Heavy metal pollution and nutrient levels in Lake Muhazi, Rwanda

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Abstract

Most tropical African lakes are facing problems of rapid population growth in the riparian communities, which normally discharges pollution loads into the lakes. This has led to the deterioration of water quality in receiving lakes. Some lakes are getting eutrophic whilst others are facing problems of siltation and heavy metal discharges, thereby reducing their economic and aesthetic values. Some lakes are experiencing a decrease in fish production. In Rwanda, generally the surface waters are full of sediments caused by soil erosion. The proliferation of water hyacinth and other aquatic weeds is now a common phenomenon. The reduction in lake water levels and low fish production are also main problems of lakes in Rwanda. In particular, Lake Muhazi has experienced a dramatic decrease in fish production since the eighties, typified by low water transparencies and high turbidities. The lakeshores are now being developed for ecotourism and this requires sound environmental management to make the planned activities viable.

The purpose of this study was to investigate the nutrient status of Lake Muhazi by assessing vertical and horizontal distributions of nutrients in the Lake. The parameters studied are nitrogen, phosphorous, chlorophyll a, and Secchi disc measurements. The nutrient levels were determined over a period of four months from July 2007 to October 2007. Four sampling stations were located within the lake and the sampling was done fortnightly. The samples were collected at depths of 0.5 m, 2 m, 5 m, and 1 m from the bottom of the lake. Samples were taken using a Van dorn Bottle water sampler and were analyzed for heavy metals, TP, TN, NO_2-N, NO_3-N and chlorophyll-a using the Standard Methods. Field measurements of temperature, transparency (Secchi disc), and pH were also measured. The results indicate that the nutrient levels in the Lake are higher than previously reported figures and urgent intervention is required. It was observed that the high nutrient levels in the lake are related to landuse activities in the catchment. It is recommended that farming practices and erosion be controlled on the catchment to contain pollutant discharges into the Lake.

Keywords: Lake water quality, Lake Muhazi, Landuse practice, Nutrient loading, Trophic status.

1.0 Introduction

The most common ways in which humans affect aquatic ecosystems is through altering nutrient dynamics (Boostma and Hecky, 1993). Most tropical African lakes are facing problems of rapid population growth in the riparian communities, which normally discharges pollution loads into the lakes. This has led to the deterioration of water quality in receiving lakes (Wandiga, 2003). Some lakes are getting eutrophic whilst others are facing problems of siltation and heavy metal discharges, thereby reducing their economic and aesthetic values. Some lakes are experiencing a decrease in fish production (Nilssen, 1984; Wadinga, 2003).

Generally in Rwanda, the physical and chemical quality of the waters of the lakes and its biological diversity are impaired by sediments caused by erosion (MINITERE, 2005).

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Water bodies in Rwanda are facing other problems such as low productivity, declining of water level (ADB, 2003) and their pollution by water hyacinth and other aquatic weed is a new and alarming phenomenon (MINITERE, 2005). In particular, Lake Muhazi has experienced a dramatic decrease in fish production since the eighties, and this may have been caused by bad practices in fishing (small size mesh nets, strike and poison fishing) and others sources of pollution because there was a decrease in Secchi depth to 0.65 m in 1987 *vs* 1.5 m in the fifties (Plisnier *et al.,* 1993).

Since the lakeshores are now being developed for ecotourism many changes are estimated to have occurred as a result of the new installation of hotels and restaurants that increase the nutrient loading in the lake and this requires sound environmental management to make the planned activities viable.

The purpose of this study is to investigate the nutrient status of Lake Muhazi by assessing vertical and horizontal distributions of nutrients in the Lake. As nutrients are entering into the lake from external inputs (points and non-points sources) or are derived by internal recycling from the decay of organic mater and dissolution from bottom sediments (Chapman, 1996), this study was focused only on water column because nutrient concentration within the water column is important as it is from here that nutrients are taken up by phytoplankton which may then form blooms if excess nutrients are present.

