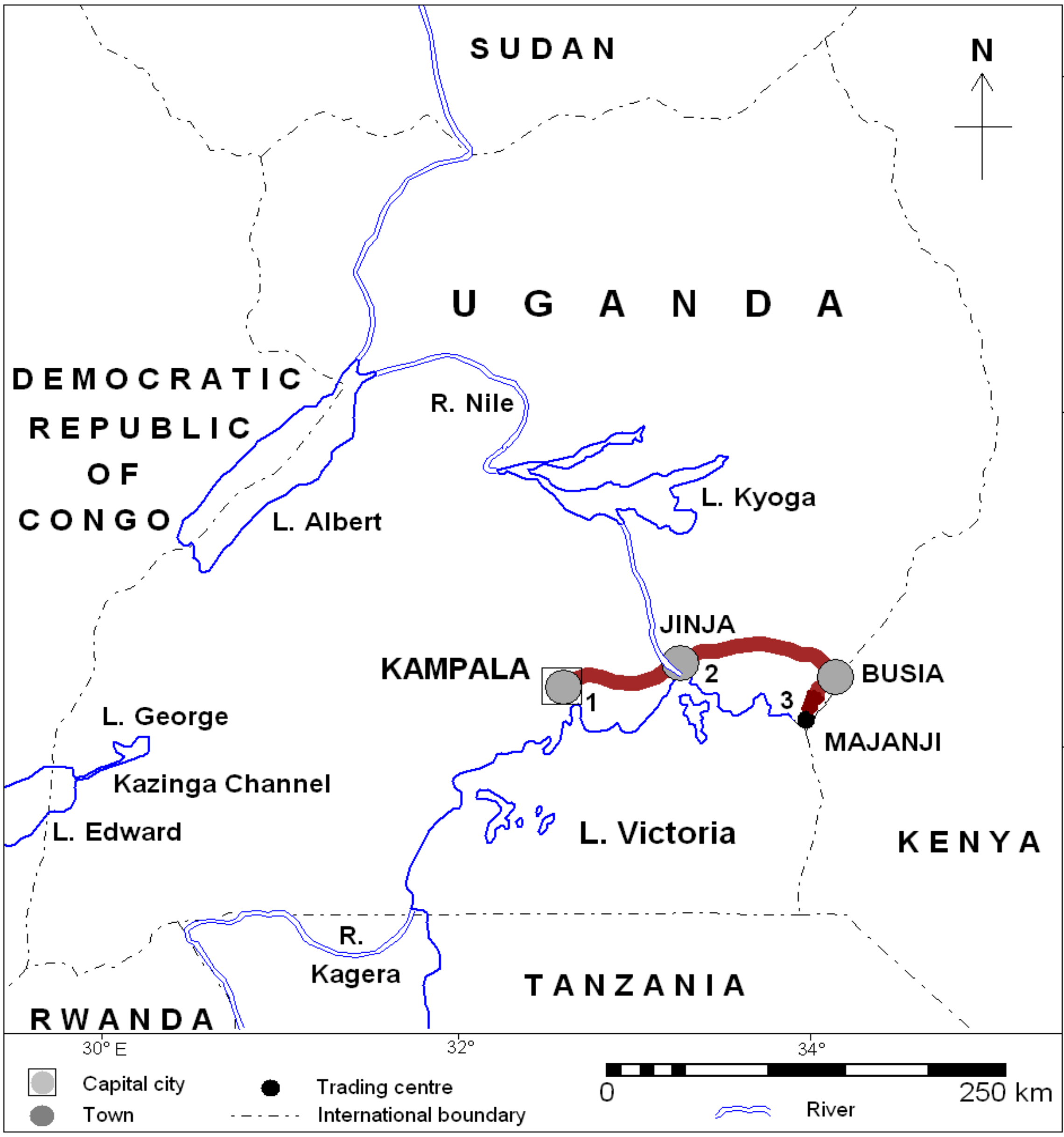

Figure 1: Map of Uganda showing location of study areas (1-3)

conductivity (EC), redox potential (Eh), turbidity (NTU) and oxygen (O_2) for water.

The sediments and soils sampled using a hand auger were kept in polyethylene bags. Lung fish (*Protopterus aethiopicus*) which is accustomed to the swampy environment was bought from the local fishermen found within the sampled areas. The sampled materials were preserved in coolers containing ice and later transferred to a deep freezer at the University.

Nakivubo Channel (Kampala)

The sampling started with the mouth of the channel (NC1) at Bat Valley (Fig. 2) through the bus park and Owino market circuit to Mukwano industries and the remaining industries up to the end of the constructed Nakivubo channel about 50 metres after the railway bridge below Luzira Prison.

The sampling was continued within Lake Victoria to capture the effluents after they had passed through the Murchison Bay wetland.

A sample would be taken both upstream and downstream of any industry in order to ascertain the level of contamination. The streams adjoining the channel both natural for example Kitante and man-made like Kibira plus pipeline bringing in effluent to the channel like the NWSC and Uganda Breweries Ltd. at Port Bell were sampled before they join the channel and a few metres after they had joined.

Kinawataka (Kampala)

Samples were got from both upstream and downstream the Vubyabirenge, Kinawataka and Fish Packers (Pepsi) streams (Fig.2) and after the confluence of the three streams opposite Kyambogo junction and behind Oxygas plant. Sampling was continued where the effluent water enters the Kinawataka wetland after the Kireka-Mbuya road and Butabika hills up to where it loops and joins Murchison Bay in the Kirombe-Port Bell area.

Napoleon Gulf (Jinja)

The sampling stations were mostly concentrated on the pipeline of the NWSC (Fig.3) which collects all the municipal and industrial effluents in Jinja town. Samples were also collected from the access transects 1 & 2 of the Lake Victoria Environmental Management Programme (LVEMP) within the Kirinya wetland (water from the sewer pipe had gone through the wetland) and in Lake Victoria. There was no lung fish sampled in the Napoleon Gulf as it was unavailable during the time of sampling.

