Selected trace metal concentration in bottom water and sediments of Kyoga basin lakes, and its potential to aquatic pollution

By

Ocaya Henry

Senior Research Technician – Water Environment

November 2010

1.0 Introduction

Although other research studies on areas such as the physical-chemical, nutrients and phytoplankton status of Lake Kyoga systems have been given a lot of attention (e.g. Mungoma 1988 and NaFIRRI 2006)**,** efforts to determine the pollution status of this system, especially by heavy metals as one of the worldwide emerging environmental problems, is still limited. Many trace metals are regarded as serious pollutants of aquatic ecosystems because of their persistence, toxicity and ability to be incorporated into food chains (Mwamburi J., and Nathan O.F., 1997). Given the rapid human population growth and the associated economic activities both within the rural and urban areas in Uganda, such fish production systems are becoming very prone to various kinds of pollution including that by heavy metals. Anthropogenic factors such deforestation, use of chemicals and dumping of metallic products, spillages of fuels from outboard engines and many others and or natural processes involving atmospheric deposition by wind or rain, surface run-offs and streams flows from the catchment introduces heavy metals into the lake environment,.

Lake Kyoga system which include lakes such as Kyoga main, Kwania, and other small ones e.g. Nawampasa and Nakuwa are located in an area which may expose them to some of the above factors and therefore such environmental problem may not be ruled out from this important fish production system. Cases of heavy metal pollution are reported as emerging from lakes like Edward in the Albertine region (Bugenyi and Lutalo-Bosa 1990) and inshore areas of northern Lake Victoria (Ogutu 1999, Ochieng 2006, Ochieng *et al*, 2008). Copper mining as well as the mushrooming of industries around Lakes Edward and Victoria, are just some of the human activities that contribute to emergence of heavy metal pollution in these water bodies. The need therefore, for an early investigation on metal pollution and intervention in other fish production systems such as the Kyoga system is necessary to conserve and protect these fisheries production systems from such environmental problem.

Heavy metals of principal interest in pollution biology are zinc, copper, lead, mercury, cadmium, nickel and chromium (Hellawell J. M,). The presence of these metals in an aquatic system can result in toxic pollution and water quality degradation. Bio concentration through the food chain (i.e. sediment to the invertebrates to fish and to man) presents a potential health risk to human beings who are the final consumers of the lake water and fish. This may impact on fish quality and the income generated both locally and through exports. Traditionally, most fisher and other riparian communities are only familiar and hear more about fish aspects e.g. fish catches but know little about environmental issues like heavy metal pollution of lakes, and its effects on the fish. As mentioned above, heavy metal pollution once introduced into the system will remain in place for several years. Generating this kind of environmental information and passing it to the concerned leaders e.g. BMUs and Fisheries Resource Officers, this would provide an opportunity of creating awareness among the entire fisher and other riparian communities of Lake Kyoga system on this emerging problem. Information on point sources, concentration ranges in sediments and water column and the trends in distribution in the entire lake environment is vital in characterisation of the lake and for developing management measures towards such kind of lake pollution.

The purpose of this study that led to preliminary data collections in the months of January 2006, December 2008, February 2009, April 2009, April 2010, May 2010 and June 2010 by NaFIRRI, was specifically to investigate the status of heavy metals (copper, Cu; Zinc, Zn; Lead, Pb iron; Fe) in bottom water and sediments of Lake Kyoga system and relate the information to the safety of Lake Environment and its fisheries.

2.0 Objective of the study

The major objective was to generate baseline information on levels of heavy metals in the Lake Kyoga system as part of safeguard towards its water environment and the associated fisheries.

2.1 Specific objective

a) To establish the concentration levels of selected metals (copper, zinc, lead and iron) in both the sediments and bottom water from the entire zones of the lakes;
b) To relate the concentrations of these elements in the lake environment to present environmental quality and safety of the fisheries.