2. Study area

Lake Muhazi is a small lake in Rwanda which is situated in East Province of Rwanda along the northern margin of Rwamagana District (Ministry of Infrastructure, 2007). With an altitude of 1 443 m, the lake has a total catchment surface area of 829 km^2, a surface area of 33 km^2, a depth of about 14 m (max) and 10 m (mean) and a volume of 330 million cubic meters. The length of this lake is 37 km with a mean width of 0.6 km (Plisnier *et al.,* 1993). Lake Muhazi has always had a small earth dam at its discharge into Nyabugogo River. However, in 1999, the Rwandan government constructed a concrete dam on Lake Muhazi, in an attempt to protect it from drying up. The water level of Lake Muhazi has dropped considerably since 1970 as a result of increased water demands for irrigation of rice and sugar plantations downstream on the outskirts of the Kigali city and water supply to the Rwamagana City via Gishari Water Treatment Plant (Ministry of Infrastructure, 2007).

Lake Muhazi is divided into two parts: the western part towards the lake outlet, which is located on schist and surrounded by steep hills and the eastern part which lies on granitic soils. Plisnier (1993) characterize the lake Muhazi as a shallow lake with a rather unstable diurnal stratification and with slight differences in mixing regime between its eastern, deepest part and its western, shallowest part. The lake has a relatively high organic content, but is generally characterized by a low turbidity in the range of approximately 5 to 30 NTU (Ministry of Infrastructure, 2007). Its fish fauna is quite poor (Ministry of lands resettlement and environment, 2003) but the phytoplankton of this lake is quite rich (Lejeune and Frank, 1990).

3. Materials and methods

The study has been performed from July to October. Water samples have been collected approximately every two weeks at four sampling stations in Lake Muhazi and at 15 sampling stations on the inflow streams as shown on the Fig 1. The geographic coordinates of the sampling sites in lake are indicated in Table 1 and those of the sampling sites on streams are indicated in Table 2. At each site, water quality parameters were measured at 0,5m, 2m, 5m, and 1m from the bottom of the lake from four selected sampling points, at the entrance of streams into the lake and at the stream outlet of the lake. Chemical analyses were carried out soon after collection.

Water quality assessments typically consist of three aspects: physical, chemical, and biological, all of which are directly linked to each other and associated with the properties of a lake (Michaud, 1991). The nutrients are the main chemical parameter which has been analyzed in Lake Muhazi but others parameters can influence it such as the physical parameters (temperature, dissolved oxygen, pH, transparency, turbidity and conductivity) and the biological parameter (Chlorophyll-a).

Samples were taken using a VanDorn sampler and immediately placed on ice in cooler box. Collected water samples were stored in 560 mL plastic bottles, which must have been rinsed with HCl (1M) and then with distilled water. The samples was carefully preserved according to the table 3 (Plisnier and Descy, 2002). Secchi depth was read using a 20 cm diameter Secchi disk. The temperature and the pH were also measured.

Inorganic nutrient samples ($N\text{-}NO_3$, $N\text{-}NO_2$, PO_4) were first filtered through filters (0.45 µm) before being analyzed using the spectrophotometer. TN and TP samples were unfiltered and digested with alkaline persulfate solution (Darchambeau *et al.*, 2007). After the digestion all phosporus is convert into orthophosphate and then analysed using the ascorbic method. After digestion the TN is converted to nitrate and is analysed using the cadimium reduction method. For nitrate the cadmium reduction method was used and nitrite by the α-naphthylamine method (Zhang *et al.* 2005).
To measure chlorophyll-a, 500ml of each water sample were filtered on a GF/C filter, and the chlorophyll-a is extracted with 80% ethanol. The difference in absorbance of the solution before and after acidification, measured at 665 and 750nm is a measure of the chlorophyll-a content (Kruis, 2005).