SYMBOLS

BT	=	Britannia
CF	=	Crestfoam Industry
ES	=	Easthide skins
GLC	=	Great Lakes Coffee Co. Industry
HW	=	Hwang Sung Limited Industries, etc
KPI	=	Kampala Pharmaceutical Industry
KW	=	Kinawataka Wetland
BMK	=	BMK Industry
MKI	=	Mukwano Industries
MP	=	Uganda Meat Packers and City Abattoir
NC	=	Nakivubo Channel
NKI	=	Nakawa Industrial Area with Crown Bottlers, Shimuk, Kiwa
NSP	=	Nakasero Soap Works
NWSC	=	National Water and Sewerage Corporation Discharge pipe
OWM	=	Owino Market
STB	=	Ship Toothbrush
UB	=	Uganda Breweries
UBA	=	Uganda Baati Limited
UBT	=	Uganda Batteries Industry
UNL	=	Unilever Industries
WSP	=	Wisporo Industry

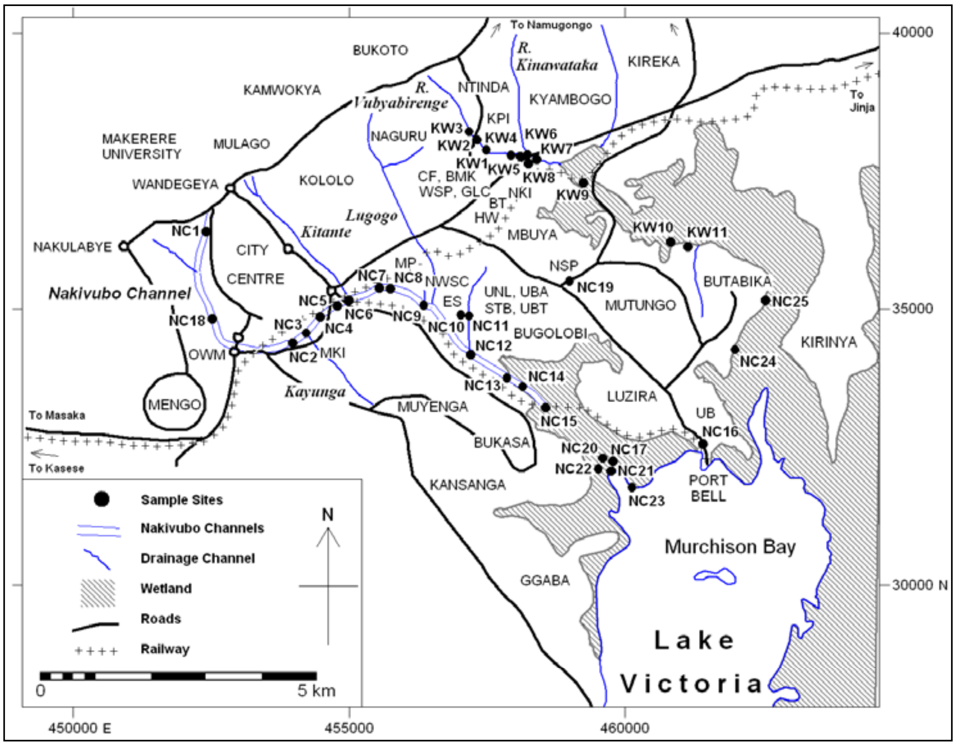

Figure 2: Map showing sample locations along in Kampala (Nakivubo channel and Kinawattaka stream)

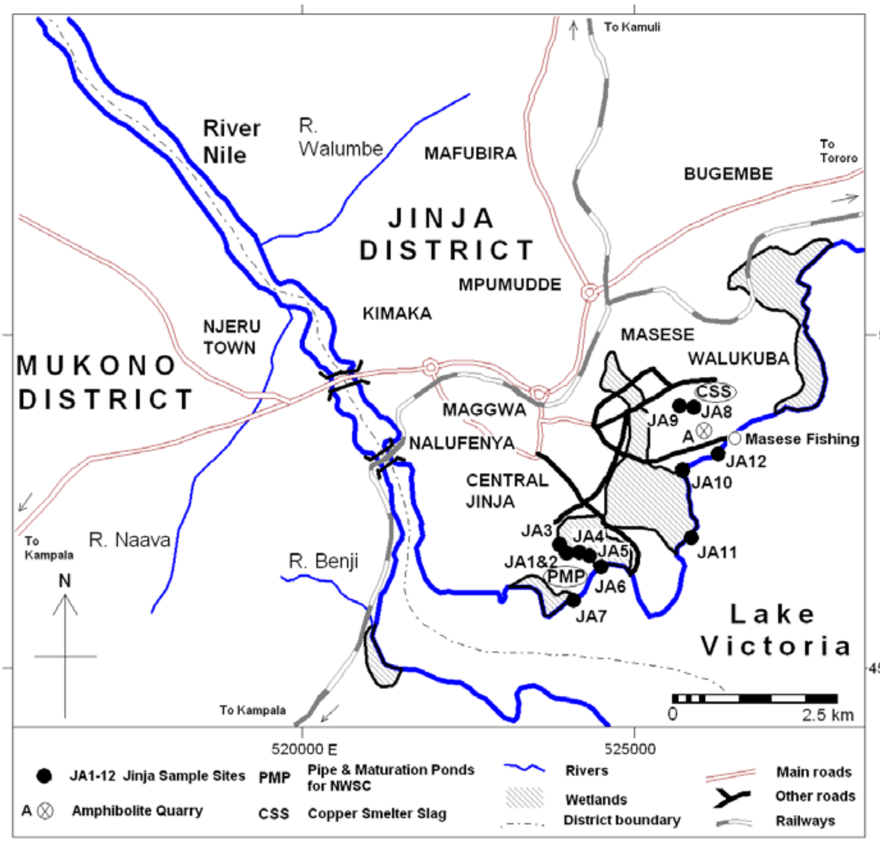

Figure 3:. Map showing sample locations in Jinja

The copper slag trail from Walukuba hill was systematically sampled up to the wetland and within Lake Victoria after the wetland.