3.0 Materials and methods

3.1 Study area

The study covered four lakes namely Lakes Kyoga, Kwania and the selected nearby small ones like Nawampasa and Nakuwa (Fig. 3.1). It involved sampling from various sites randomly located while considering specific habitats such as river inlets, near shore and open waters within each lake. For this case, near shore and open water sites were within a range of 150-1500 m and >1500 m, respectively. The eastern zone of Lake Kyoga composed of sites such as Pingire, Kaita, Mugalama, Mulondo, Kakoge and Nkondo, while the central consisted of Kiwantama, Muntu, Kyankole and Kawongo. Kiguli, Zengebbe. Lwampanga, Kayago and Namasale, were the sites on the west of Lake Kyoga (Fig. 3.1). Lake Kwania had Kacung on the east, Chawente and Atuma in central, and Kakoge, Apalamio and Pabo in the west. Sampling sites in Lake Nawampasa were Kyanzire, Namalogwe and Nkodokodo, whereas those of Lake Nakuwa were Namawa, inlet of River Mpologoma, Nangala, Nkalala, Opeta near shore and off shore sites (Fig 3.2).

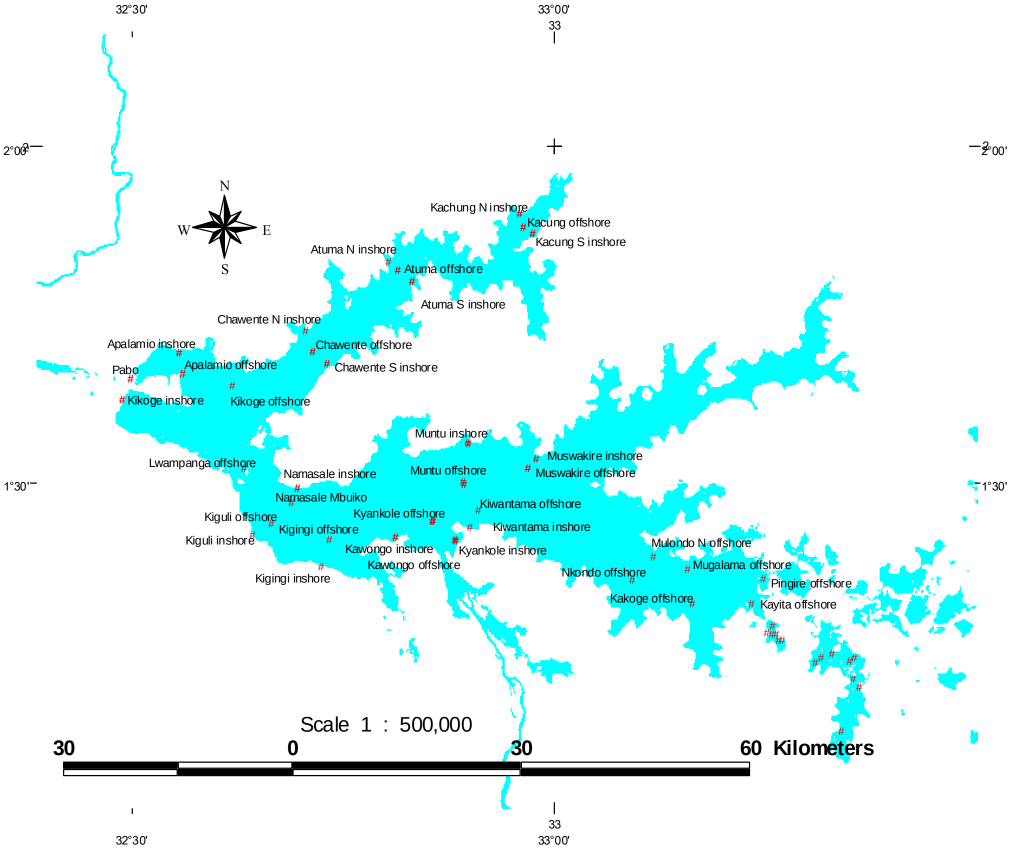


Fig. 3.1 Sampling sites on Lake Kyoga system during pollution survey of 2006 – 2010