4. Results and discussion

4.1. Characteristics of inflow rivers of Lake Muhazi

The temperature of water cannot really be compared between the various inflow rivers because of different times of taking measurements for each inflow river during the day. However, it is noted that Kiruhura presents the weakest average temperature (19.5°C). The concentrations of TP in those Inflow Rivers range from 0.018 mg/l to 0.352 mg/l with the highest value at Gahurura. Also the Ntaruka River has high TP concentration (0.234 mg/l) as it is shown by the figure 2. The concentration of TN range from 0.075 mg/l to 0.908 mg/l as it is also shown by the figure 2. Gahurura River has the highest concentration of TN. This is due to its location in a big wetland which is under cultivation. Similarly Kanyonyomba River has 0.433 mg/l of concentration of TN because is as well under rice cultivation.

4.2. Nutrients profile of the lake

The load of nutrients (total nitrogen and phosphorus) which travels from the river towards the lake gives an estimate of the degree of eutrophication of the ecosystems (Rivas *et al.*, 2000). Total nitrogen (TN) levels average in inflows rivers was 0.26 mg/l and the total phosphorus is about 0.09 mg/L. It seems that these values are low compared by those found in lake. The TN levels fluctuated slightly with depth, with the maximum concentration (3.41 mg/L) occurring at 2m depth at Kibilizi site (Fig 1), and the minimum value was 0.27 mg/L at 0.5 m depth at Nyarubuye site. Significant horizontal variation in this parameter was observed. The concentration of TN increases from East to the West of the Lake (Table 4). The nitrate concentrations are low at the surface and 1m from the lake bottom (Table 4). During this research nitrite was found at low concentrations whereas in 1993 this ion was absent according to Plisnier (1993).

4.3. Temperature and pH Profile of Lake Muhazi

The temperature profiles of Lake Muhazi were taken from each sampling point at different depths. The data collected shows a difference in temperature of approximately 2°C between surface and the depth of 10 m except for the temperature profile measured on 28/08/2007 where the difference was about 4°C at Kavumu (Table 5). In general the water temperature decreases regularly by surface towards the bottom.

At each sampling point, the pH decreased with the depth. The pH of the bottom is lower by 1 to 2 units with that of surface. The pH is higher at the surface water when the activity of the phytoplankton is intense. This phenomenon which occurs mainly in summer (here especially in mid-June and at the end of August), is related to the assimilation of CO_2 dissolved by the phytoplankton in water. The mean pH at the surface of the lake varied between 7.8 and 8.3. The general mean pH of the lake was 7.8.

4.4. Chlorophyll-a and transparency (secchi disc)

The concentration of chlorophyll-a in water is an index of the richness of the lake in phytoplankton. The results from various measurementss of chlorophyll-a concentration with various depths are presented at Table 6. It is observed that the chlorophyll-a concentration was high at 0.5 m depth (here: 27.8 µg/l) and the general average of the measurements taken is 18.1 µg/l (standard deviation equal to 3.6).

Various authors (Damas, 1954; Mukankomeje, 1988; Descy, 1989 and Plisnier, 1989) noted that the maximum concentration of chlorophyll-a was between 1 m and 2 m of depth. This phenomenon is explained by an optimum in quality (frequency) and quantity (lux) of the light for the phytoplankton. The concentration decreases with the depth because of reduction of the light intensity and of the self-shading or the decreasing of the transparency of water.

The measured transparency three times during this research is on average 0.87 m at Kavumu, 0.83m at Nyarubuye and 0.77m at Kibilizi and at Rwesero is 0.7m. In 1986 and 1987 at Karambi not far from Kavumu, on the eastern part of the Lake Muhazi, the average of monthly measurements was 0.81 m. Also the transparency at Karambi was practically always higher than 0.10 m than that measured at Giheta, not far from Kibilizi the west of the lake in 1986 and 1987(Plisnier,1989) as it is the case during this research. In this lake, the evolution of the transparency was explained by the evolution of the phytoplankton measured in less quantity when the transparency increased (Plisnier, 1993).