Berkeley Bay (Busia)

The sampling was first done near the source of the rivers Nasigombe (after Lunyo town) and Nalwire before Hukeno (Makina) trading centre (Fig.4). All the rivers (Nasigombe, Nalwire and Sio) were then sampled at points before the wetland and within Lake Victoria after the water has gone through the wetland. Two samples were collected from river Tira to test the influence of artisan gold mining.

MATERIALS AND METHODS

Treatment of Samples

Water

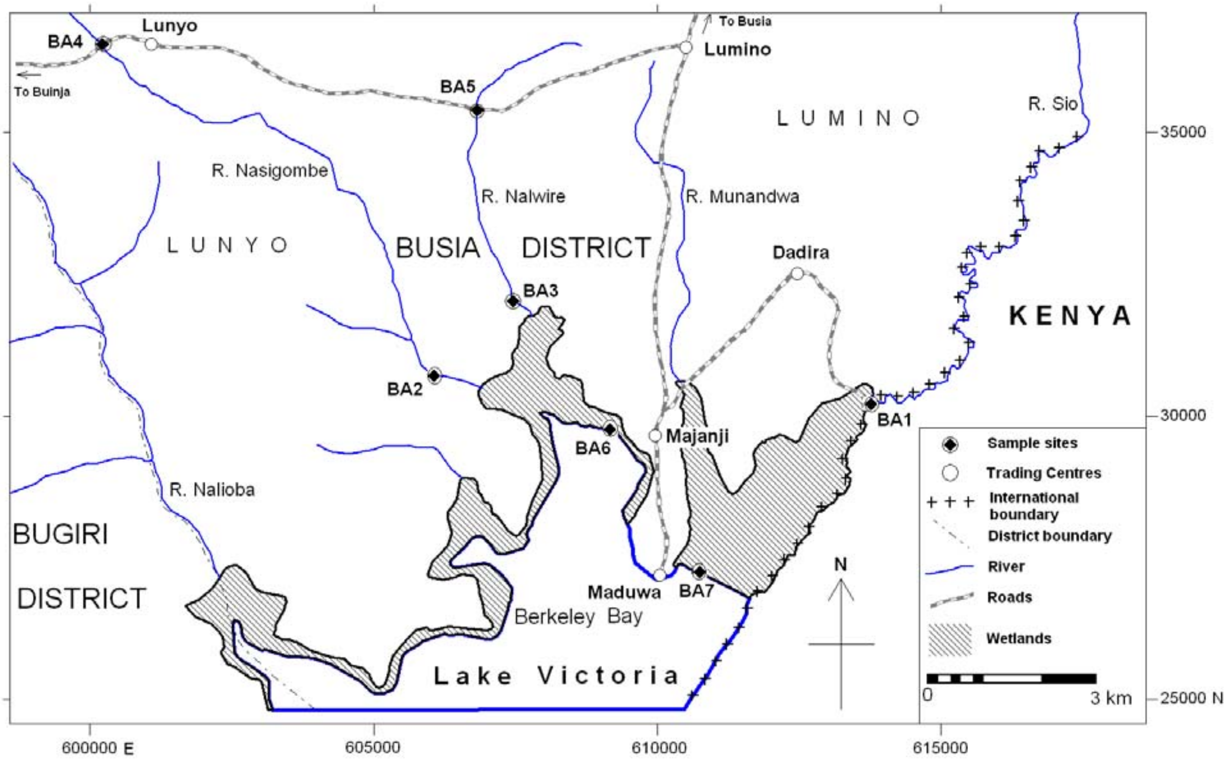

Figure 4: Map showing sample locations in Busia

MATERIALS AND METHODS

Treatment of Samples

Water

The water was filtered using cellulose nitrate filter papers (0.45μm pore size) and 3 drops of concentrated nitric acid were added for preservation. The bottles were put back in the deep freezer at 4°C until they were dispatched to the University of Dar Es Salaam, Tanzania for heavy metal analysis.

Soils and Sediments

The samples were spread on aluminium foil and dried overnight in an oven set at 105°C. After cooling, they were pulverised in a ceramic agate mortar and sieved in nylon sieves to 80 mesh and packed in heavy duty polyethylene bags.

Fish

The fish was preserved whole in the cooler and then later The water was filtered using cellulose nitrate filter papers

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Soils and Sediments
The samples were spread on aluminium foil and dried overnight in an oven set at 105°C. After cooling, they were pulverised in a ceramic agate mortar and sieved in nylon sieves to 80 mesh and packed in heavy duty polyethylene bags.

Fish
The fish was preserved whole in the cooler and then later in the deep freezer. The fish was dissected and the dorsal muscle freeze dried in the freeze drying facility at the Department of Biochemistry.

Analysis of Samples
All the analysis of heavy metals was done at the Southern and Eastern Mineral Centre (SEAMIC) Tananzania using a Flame Atomic Absorption Spectrophotometer (AAS).

Soil and Sediments
These were analysed for heavy metals. 0.5 g of each sample was digested with 2 ml aqua regia (HCl/HNO_3 3:1) in a test tube placed in a water bath. The water bath was thermostatically controlled at 95 ÚC. After cooling the samples was diluted to 20 ml and vigorously mixed by a vortex shaker, and then left to settle. The clear solution analysed for heavy metals Cu, Pb, Zn, Cd, Co, Ni, Cr and Mn.

Water
Each sample was directly aspirated into the AAS without any prior treatment.

Fish
This was also analysed using AAS.

Mercury

For total mercury (THg) analysis, 0.5 to 1 g of sediment or fish muscle tissue were placed in a thick-walled 50 ml volumetric flask and digested with 2 ml of HNO_3-$HClO_4$ mixture (1:1) plus 5 ml of H_2SO_4 for 20 minutes at 205° C on a hot plate. After cooling, the digested sample was made up to 50 ml by adding mercury-free water to the digestion vessel. The vessel was then capped and shaken vigorously to homogenize the sample solution. Analysis of THg in the solution was done by cold vapour atomic absorption (CVAA) using a semi-automated mercury analyser.