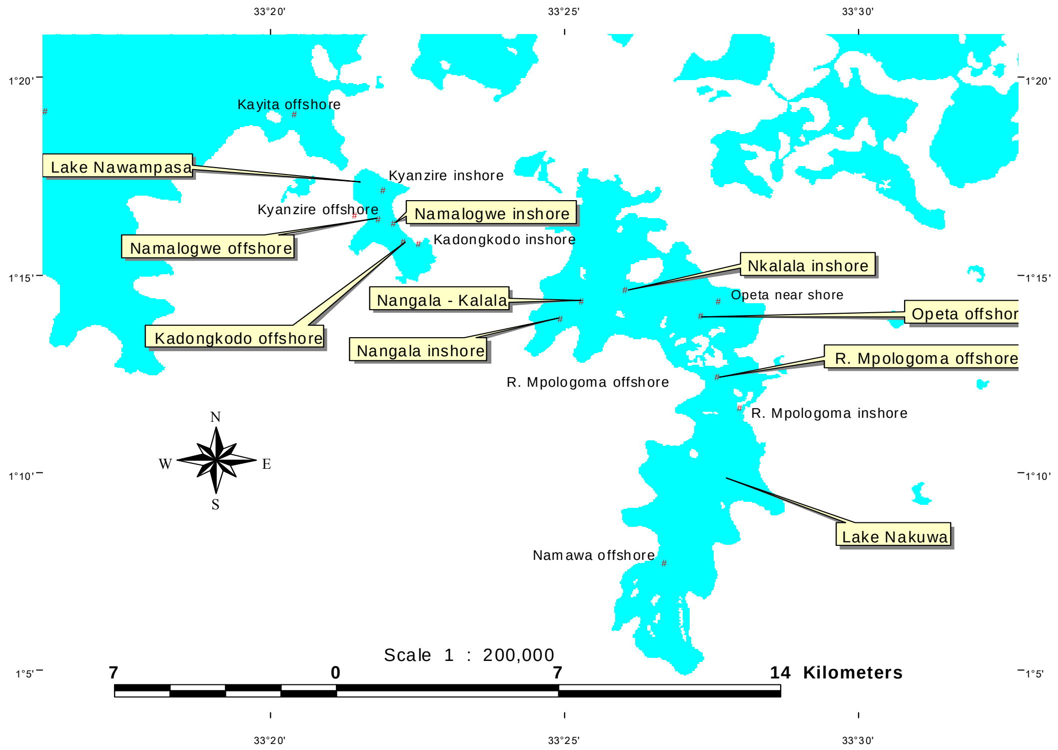


Fig 3.2 Sampling sites on Lake Nakuwa and Nawampasa during pollution survey of 2009

3.2 Sampling and analytical procedures

At each site, three sediment samples were collected using a petite Ponar grab. Sediment samples were combined to form a composite and thoroughly stirred to attain homogeneity. A small portion of about 250 g was placed in black polyethylene bag and taken to NaFIRRI for analysis. Analyses for selected metals (copper, Cu; zinc, Zn lead; Pb, calcium, Ca, magnesium, Mg and sodium, Na were done following specified methods (APHA 1992, UNESCO-IHE 2005). One-Way ANOVA in combination with Tukey HSD as Post Hoc Test (alpha = 0.05), under SPSS 11.0 for windows, was used to detect for significant differences in heavy metal concentrations only within the larger lakes of Kyoga and Kwania, and also among all the four sampled lakes.

4.0 Results

4.1 Sediment

Cu ranged between 0 – 51µg/g DW. The highest concentration of 51.0µg/g DW was in Lake Kioga and this appeared as being beyond what is reported for unpolluted sediment (33µg/g DW).

Lake Kwania did not have any trace of Cu. Zinc in sediment ranged between 0 to 133µg/g DW with highest concentration noted in Lake Kioga. Lakes Kwania, Nakuwa and Nawampasa all had traces of Zn which however, were within the range for unpolluted lake sediments (95µg/g DW). Total Iron in sediment ranged between 10140µg/g DW to 98930µg/g DW. The highest Total Fe in sediment was observed in Lake Kioga. Sediment Fe concentration appeared to be within the range for unpolluted sediment (41,000µg/g DW). Lead which is considered the most environmentally toxic of all the other metals analyzed was however not detected in all the sediment samples. The reported concentration in unpolluted sediment however is 19µg/g DW, which therefore means that the sediment were still free of this toxic metal. A summary of the sediment heavy metals concentrations are shown in Table 1 below. The mean concentrations and corresponding standard deviations for each lake are also shown in figures 1 – 3 below.