It is important to note that the transparency seems to have relatively increased since the study of Plisnier (1993). Plisnier found in 1993 a transparency of 0.65 m versus 0.82 m today. Perhaps this corresponds to a decrease in the content of sediments coming from erosion since the set up of the Ministerial Order in 2005 which prohibit the cultivation near water body. Also the building of the dam at the outlet of the lake had increased the lake level therefore dilution of phytoplankton.

4.5. Heavy metals concentration

Heavy metals have a high atomic number. Most current and more dangerous are lead (Pb), cadmium (Cd), chromium (Cr), zinc (Zn) because are carcinogenic. During this research, we didn't find the Cr, and the copper (Cu) in water column and inflow rivers of Lake Muhazi. The concentration of heavy metals in inflow rivers of Lake Muhazi varied according to the geological nature of the rocks in the catchment. The lowest (0 mg/l) concentration of Zn was recorded at Nyamarebe and Mwange rivers, while the highest (0.33 mg/l) was recorded at Gahurura. For Mn, the lowest concentration (0.04 g/l) was recorded at murama and the highest (4.97 mg/l) at Kiruhura. The lowest iron (Fe) concentration (0.45 mg/l) was recorded at Nyakambu and the highest (52.76 mg/l) was at Kiruhura. For Cd the lowest concentration (0.03 mg/l) was recorded at Kiruhura and the highest (0.04 mg/l) at Nyagatugu. Pb concentrations vary between 0.05 mg/l and 1.04 mg/l with the lowest at Mwange and the highest at Isereka (outlet of the lake).

The concentration of heavy metals in water column is high at the 1 m depth from the bottom of the lake at Kavumu site (Figure 4). This is explained by that Lake sediments are a major repository of heavy metals, both of anthropogenic and natural origin. However, these metal pollutants can be released to overlying water column from the sediments when environmental conditions (e.g., redox regime, degradation of organic matter, pH and bioturbation) change (Ma and Lui, 1999). At nyarubuye is the opposite case (Figure 5) because the high record of heavy metals is at 0.5m of depth except for the Cd whose the high record is at the 1m from the bottom of the lake. At Kibilizi (Figure 6) high records of heavy metals also are record at 0.5m except for the Cd and Mn whose the high records are at the 1m from the bottom of the lake. This case of having high concentration at the surface is may be caused by the pollution of water by navigation in motor boats. The concentration of Zn in water column is between 0.018 and 0.225 mg/l, for Mn is between 0.143 and 1.738 mg/l, for Fe is between 0.524 and 4.591 mg/l, for Cd is between 0.026 mg/l and 0.091 mg/l for Pb is between 0.074 and 1.525 mg/l.

5. Conclusions and recommendations

1. Lake Muhazi is generally able to cope with the current pollution loads through self-purification.
2. Vertical nutrient profiles show a lot of variability, making it difficult to rely on these nutrient concentration profiles to understand the nutrient dynamics in Lake Muhazi. It is suspected that there are other sources of pollution inflows in the lake other than those measured on inflow rivers.

3. The increase in nitrate concentrations around at 0.5m is due to the consumption of that ion in the photic by the phytoplankton.
4. Temperature profiles did not depict distinct stratification, although there is a very slight decrease at Site Kavumu on 28/08/07
5. Chlorophyll-a concentrations peaked at the Rwesero site with the average concentration of 21.3 µg/l, showing that the lake becomes highly productive towards the dicharge point.

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7. References

Anderson J., Paakh B., and Heiskary S. (2000). Lake of Woods Trophic Status Report 1999. Minnesota Pollution Control Agency. http://www.pca.state.mn.us/publications/reports/wq-lar3-05.pdf site visited on28/05/2007

Bootsma H. A. and HECKY R. E. (1993). Conservation of the African Great Lakes: A Limnological Perspective. Journal Conservation Biology. Volume 7: pp 645-656, No. 3, September 1993

Chapman D. (1996). Water quality assessment: A guide to the use of biota, sediments and water in environmental monitoring. Second edition

Darchambeau F., Leporcq B., Pasche N. (2007).Nutrient analysis procedure for ECOSYKI and EAWAG research projects on Lake Kivu.