RESULTS

Water

Physico-chemical Parameters

Nakivubo Channel

Results are shown in Table 1. High pH values, up to 9.5, are observed in the effluents from Uganda Breweries, which enter directly into the lake. At other places, the pH was within accepted levels.

Table1. Physico - chemical properties of Nakivubo Channel waters

Sample	pH	EC (µS/cm)	Turb. (NTU)	Oxygen mbar
NC1	5.6	226	17.19	104
NC1	7.5	444	182.7	37
NC2	7.5	444	182.7	29
NC3	6.9	293	17.58	68
NC 4	7.3	449	60.93	14
NC 5	7.3	487	25.88	23
NC 6	6.8	516	898.4	2
NC 7	6.8	492	177.5	2
NC 8	7.1	510	20.1	69
NC 9	7.2	813	121.3	4
NC 10	7.4	45000	219	79
NC 11	6.2	624	15.96	36
NC 12	7.4	461	22.81	36
NC 15	7.3	465	22.03	17
NC 16	9.5	667	43.78	110
NC 17	7.4	291	9.74	130
NC 18	7.6	350	17.47	60
NC 19	7.4	174	17.37	93
NC 20	7.4	351	15.09	106
NC 22	6.9	319	11.02	33
NC 23	7.9	129	11.03	161
NC 24	6.9	195.8	17.22	9
NC 25	6.4	80.5	14.74	153
NEMA (MPL) [a]	6.0 - 8.0	-	300	
WHO Guidelines [b]	6.5 - 8.5	400		

[a] NEMA Maximum Permissible Limits for Discharge of Effluent or Waste Water
[b] World Health organisation guidelines for drinking water quality (1984)

Effluents from a skin and hides factory (Easthides) have very high electrical conductivity – EC – (45000 µS/cm) indicating high dissolved solids which could include chromium. Below the factory, local people cultivate yams, sweet potatoes and sugar canes. WHO and EU guidelines give 400 µS/cm as the guide level for potable water. Of the 25 sites sampled, only seven have EC falling below EC guidelines.

Turbidity in most places is below NEMA standards effluent discharge of 300 NTU but is higher where the water effluent from industry joins the channel e.g. NC 6 from after Mukwano Industries and NC 10 near Easthides skin tanning plant . Oxygen is also low where water contains sewage indicating possibly high oxygen demand by the microorganisms in the sewage and organic material.

Kinawataka Stream and Ntinda Industrial Area

EC is highest in runoff from industries along Jinja Road (Table 2) as shown by samples KW 4 and KW 7. Other high values are observed some distance from the industrial area suggesting influence of geology and possibly vegetation.

Table 2. Physicochemical properties of waters from Kinawattka stream and Ntinda Industrial Area

Sample	pH	EC (µS/cm)	Turb. (NTU)	Oxygen mbar
KW 1	6	474	156	37
KW 2	6.8	190.8	72.17	111
KW 3	7.4	187.1	30.89	116
KW 4	6.1	720	79.2	67
KW 5	6.6	220	83.24	65
KW 6	7.1	282	120.3	58
KW 7	7.3	762	142.2	23
KW 8	7.6	449	177.1	46
KW 9	7	386	57.84	0
KW 10	7.2	386	52.02	67
KW 11	6.9	189.9	43.62	60
NEMA (MPL)	6.0 - 8.0		300	
WHO Guidelines	6.5 - 8.5	400		

Turbidity is highest within Ntinda industrial area and streams receiving effluents from industries on Jinja road (KW 1, KW 7 and KW 8). Oxygen is lowest within the wetland and this could be due to vegetation matter.

Jinja

Water and effluent pH values in Jinja were generally high (7.5-9.0) (Table 3) compared to those recorded in Nakivubo Channel and Kinawataka areas in Kampala.

Table3. Physico - chemical properties of Jinja waters

Sample	pH	EC (µS/cm)	Turb. (NTU)	Oxygen mbar
JA 1	8.4	884	39.8	149
JA 2	7.8	867	239.3	12
JA 3	8.3	891	45.61	157
JA 4	7.9	914	66.28	13
JA 5	7.7	820	190.3	1
JA 6	8.8	102.4	20.28	144
JA 7	9	101.3	23.75	160
JA 10	9.1	2530	297	83
JA 11	9.4	103.3	30.93	177
JA 12	9.4	103.1	49.15	182
NEMA (MPL)	6.0 - 8.0		300	
WHO Guidelines	6.5 - 8.5	400		

High EC values (860 to 890 µS/cm) are recorded in the NWSC wastewater and runoff from the former copper smelting plant (2530 µS/cm), indicating high dissolved solids. Metals contained in the slag could be entering the lake.

Busia

Busia wetlands exhibit normal levels of physico-chemical parameters and thus are pristine or little disturbed (Table 4). One point (BA 5), however, had a high EC value (1820 µS/cm), which is probably due to the influence of grazing.