		N	Mean	Std. Deviation	Minimum	Maximum
Cu	Kioga	72	18.8	10.8	0.0	51.0
	Kwania	12	0.0	0.0	0.0	0.0
	Nakuwa	10	15.8	6.9	0.0	25.0
	Nawampasa	5	12.4	7.8	0.0	20.0
	Total	99	15.9	11.3	0.0	51.0
Zn	Kioga	72	47.8	27.2	0.0	133.0
	Kwania	12	45.0	26.8	0.0	90.0
	Nakuwa	10	69.0	16.3	50.0	90.0
	Nawampasa	5	68.0	14.4	50.0	90.0
	Total	99	50.7	26.6	0.0	133.0
Fe	Kioga	72	36239.6	22396.6	10140.0	98930.0
	Kwania	12	29623.3	24895.1	12180.0	91700.0
	Nakuwa	10	37075.6	25853.2	11422.0	76440.0
	Nawampasa	5	32238.6	12453.2	16533.0	45330.0
	Total	99	35320.0	22496.3	10140.0	98930.0
Pb	Kioga	72	0.0	0.0	0.0	0.0
	Kwania	12	0.0	0.0	0.0	0.0
	Nakuwa	10	0.0	0.0	0.0	0.0
	Nawampasa	5	0.0	0.0	0.0	0.0
	Total	99	0.0	0.0	0.0	0.0

Table 1 Summary of the corresponding sediment heavy metal concentrations in the four lakes