Eaton A.D., Clesceri L.S., Rice E. W. and Greenberg, A.E. (2005). Standard Methods for the Examination of Water and Wastewater. 21 Edition. American Public Health Association, American Water Works Association and Water Environment Federation.

Kruis F. (2005). Environmental Chemistry. Selected Analytical Methods. Lecture note from IHE LN0188/05/1

Lejeune A. and Frank V. (1990). Distribution of Lutra maculicollis in Rwanda: Ecological constraints *IUCN Otter Spec. Group Bull.* **5**: 8- 16

Lim N. C. (2001) Assessment of reservoir water quality and its application to reservoir management in the central plains http://www.kbs.ku.edu/people/assets/staff_cv/lim_thesis.pdf site visited on 24/05/207

Ma Y. J. and Liu C. Q. (1999) Seasonal migration of redox boundary and its influence on water quality in lake lugu, yunnan, china. The State Key Lab. of Environ. Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences. Ninth Annual V. M. Goldschmidt Conference.

Michaud J. P. (2006). A Citizen's Guide to Understanding and Monitoring Lakes and Streams. Washington. http://www.ecy.wa.gov/Programs/wq/plants/management/joysmanual/nutrients.html site visited on 17/04/2007

Ministere of Lands, Reseltlement and Environemnet. (2003). National strategy and action plan fro the conservation of biodiversity in Rwanda.

Ministry of Infrastucture. (2007). Rwamagana, Rwanda Conceptual Master Plan.

Nilssen P. J. (1984). Tropical lakes-funcutional ecology and future development: the need for a process-orientated approach. Hydrobiologia 113, 231-242 (1984).

Parinet B., Lhote A. and Legube B. (2004). Principal component analysis: an appropriate tool for water quality evaluation and management-application to a tropical lake system. Ecological Modelling**,** Volume 178, Issues 3-4, 1 November 2004, Pages 295-311

Plisnier P.-D. (1989). Etude Hydrobiologique et Développement de la Pêche au Lac Muhazi (Bassin de l'Akagera, Rwanda) (in French). Hydrobiologic Study and Fishing Development at Lake Muhazi (Akagera Catchment, Rwanda). Final report (1986-1988). Namur, Belgique.

Plisnier P.D. and Descy J.P. (2002**).**Climate variability as recorded in Lake Tanganyika**.** Facultes universitaires notre-dame de la paix, Namur. http://www.fundp.ac.be/sciences/biologie/urbo/Field&Lab_%20Manual_Mpulungu_Aug02.pdf site visited on08/05/2007

Plisnier P-D., Mukankomeje R., Descy J-P. and Massaut L. (1993). Lake Muhazi, Rwanda: limnological features and phytoplankton production. Hydrobiologia 257: pp 107-120, 1993

Prepas, E. E.; Charette, T. (2003). Worldwide Eutrophication of Water Bodies: Causes, Concerns, Controls. Treatise on Geochemistry, Volume 9. Elsevier, 2003, p.311-331

Rivas Z., Ledo de Medina H., Gutiérrez J. and Gutiérrez E. (2000). Nitrogen and Phosphorus levels in sediments from tropical Catatumbo river (Vennezuela). Water, Air, and Soil Pollution117: 27-37, 2000

U.S. Environmental Protection Agence. (2006). Great Lakes Monitoring, Trophic State of the great lake. http://www.epa.gov/glnpo/glindicators/water/trophicb.html site visited on 27/05/2007

Wandiga S.O. (2003). Lake Basin Management Problems in Africa: Historical and Future Perspectives http://www.povertyenvironment.net/?q=lake_basin_management_problems_in_africa_historical_and_future_perspectives site visited on12/05/2007

Zhang M.,Xu J., Xie P. (2007). Nitrogen dynamics in large shallow eutrophic Lake Chaohu. China Environ GeolDOI 10.1007/s00254-007-0957-6