Table 4. Physico - chemical properties of Busia waters

Sample	pH	EC (µS/cm)	Turb. (NTU)	Oxygen mbar
BA1	7.03	168.5	28.22	159
BA2	8.84	700	718.9	196
BA5	7.44	1822	150	75
BA6	8.41	112.9	149	149
BA7	8.06	109	40.19	165
BA8	6.92	220	29.76	106
BA9	6.31	219	25.65	78
NEMA (MPL)	6.0 - 8.0		300	
WHO Guidelines	6.5 - 8.5	400		

Heavy Metals

Water

The metal contents of water from the sampled areas are given in Table 5 and are compared to the NEMA maximum permissible contents in industrial effluent. In Nakivubo

Table 5. Heavy metal contents (in mg/l) water

Nakivubo Channel								
Sample	**Cu**	**Pb**	**Zn**	**Cd**	**Cr**	**Ni**	**Co**	**Mn**
NC1-A	0.02	0.06	0.01	0.001	<0.01	0.01	0.08	1.2
NC2	0.01	0.01	0.01	0.012	<0.01	0.01	0.08	0.25
NC5	0.01	0.01	0.01	0.001	<0.01	0.03	0.04	0.03
NC5-B	0.01	0.06	0.01	0.001	<0.01	0.03	0.06	0.46
NC7	0.01	0.01	0.01	0.001	<0.01	0.01	0.07	0.81
NC9	0.01	0.22	0.02	0.001	<0.01	0.05	0.11	0.45
NC10	0.02	0.26	0.06	0.014	<0.01	0.13	0.16	0.44
NC11	0.01	0.11	0.12	0.001	<0.01	0.03	0.09	0.82
NC12	0.01	0.06	0.01	0.001	<0.01	0.01	0.07	0.79
NC15	0.01	0.24	0.01	0.001	<0.01	0.05	0.11	0.59
NC16	0.01	0.11	0.04	0.009	<0.01	0.05	0.06	0.07
NC20	0.01	0.01	0.01	0.01	<0.01	0.01	0.06	0.05
NC22	0.01	0.01	0.01	0.01	<0.01	0.03	0.08	0.58
NC23	0.01	0.01	0.01	0.014	<0.01	0.01	0.06	0.01
Kinawattaka Stream								
KW2b	0.06	1.44	0.01	0.001	0.02	0.01	0.06	1.17
KW3	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.85
KW5	0.01	0.01	0.01	0.018	0.01	0.01	0.01	0.4
KW6	0.01	0.28	0.01	0.016	0.01	0.01	0.01	1.04
KW7	0.01	0.01	0.01	0.012	0.01	0.01	0.01	0.93
KW8	0.01	0.13	0.01	0.014	0.01	0.01	0.01	0.91
KW9	0.01	0.01	0.01	0.009	0.01	0.01	0.01	0.42
KW10	0.01	0.09	0.01	0.013	0.01	0.01	0.01	0.7
Jinja								
JA1	0.01	0.01	0.01	0.019	0.01	0.01	0.05	0.04
JA2	0.01	0.01	0.01	0.014	0.01	0.01	0.01	0.23
JA4	0.02	0.01	0.01	0.019	0.01	0.04	0.01	0.26
JA6	0.01	0.01	0.01	0.015	0.01	0.01	0.01	0.01
JA7	0.01	0.01	0.01	0.018	0.01	0.01	0.01	0.03
JA10	0.02	0.26	0.01	0.014	0.02	0.07	0.16	0.35
JA11	0.01	0.1	0.01	0.001	0.01	0.01	0.05	0.01
Busia								
BA1	<0.01	0.03	<0.01	<0.001	<0.01	<0.01	0.01	0.03
BA6	<0.01	0.01	<0.01	<0.001	<0.01	<0.01	0.01	0.01
BA7	<0.01	0.09	<0.01	<0.001	<0.01	<0.01	0.05	0.02
NEMA MPL	1	0.1	5	0.1	1	1	1	1
WHO	0.1	0.05		0.005		0.05		

Channel, most of the samples from all the areas are below the NEMA maximum permissible levels for effluent for all the analysed heavy metals apart from lead. Three samples from Nakivubo Channel (NC9, 10 and NC11) have unacceptable values for Pb (0.06 to 0.24 mg/l). NC9 is after the effluent of National Water and Sewerage Corporation (NWSC), NC 10 from a hides and skins processing plant and NC 11 is effluent below several industries including Uganda Batteries Ltd (Fig 2).

Three samples (KW2b, KW6 and KW8) from Kinawattaka stream have more than acceptable values for Pb in the Ntinda-Nakawa industrial area. The highest value of 1.4 mg/l (KW2b) is from the blue effluent of the Kampala Pharmaceutical Industry and is over ten times the NEMA guidelines for effluent discharge. KW 6 is effluent from Ntinda Industrial area and KW 8 is below Oxygas (oxygen and acetylene plant).

Two samples from Jinja (JA10 and JA11 downstream of a former copper smelting plant) have higher than acceptable values for Pb (0.1 - 0.26 ppm).

All water samples from Busia have metal contents below NEMA acceptable limits and WHO guidelines values.

Soil and sediments

The distribution of heavy metals in various materials sampled from the wetlands is shown in Table 6 and compared to average values of an uncontaminated shale (Foerstner & Wittmann, 1979).

At the source of the Nakivubo Channel (Bat Valley area) there are elevated levels of Pb (35.9 ppm) and Cr (119.6 in the sediments (sample NC 1). The same applies to a sample after Mukwano Industries (about 30 m downstream) with 50.7 ppm Pb and 156.9 ppm Cr (sample NC 5). Samples from below the National Water and Sewerage Corporation (NC9), Easthide hides processing plant (NC 10) and effluent from Uganda Baati (various steel products), Uganda Batteries and Casements Ltd. (assorted metal frames) (NC 11) are also enriched in Pb (74.4 –157.2 ppm). The sediments after the paint-packing factories (NC 10), upstream of Mukwano Industries (NC 2) effluent from Uganda Batteries and other industries (NC 11), contained elevated values Zn (158 – 1641 ppm) and Cr (79.1 ppm).

Along Kinawattaka stream, there are high values of Pb in sediments from upstream of the Industrial Area below a petrol station supplying leaded fuel (KW 3), downstream of Britania food and Hwang Sung fish processing plants and SWT tanners - dealers in hides and skins - (KW 5) and at Oxygas (oxygen and acetylene gas plant) (KW 8) ranging between 30.8 and106.7 ppm. Samples KW 3 and KW 5 also have high concentrations of Cr (116.2 and 153.2 ppm respectively. The sediments from around Oxygas have enriched concentration of Cd (0.56 ppm) and Zn (589 ppm). Sediments taken from where runoff from a vehicle washing bay (KW 9) joins the stream shows elevated contents of Zn (175.9 ppm).