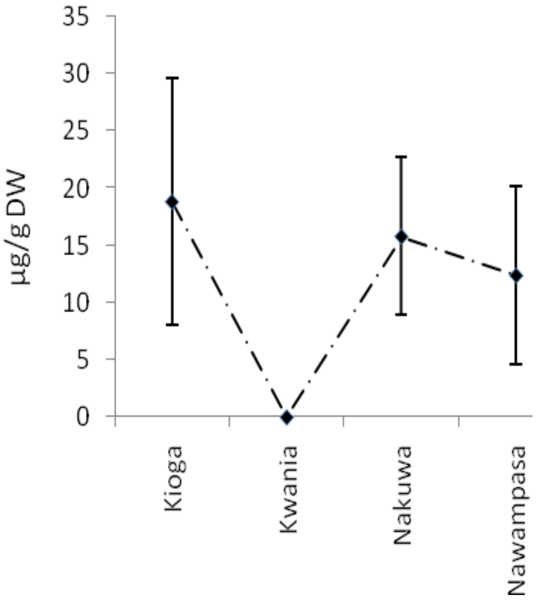


Fig 1 Mean Cu in sediment

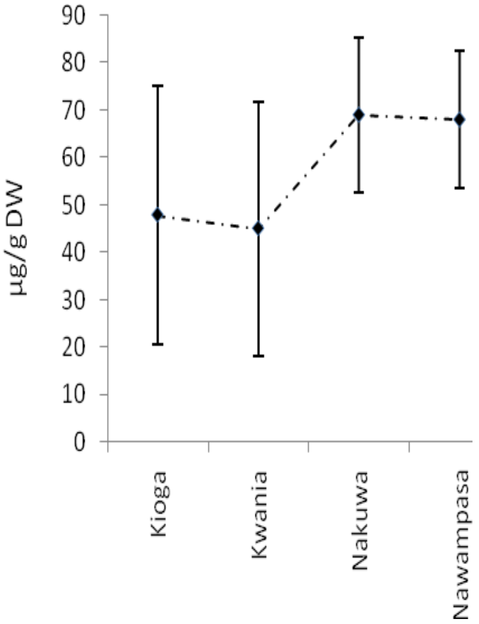


Fig 2 Mean Zn in the sediment

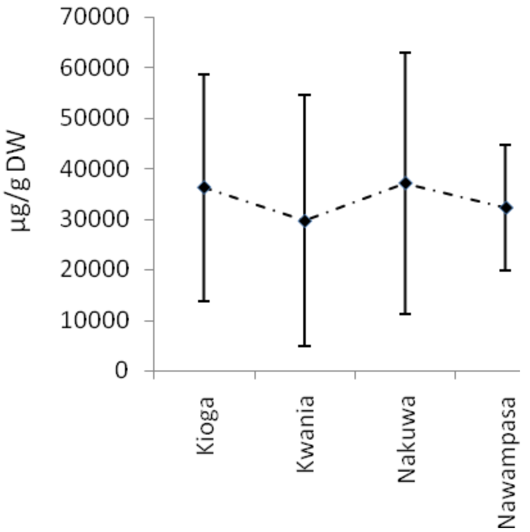


Fig 3 Fe in sediment

When a One way statistical test for ANOVA was done the result showed that there was no significant difference in sediment heavy metal concentrations in the four lakes ($P < 0.05$). Comparison for heavy metal concentrations according to zones was done and the observations are shown in figures 4 – 7 below. According to the results the Eastern zone of Lake Kioga had the highest Cu concentration (24.7 ±11.7 µg/g DW) where as Lake Kwania did not have any traces of it (Fig 4). Some traces of Cu were detected in the zones of Lake Nawampasa. The observed concentrations in all the four lakes however were still within the range for unpolluted sediment (33µg/g DW). Zn in all the four lakes did not vary so much from each of the sampled lakes (Fig 5). However the mean concentrations were within the background level for unpolluted sediments (95µg/g DW). The highest mean Total Fe (40839.2 ± 22343.3µg/g DW) was observed in Kwania West and least in Kwania Central (Fig 6).

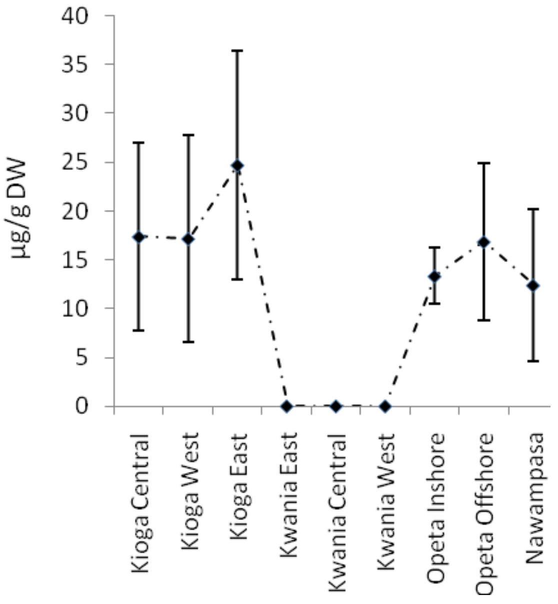


Fig 4 Cu variations according to lake zones

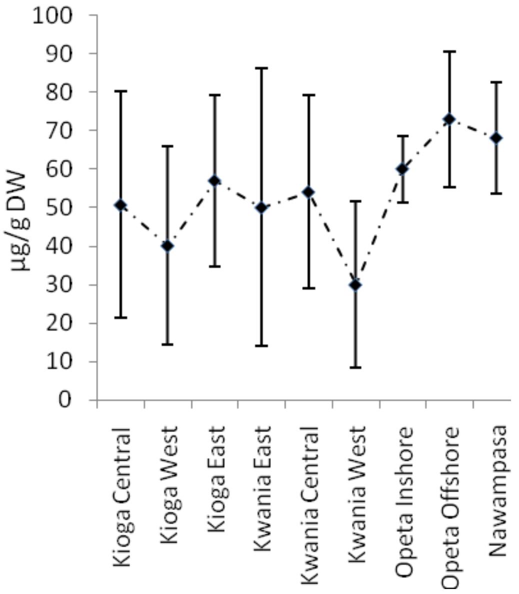


Fig 5 Zn in sediment according to lake zones

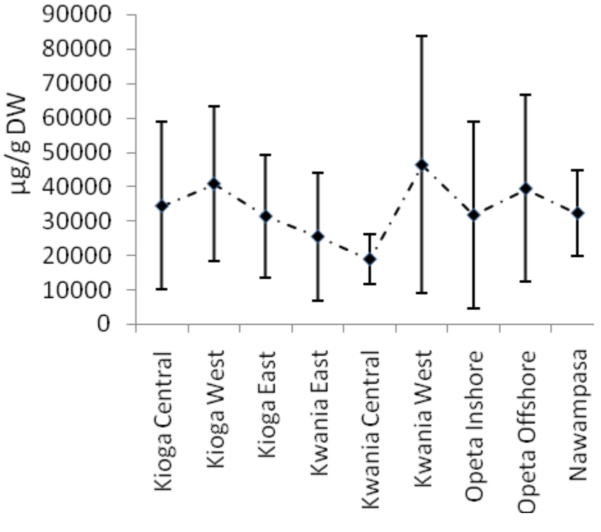


Fig 6 Fe according to the zones

A summary of mean concentrations according to the Zones are shown in Table 2 below.