Tables and Figures

Table 1: Coordinates of sampling sites in lake

Sampling Site in lake	Location
Kavumu	S-01º 50′ 35.4″ E-030º 25′ 58.6″ Elevation 1455m
Nyarubuye	S-01º 52′ 27.9″ E-030º 21′ 32.1″ Elevation 1444m
Kibilizi	S-01º 50′ 17.0″ E-030º 18′ 18.4″ Elevation 1440m
Rwesero	S-01º 48′ 14.5″ E-030º 10′ 48.0″ Elevation 1448m

Table 2. Coordinates of sampling sites in streams

Sampling site in streams	location
Ntaruka	S-01º 52’16.8’’ E-030 º30’ 01.5 Elevation 1447m
Gashogosho	S-01º 50’16.2’’ E-030 º28’ 35.6 Elevation 1441m
Nyakambu	S-01º 49’30.9 E-030 º27’ 23.0 Elevation 1444m
Nyamarebe	S-01 º48’50.6’’ E-030 º26’34.7 Elevation 1446m
Kanyonyomba	S-01 º48’31.2’’ E-030 º22’27.1’’ Elevation 1452m
Njume	S-01 º50’57.2’’ E-030 º19’35.7 Elevation 1448m
Buganya	S-01 º48’46.5’’ E-030 º16’22.2 Elevation 1448m
Nyagatugu	S-01 º49’29.1’’ E-030 º15’22.4 Elevation 1446m

Murama	S-01 º47'22.8'' E-030 º19'35.7 Elevation 1448m
Isereka	S-01 º50'57.2'' E-030 º09'22.5 Elevation 1435m
Mwange	S-01 º46'40.0'' E-030 º07'48.5'' Elevation 1442m
Nyabugogo	S-01 º48'31.5'' E-030 º07'41.2'' Elevation 1432m
Gahurura	S-01º 54'52.6 E-030 º25' 59.3 Elevation 1446m
Ingarani	S-01º54'10.8'' E-030 º25' 18.0 Elevation 1443m
Kiruhura	S-01º55'44.5'' E-030 º21'45.8'' Elevation 1460m

Table 3. Procedure and preservation time when direct analysis is not possible

To analyze…	Procedure	Container	Time
Total Phosphorus	Add 0.5 mL 4N sulphuric acid in 40 mL sample	Red cap vial	Weeks
Orthophosphate (PO_4^{3-})	A. Refrigerate the sample at ≤ 4ºC	Plastic bottle (filtered water)	24 H
	B. For longer storage, add 0.5 mL 4N sulphuric acid in 50 mL sample	Red cap vial	>24 H
Nitrogen Ammonia (NH4+)	A. Refrigerate the sample at ≤ 4ºC	Plastic bottle (filtered water)	24 H
	B. Store in deep freezer	Red cap vial	Weeks
Nitrite (NO2-)	A. Store the sample at ≤ 4ºC	Plastic bottle (filtered water)	24 H
	B. Store in deep freezer	Red cap vial	Weeks
Nitrate (NO3-)	A. Store the sample at ≤ 4ºC	Plastic bottle (filtered water)	24 H
	B. Store in deep freezer	Red cap vial	Weeks

Source: Plisnier P.D. and Descy (2002)

Table 4. Variation of TN, nitrate and nitrite with depth of lake on 28/08/07

Site 1 KAVUMU	TN (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)
0.5	1.803	0.8	0.003
2	0.828	0.5	0.000
5	0.907	0.8	0.007
11	0.804	0.4	0.004
Average	1.0855	0.625	0.005
Site 2 NYARUBUYE			
0.5	0.269	0.3	0.007
2	0.469	0.6	0.012
5	1.803	1.7	0.007
12	0.905	0.6	0.004
Average	0.862	0.8	0.007
Site 3 KIBILIZI			
0.5	0.738	0.5	0.005
2	3.412	2.4	0.000
5	1.805	1.2	0.012
10	0.525	0.8	0.005
Average	1.62	1.225	0.007
Site 4 RWESERO			
0.5	1.603	1.2	0.003
2	1.209	0.8	0.009
5	0.903	0.2	0.003
Average	1.238	0.733	0.005