Table 6. Heavy metals (in ppm) in sediments

Sample	Cu	Pb	Zn	Cd	Cr	Ni	Co	Mn
Nakivubo Channel								
NC1	18.6	35.9	47.8	<0.001	119.6	15.7	7	226
NC2	18.9	23	158.4	<0.001	63.3	8.2	4	141.5
NC5	24.8	50.7	73.9	<0.001	156.9	14	8	594
NC7	16	21.3	101	<0.001	79.1	10.2	3.8	101.8
NC9	11.5	28.2	66.3	<0.001	58.6	10	3.4	104.4
NC10	24.9	157.2	1641	<0.001	93.1	22.3	9.8	250.3
NC11	24.3	74.4	229	<0.001	270	19.8	9.4	245.2
NC12	9.5	20.5	68.2	<0.001	41.8	10	5.4	123.8
NC15	12.2	21.7	18.3	<0.001	57.6	10.3	6	210.3
Kinawattaka stream								
KW3	20.2	30.8	41.4	0.001	116.2	19.7	9.8	438.6
KW5	24.9	31.4	57.3	0.194	153.2	19.8	9.7	230.4
KW6	14.9	16.2	38.9	0.077	83.3	11.7	4.7	155.6
KW7	7.6	17.6	9.8	0.001	14	9.1	2.8	141.8
KW8	24.7	106.7	589	0.564	54.9	24.6	9.4	478.5
KW9	17.8	26.7	175.9	0.171	39.9	17.7	5.6	166.7
KW10	8.9	20.5	71.7	0.086	22	11.7	10.3	625.5
Jinja								
JA2	4.2	0.2	30	0.001	2.3	0.7	0.4	36.1
JA7	75.6	15.9	78.8	0.403	271	80.3	46.5	1358
JA10	142.3	14.1	72.1	0.34	102.9	84.7	26.4	512.9
Busia								
BA1	17.3	2.9	7.5	<0.001	19.7	12.1	7.6	583.9
BA6	11.7	2.5	9	<0.001	75.1	16.5	7.7	259.7
BA7	1.7	0.9	2.9	<0.001	12.9	2.4	1.7	85.1
Shale standard*	45	20	95	0.3	90	68	19	850

* After Foerstner & Wittmann (1979)

In Jinja, a sediment sample (JA7) picked on the shores of Lake Victoria below the leather tannery has high concentrations of Cr (271 ppm), Cu (75.6 ppm), Ni (80.3 ppm) and cobalt (46.5 ppm). A sample (JA10) on the trail for the copper slag from the smelter that was picked from the fringes of the Kirinya wetland at Masese has elevated values of Cu (142.3 ppm), Cr (102.9 ppm), Ni (84.7 ppm) and Co (26.4 ppm).

The Berkeley Bay in Busia wetland is pristine. All the sediments sampled from rivers draining the wetland plus the Lake Victoria sediment samples have low concentrations of Cu, Pb, Zn, Cd, Cr, Ni and Co.

Mercury

Because of the toxic nature of mercury, selected samples were analysed for mercury. These were samples that had shown high metal contents in Kampala and Jinja, and from Busia. The results are given in Table 7.

Table 7. Mercury contents in sediments

Sample	THg ng/g dw
Nakivubo Channel	
NC1	65.6
NC2	37.8
NC5	108.1
NC10	95.1
Jinja	
JA 7	64.8
JA 10	19.4
Busia	
BA 1	41.4
BA 6	28.0
BA 7	33.4

Normal soils have Hg concentrations around 100 ppb dw and only the sample NC5 (108.1 ng/g dw) which was collected after Mukwano Industry exceeds the value.

Fish

Fish samples could only be located from a few places along Lake Victoria shores close to Nakivubo channel. The results are given in the Table 8 below.

Table 8. Mercury content in fish

Sample	THg (ng/g) dw
NC15(1)	28.3
NC15(1)	32.7
NC15(3)	38.9
NC15(4)	28.5
NC17	20.3

The European Commission recommends a limit of 0.5-1 ppm (500 – 1000ng/g) Hg in fish. The Hg concentrations determined in the fish samples are below the limit value.

DISCUSSION

The European Commission recommends a limit of 0.5-1 ppm (500 – 1000ng/g) Hg in fish. The Hg concentrations determined in the fish samples are below the limit value.

The buffering capacity of any wetland (Okurut *et al*. 2000) can indirectly be monitored by the measurement of its physical parameters (pH, EC, Eh, NTU, oxygen content and temperature). This can be augmented the determination of the heavy metal uptake by the various species in the wetland (e.g. fish, plants). Different organisms may have tolerable levels for the different heavy metal concentrations. Deficiencies can cause some deformities and some high concentrations are stressful or toxic and in extreme circumstances they become fatal.

Water

In this investigation, some hotspot areas with anomalous values of physico-chemical parameters have been identified. High pH values occur in the effluent from Uganda Breweries Ltd. The basic water may have an effect on organisms sensitive to high pH.

High EC values exceeding EC guidelines for drinking water are recorded in several locations including effluent from downtown areas, downstream of Mukwano Industry, within the Industrial Area both along Nakivubo Channel and Kinawattaka stream. The highest value of EC was measured in effluent from Easthide skin processing plant indicating high Total Dissolved Solids (TDS) emanating from the chemicals used in the tanning process. In Jinja, high EC values occur in water around the NWSC water treatment plant and downstream of the former copper smelting plant. Most industries in Jinja release their effluent in the NWSC sewer network and this could explain the presence of relatively high TDS in the treated sewage. High TDS downstream of the former copper smelter would originate from metals released from the slag stockpile that was left behind after operations ceased. The high TDS at one site in Busia where there is no industrial activity may be due its being a watering point for cattle. High TDS may be a result of decomposition of faeces releasing phosphates and nitrates.