		N	Mean	Std. Deviation	Minimum	Maximum
Cu	Kioga Central	29	17.4	9.78	0.0	30.0
	Kioga West	28	17.2	10.6	0.0	30.0
	Kioga East	15	24.72	11.76	10.0	51.0
	Kwania East	3	0.0	0.0	0.0	0.0
	Kwania Central	5	0.0	0.0	0.0	0.0
	Kwania West	4	0.0	0.0	0.0	0.0
	Opeta Inshore	3	13.3	2.98	10.0	15.0
	Opeta Offshore	7	16.8	8.09	0.0	25.0
	Nawampasa	5	12.4	7.8	0.0	20.0
	Total	99	15.9	11.3	0.0	51.0
Zn	Kioga Central	29	50.6	29.5	8.0	133.0
	Kioga West	28	40.1	25.9	.0	117.0
	Kioga East	15	56.9	22.4	22.0	103.0
	Kwania East	3	50.0	36.0	10.0	80.0
	Kwania Central	5	54.0	25.1	30.0	90.0
	Kwania West	4	30.0	21.6	.0	50.0
	Opeta Inshore	3	60.0	8.7	50.0	65.0
	Opeta Offshore	7	72.8	17.8	50.0	90.0
	Nawampasa	5	68.0	14.4	50.0	90.0
	Total	99	50.7	26.6	.0	133.0
Fb	Kioga Central	29	34349.4	24374.2	10634.0	98930.0
	Kioga West	28	40839.24	22343.3	10140.0	80700.0
	Kioga East	15	31308.04	17807.5	12396.0	77083.0
	Kwania East	3	25406.7	18541.4	12180.0	46600.0
	Kwania Central	5	18796.0	7337.1	13680.0	31730.0
	Kwania West	4	46320.0	37237.5	12930.0	91700.0
	Opeta Inshore	3	31685.0	27211.8	15422.0	63100.0
	Opeta Offshore	7	39385.8	27110.9	11422.0	76440.0
	Nawampasa	5	32238.6	12453.2	16533.0	45330.0
	Total	99	35320.0	22496.3	10140.0	98930.0
Pb	Kioga Central	29	0.0	0.0	0.0	0.0
	Kioga West	28	0.0	0.0	0.0	0.0
	Kioga East	15	0.0	0.0	0.0	0.0
	Kwania East	3	0.0	0.0	0.0	0.0
	Kwania Central	5	0.0	0.0	0.0	0.0
	Kwania West	4	0.0	0.0	0.0	0.0
	Opeta Inshore	3	0.0	0.0	0.0	0.0
	Opeta Offshore	7	0.0	0.0	0.0	0.0
	Nawampasa	5	0.0	0.0	0.0	0.0
	Total	99	0.0	0.0	0.0	0.0

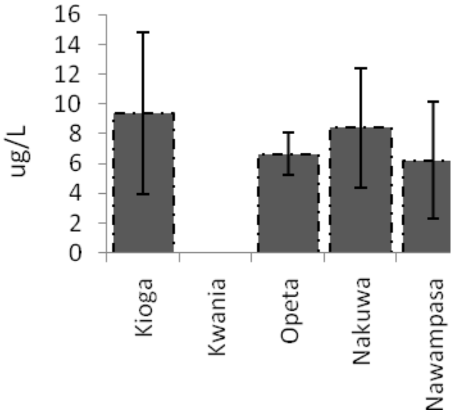
Table 2 Summary of mean sediment concentrations according to lake zones

When Post Hoc test using Tukey HSD statistical procedure ($\alpha = 0.05$) for multiple comparison of individual lake with the other lakes was done the following were the observations. There was a significant difference between Lake Nakuwa and Kwania ($P < 0.05$) with regard to mean Cu concentrations but not with the other Lakes. Tests for ANOVA showed that there was a significant difference between the five lake zones with regard to Zn concentrations but none with the other heavy metals. The implication to the observations is that the traces of Cu and Zn in these lakes are probably attributed to geological factor as well as the weathering processes.

Statistical test (Tukey HSD) between the lake zones showed that there was significant difference ($P < 0.05$) in Cu concentration between sediments got from Central and Western Kioga with that from the Central and Western Lake Kwania, but no significance with sediments from the other lake zones. This probably implies that central and western Kioga may share the same geological origin with the central and western portion of Lake Kwania. Tests for correlation showed that there were no significant correlations among all the zones particularly with regard to Cu, Zn and Fe.

4.2 Bottom water

The concentration of Cu in bottom water for all the five lakes ranged between 0 – 25.7 µg/L. The highest Cu concentration was detected in Lake Kioga (Fig 7). Cu concentration in all the five lakes was quite low below the WHO level of 2000µg/L considered to be of environmental health concern. Mean Zn concentration ranged between 0 – 66.7µg/L and the highest was in Lake Nakuwa followed by Lake Nawampasa (Fig 8). Lake Kioga and Kwania had lower Zn levels. All in all the concentration of Zn in sediment was quite low below the safe level of 3000µg/L for environmental health. The concentration of Total Fe in bottom water ranged between 507 – 4946.5 µg/L. The highest Total Fe was noted in Lake Nakuwa (Fig 9). Fe was however quite high above the aesthetic limit of 300µg/L by WHO standards. Test for ANOVA revealed no significant difference in the mean heavy metal concentrations in all the four lakes. However, Post Hoc Test using Tukey HSD statistical procedure for multiple comparisons showed that there was a significant difference in Cu concentration for Lakes Kwania and Nakuwa ($P < 0.05$) but not in the other Lakes. The implication to this however is that Cu was originating from natural sources such as weathering other than from anthropogenic sources.



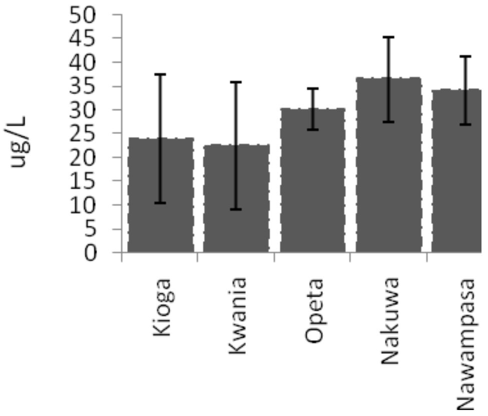


Fig 7 Cu in bottom water

Fig 8 Zn in bottom water

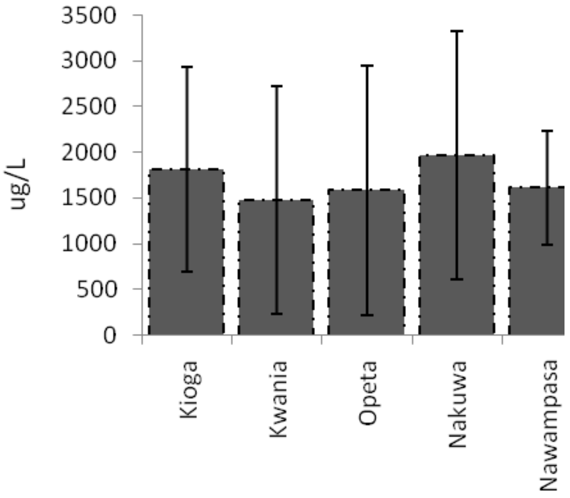


Fig 9 Fe in bottom water

5.0 Conclusion

The concentrations of Cu, Zn and Pb are still within the acceptable limit for environmental health. This means that the four Lakes may still be safe for fishery production in terms of any possible heavy metal contamination. Influence by human actions that could possibly introduce and thus enhance heavy metal concentration is still minimal as evidenced by the low occurrence of Lead below the detection limit. Although the possibilities of non point source pollution such as dry and wet atmospheric deposition, entry through other water bodies like the R. Nile and R. Mpologoma, surface run off from agricultural farmlands, wastes from household may all contribute altering the situation sooner than expected. Some of these trace metals (i.e. Cu, Fe, Zn) though considered essential micronutrients to both aquatic plants and animal life, they have the potential of exhibiting toxicity when in excess concentrations. The presence of heavy metals in the aquatic environment may impact on the physiology, anatomy behaviors of fish as well as the benthic organisms that the fish feeds on. This has direct influence on the food web. Heavy metals too have a major role on what goes on at the sediment bottom water interface. For instance Fe form complex compounds with Phosphorus that regulates the release of Phosphorus into the aquatic environment. These are just some of the reasons as to why it is vital for research to provide that information through regular and consistent monitoring surveillances so as effective and informed decision are made.