Most of the heavy metals are below maximum permissible limits for both NEMA and WHO. In the Nakivubo Channel samples with Pb values exceeding the WHO limits include samples from National Housing Corporation housing estate, downstream of Uganda Batteries Ltd. and NWSC effluent. This could be ascribed to lead from PbO paints, battery manufacture and dilapidated lead sewage pipes. Along Kinawataka stream, samples with high Pb values are from the Kampala Pharmaceutical Industry (1.4 mg/l – being 14 times the NEMA acceptable value for effluent) and the Ntinda-Nakawa industrial area. The Pb could be originating from the leaded fuel in the industries and the chemicals used in manufacture of drugs that may contain Pb-organo compounds. Disposal sites for old batteries left at petrol stations are not known and these could also contribute to the Pb. In Jinja, high Pb contents are recorded in samples from downstream of the former copper smelter. The Pb could be originating from slag that was left behind. Some could be coming from the fuel used to operate the crushers and other equipment at the nearby amphibolite quarry in Masese

This could be ascribed to the leaded fuel used in the industries spilling over into the effluents.

Heavy Metals in Sediments

Lead

The Pb levels in some sediments around the Uganda Batteries and metal frames factories are relatively high and they need to be thoroughly investigated. Although Pb is expected to have low phytotoxicity (Chino, 1981) because of its strong affinity to organic matter, when environmental conditions e.g. change in pH, it may become mobile. The area downstream is heavily cultivated. This may go into the food chain. Two samples of fish are between 1.2 to 5 times higher than acceptable values of 1 ppm Pb.

A remedy must be sought for the Pb levels in the effluents of the industries where the metal is high in effluents. The use of leaded fuel is expected to stop at the end of 2006.

Copper

The average Cu content in soils/sediments is considered to be about 30 ppm. The Cu analyses in the present study are within acceptable range, except for the samples from the copper slag trail in Jinja, which show elevated Cu levels. Although copper toxicity in humans is rare, aquatic organisms are potentially at risk from Cu exposures (Adriano, 2001). Given that areas showing high Cu concentrations are on the fringes of the lake, mitigation measures are required to reduce Cu inflow into the lake. The fish samples analysed, however, have Cu concentrations below maximum permissible values.

Zinc

The average concentration of Zn in soils/sediments is 90 ppm. The sediments collected from around Uganda Baati (galvanised iron sheets factory), effluent of Ntinda – Nakawa Industrial Area have high concentrations of Zn. The factories upstream dealing in galvanised scrap may be releasing Zn into the effluent.

Zn is an essential macronutrient for plants but is phytotoxic when in excess. Phytotoxicity may cause decreased crop yield and quality and likelihood of Zn transfer into the food chain (Adriano, 2001).

Cadmium

The average Cd content in soils is 0.35 ppm. The sediments sampled during this investigation have lower values except samples associated with the former Cu smelter and industrial operations involving Zn scrap. A sample taken slightly away from the mouth of Nakivubo Channel into Lake Victoria has 1.9 ppm for Cd. This was mostly peat got from rotten *Cyperus papyrus*. The organic matter there was capable of complexing with Cd especially from the sewage sludge.

Cadmium is a non-essential element. It is both bioavailable and toxic. It interferes with metabolic processes in plants and can bioaccumulate in aquatic organisms and enter the food chain (Adriano, 2001). Though the concentrations obtained are not extremely high, effluents from locations where elevated values are obtained should be treated before discharging into the environment.

Chromium

The average Cr concentration in soils is reported to be 40-50 ppm. Some samples in this study had high Cr concentrations, possibly due to Cr released in the effluent during industrial operations, pharmaceutical industry and from the former Cu smelter.

In most soils, Cr phytotoxicity is expected from Cr (VI) as it may interfere with nutrient metabolism of plants causing stunted growth, poorly developed root systems and discoloured leaves (McGrath, 1991). When it enters the food chain, Cr (VI) is toxic to humans. The effluents with high Cr contents should be treated before discharge.

Nickel

The average Ni concentration in soils/sediments is reported as 20 ppm. High Ni concentrations are associated with the Cu smelting. The Cu slag is still rolling downhill up to the wetland and therefore impacting on it.

Although Ni is relatively less toxic to invertebrates, it can be toxic to aquatic organisms such as reduction in skeletal calcification and diffusion capacity of gills (Moore, 1991). The runoff from the slag may therefore affect fish in the lake.

Cobalt

The average abundance of Co in soils/sediments is around 8 ppm (Adriano, 2001). Apart from samples taken around the former Cu smelter, the majority of the analysed sediments have concentrations within this acceptable range. High Co concentrations are attributed to the breakdown of the sulphides associated with the Kilembe ore that was smelted at Jinja.

Cobalt is relatively non-toxic animals and man and deficiency of Co is of far greater concern than potential toxic levels in plants (Smith, 1990).

Manganese

The average abundance of Mn in the shale standard is 850 ppm. The Mn concentration for the sediments that were analysed, except a sample from around a tannery in Jinja, is below this value indicating that the Mn in sediments could be due to lithological variations. The high Mn value seems to be related to tanning activities.

Mercury

Normal soils have Hg concentrations around 100 ppb DW. The sediment samples which were analysed fall within the above value apart from a sample picked after Mukwano Industry. It is possible there is a bit of Hg additive in the soap manufactured in the industry. As pointed out by Campbell et al. (2003), use of beauty creams containing high inorganic Hg concentrations, may pose a threat to THg exposure.

The Hg concentrations determined in the fish samples are below the limit value. There is therefore no threat of Hg contamination. Average values have been found to be between 24.2 to 35.4 THg (ng/g WW) in the *Protopterus aethiopicus* (Lung fish) indicating that Hg concentrations in fish were below WHO concentrations and international marketing limits (The European Commission recommends a limit of 0.5-1 ppm Hg in fish). Campbell et al. (2004) observed that the low THg concentrations in fish were attributed to the storage capacity, high oxygen concentrations and high organic matter content. They, however, caution that this should not be taken for granted as the storage capacity and the methylation rates present in the wetlands of are unknown and the gradual accumulation of THg contamination from other sources (e.g. atmospheric THg) may result in unexpected THg increases in the biota.