5.1 Limitations and recommendations

Field monitoring and investigation into the status and potential of heavy metal pollution is given less consideration if not none at all unlike the routine monitoring of nutrient enrichment and eutrophication when it comes to generating information to guide effective management of the fisheries production system. Moreover heavy metal pollution is one wide and relevant area of applied research under aquatic pollution that could be used to explain the complexity of water quality characteristics. Secondly, the potential to develop this unit of environmental research is lacking in modern instrumentation. The available skill and potential to generate data on key metals of environmental concern like Hg, Cr, As and others are not realized just for lack of support. It is an appeal to the current NaFIRRI leadership to deliberately consider this as a virgin area of applied and modern research that requires prioritization and full support in routine planning. Also that with the rapid environmental degradation currently taking place due to population increase, industrialization as well as the changes in the climate pattern there is need to establish a consistent database on the status of heavy metals in the aquatic environment that could help to characterize the lakes and provide advice to policy makers on the need to conserve and preserve the delicate lake ecosystems of Uganda.

References

1. American Public Health Association (APHA) (1992) Standard methods for the Examination of water and wastewater (18th edn), APHA, Washington, DC, pp 10–137.

2. Biney C, Amuzu AT, Clamari D, Kaba N, Mbome IL, Naeve H, Ochumba PBO, Osibanjo O, Radegonde V and Saad MAH (1994) *Review of pollution in the African aquatic environment.* In: Calamari D and Naeve H (Eds) CIFA Technical Paper, No. 25, Rome, FAO, 118pp.

3. Bugenyi FWB and Lutal-Bosa AJ (1990) Likely effects of salinity on acute copper toxicity to the fisheries of the lake George-Edward basin, *Hydrobiologia* 208: 39-44.

4. Hellawell J. M., ( ) Biological indicators of freshwater pollution and environmental management

5. Mungoma, S (1988) Horizontal differentiation in the limnology of a tropical river lake (Lake Kyoga, Uganda). *Hydrobio*. 162: 89-96.

6. Mwamburi J., Nathan O.F., (1997) The distribution and concentration levels of trace metals in water and sediments of Lake Victoria, Kenya.

7. NAFIRRI (2006) Technical report on environmental status of Lake Nakuwa.

8. NaFIRRI Baseline report 2007. A baseline survey of water and sediment quality, fisheries and invertebrates at Ngassa spit, Kaiso, Lake Albert. Prepared for Environmental Resources Management Southern Africa (Pty) Ltd (ERM) in association with Environmental Assessment Consult Limited (EACL) by the National Fisheries Resources Research Institute (NaFIRRI) August 2007, 78p.

9. NEMA (1999) State of the environment report for Uganda. Standards for discharge of effluent into water or on land, Statutory instruments No. 5 of Government of Uganda, 1999.

10. Ochieng H, Balirwa JS and Ocaya H (2009) Pollution in Lake Albert with special Reference to heavy metals, 7pp.

11. Oguttu WH (1999) Pollution from point sources into the urban wetlands of Jinja Municipality, Uganda. Msc thesis, Makerere University, 116pp. as indicators of pollution stress in northern Lake Victoria (Uganda). MSc. thesis, UNESCO-IHE, Delft, The Netherlands.

12. Piotrowski JK and Coleman DO (1980) Environmental hazards of heavy metals: Summary evaluation of lead, cadmium and mercury. A general Report, E.7/124, UNEP-Nairobi, 43pp.

13. UNESCO-IHE, Kruis F (ED) (2005) Laboratory manual on selected analytical methods: Environmental chemistry. UNESCO-IHE, Delft, Netherlands, 92pp.