CONCLUSIONS

Physico-chemical Parameters

Along the Nakivubo Channel, most physico-chemical parameters are within acceptable limits. Notable is high pH in effluent from Uganda Breweries Ltd. probably due materials used in beer brewing and high EC related to high metal loads from Hides and Skins plant which indicates high ionic concentrations while only effluents after Mukwano Industries and Easthide had high turbidity. The high turbidity is ascribed to sewage and effluent from skin tanning.

Along Kinawattaka stream industries along Jinja road contribute to metal loading into the water resulting into high EC values. In the wetlands, low values of oxygen are likely to be due decomposition of organic matter. In Jinja the high EC values in NWSC wastewater and runoff from the former copper smelting plant indicate that metals from contained in the slag enter the lake. NWSC treatment plant does not remove inorganic pollutants which result in high EC. Although the Busia wetlands exhibit normal levels of physico-chemical parameters and thus are pristine or little disturbed, one site had a high EC value which is probably due to the influence of grazing.

Heavy Metals

Water

Along Nakivubo Channel, the metals of concern are Pb and Cr especially below the NWSC sewage treatment plant and Easthide hides and skin factory which correlates with the high EC contents. Apparently the Cr-containing chemicals used for skin tanning ends up in the environment. Along Kinawattaka stream, high Pb values seem to be associated with pharmaceuticals and the acetylene gas plant. In jinja, high Cu and Pb are linked to the former Cu smelter.

Soils/Sediments

Just as in water, along Nakivubo Channel high Pb and Cr contents occur near the skin and hides factory but also near petrol stations and factories of steel products. Zinc and Cr is also relatively high in the industrial area where there are paint industries. This is likely to be due to pigments used in the paint industry. Along Kinawataka stream, Zn is high near a washing bay while soil near the acetylene plant has high Cd contents. In Jinja, the tannery contributes to Cr pollution while the former Cu smelter is responsible for Cu loading into the soils. Industries whose effluent is heavily loaded with heavy metals should first treat their effluent before it is discharged into the environment.

Mercury

Mercury concentrations both in soils and fish are tolerable with only one sample having slightly higher than normal contents. The fish is at the moment safe although fish is known to bioaccumulate mercury.

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REFERENCES

Adriano, D.C. (2001): Trace elements in terrestrial environments: Biochemistry, bioavailabilty and risks of metals. Springer Verlag. 867 pp.

Chino. M, 1981: In: Kitagishi, K. & Yamane, I. Eds. Heavy metal pollution in soils of Japan,. Japan Sci. Coc. Proc.

Foestner, U. & Wittmann, G.T.W. (1979); Metal pollution in the aquatic environment. Springer, Heidelberg, 486pp.

Haskoning – CMS, 2001a, Lake Victoria Environmental Management Project, cost benefit analysis of wetlands resources Uganda, Part III: Wetland characteristics and development scenarios, Final Report; Delt Hydraulics.

Haskoning-CMS, 2001b, Lake Victoria Environmental Management Project, cost benefit analysis of wetlands resources Uganda, Part IV: Economic analysis, Final Report; Delt Hydraulics.

Kansiime, F., Kateyo, E. and Okot-Okumu, J., 1995, Effects of pollution of inner Murchison Bay, Lake Victoria, Uganda, on the distribution and abundance of plankton.

Kansiime, F., Nalubega, M., Van Bruggen, J.J.A and Denny, P., 2003, The effect of wastewater discharge on biomass production and nutrient content of cyperus papyrus and miscanthidium violaceum in the Nakivubo wetland, Kampala, Uganda; water science and Technology, Vol. 48, IWA publishing, 233-240

Linda M Campbel, L.M.l, Dixon, D.G. & Hecky, R.E. (2003): A review of mercury in Lake Victoria, East Africa: Implications for human and ecosystem health. Journal of Toxicology and Environmental Health, **Part B, 6**:325–356,

Linda M Campbel, L.M.l, Balirwa, J.S., Dixon, D.G. & Hecky, R.E. (2004): Biomagnification of mercury in fish from Thruston Bay, Napoleon Gulf, Lake Victoria (East Africa). African Journal of Aquatic Science*,* **29(1)***: 91–96*

Mafabi, P., Kakuru, W., Arinaitwe, J. and Kizito, Y., 1998, Wetlands resources subsector component stocktaking report on Uganda's biodiversity strategy and action plan, (BSAP).

McGrath, S.P. & Smith, S. (1990): Chromium and Nickel, In: Alloway, B.J. (ed.). Heavy metals, p. 125 - 150, Blackie, Glasgow.

Moore, J.W. (1991): Inorganic Contaminants in surface water. Sprenger Verlag, New York

Mott MacDonald, 2001, Lake Victoria Environmental Management Project, Management of industrial and municipal effluents and urban runoff in the Lake Victoria basin, final report, Vol. 1, main report, NWSC, Ministry of Water, Lands and Environment.

Namakambo, N., 2000, Kampala wetlands; National Wetlands Programme.

Swallow, B.M., Walsch, M, Mugo, F., Ong, C., Shepherd, K., Place, F., Awiti, A. Mwangi, H., Ombalo, D., Ochieng, O., Mwarasomba, L., Muhia, J., Nyantika, D., Cohen, M., Mungai, D., Wangila, J., Mbole, F., Kiara, J. and Eriksson, A., 2001, Improved land management of the Lake Victoria basin: Annual technical report.

Okurut, T., Kansiime, F., Busulwa, H., Mwebembezi, L., Malinga, A. and Barugahare, V., 2000, Lake Victoria Environmental Management Project, Wetlands Component, Buffering capacity of wetlands sub-component: Buffering capacity of Kinawataka and Kisoma wetlands report; Ministry of Water, Lands and Environment.

Smith, K.A. (1990): Manganese and Cobalt, p.197-221 In Alloway A J.(ed). Heavy metals in soils, Blackie, Glasgow.