Table 5. Temperature profiles of sampling sites

SITE	**Kavumu**		
Depth	T(°C) on 02/08/2007	T(°C) on 28/08/2007	T(°C) on 18/09/2007
0.5m	23.4	26.4	22.5
2m	22.7	24.1	22.1
5m	22.4	23.3	21.9
11m	21.9	22.3	22
SITE	**Nyarubuye**		
Depth	T(°C) on 02/08/2007	T(°C) on 28/08/2007	T(°C) on 18/09/2007
0.5m	23	25.8	24.3
2m	22.5	23.8	23.7
5m	22.3	23.9	22.9
12m	22.1	22.1	22.3
SITE	**Kibilizi**		
Depth	T(°C) on 02/08/2007	T(°C) on 28/08/2007	T(°C) on 18/09/2007
0.5m	23.2	25.6	23.5
2m	22.5	24.1	23.1
5m	22	22.7	22.7
10m	21.8	22.9	20.5
SITE	**Rwesero**		

Depth	T(°C) on 02/08/2007	T(°C) on 28/08/2007	T(°C) on 18/09/2007
0.5m	27.3	24.6	24.6
2m	-	-	23.2
5m	-	-	22.6

Table 6. Concentration of chlorophyll-a in lake Muhazi (-: not taken measurements)

Date	Site	0.5m	2m	5m	Mean
26/08/2007	Kavumu	28.5 µg/l	16.1 µg/l	2.1 µg/l	15.6 µg/l
	Nyarubuye	14.3 µg/l	16.8 µg/l	6.6 µg/l	12.6 µg/l
	Kibilizi	34.3 µg/l	12.9 µg/l	3.7 µg/l	17.0 µg/l
	Rwesero	-	-	-	
18/09/2007	Kavumu	23.1 µg/l	17.8 µg/l	7.1 µg/l	16.0 µg/l
	Nyarubuye	27.4 µg/l	24.1 µg/l	8.7 µg/l	20.1 µg/l
	Kibilizi	29.7 µg/l	28.3 µg/l	10.2 µg/l	22.7 µg/l
	Rwesero	37.1 µg/l	25.2 µg/l	1.7 µg/l	21.3 µg/l
Mean		27.8 µg/l	20.2 µg/l	6.4 µg/l	18.1 µg/l
Standard deviation		7.5	5.7	3.3	3.6

Table 7. Concentration of heavy metals in inflow rivers in mg/l

SITE	Zn	Cr	Cu	Mn	Fe	Cd	Pb
Ntaruka	0.025	0.000	0	1.407	5.563	0.029	0.497
Gashogoshogo	0.029	0.000	0.003	0.405	1.400	0.028	0.670
Nyakambu	0.003	0.000	0.000	0.062	0.450	0.032	0.614
Nyamarebe	0.000	0.000	0.000	0.237	9.029	0.030	0.125
Kanyonyomba	0.012	0.000	0.000	2.861	8.324	0.036	0.597
Njume	0.010	0.000	0.000	1.132	3.864	0.036	0.390
Buganya	0.008	0.000	0.000	0.779	4.715	0.035	0.318
Nyagatugu	0.008	0.000	0.000	0.144	0.538	0.036	0.423
Murama	0.007	0.000	0.000	0.043	0.494	0.032	0.441
Mwange	0.000	0.003	0.000	0.675	6.897	0.028	0.050
Isereka	0.051	0.000	0.000	0.423	0.749	0.030	1.037
Nyabugogo	0.012	0.000	0.000	0.281	3.636	0.029	0.071
Gahurura	0.331	0.000	0.001	0.267	3.079	0.029	0.632
Ingarani	0.011	0.000	0.000	1.875	30.360	0.033	0.827
Kiruhura	0.015	0.000	0.000	4.973	52.755	0.027	0.937

Zn (Zinc), Mn (Manganese), Fe (Iron), Cd (Cadimium), Pb (lead), Cr (Chromium), Cu (Copper).

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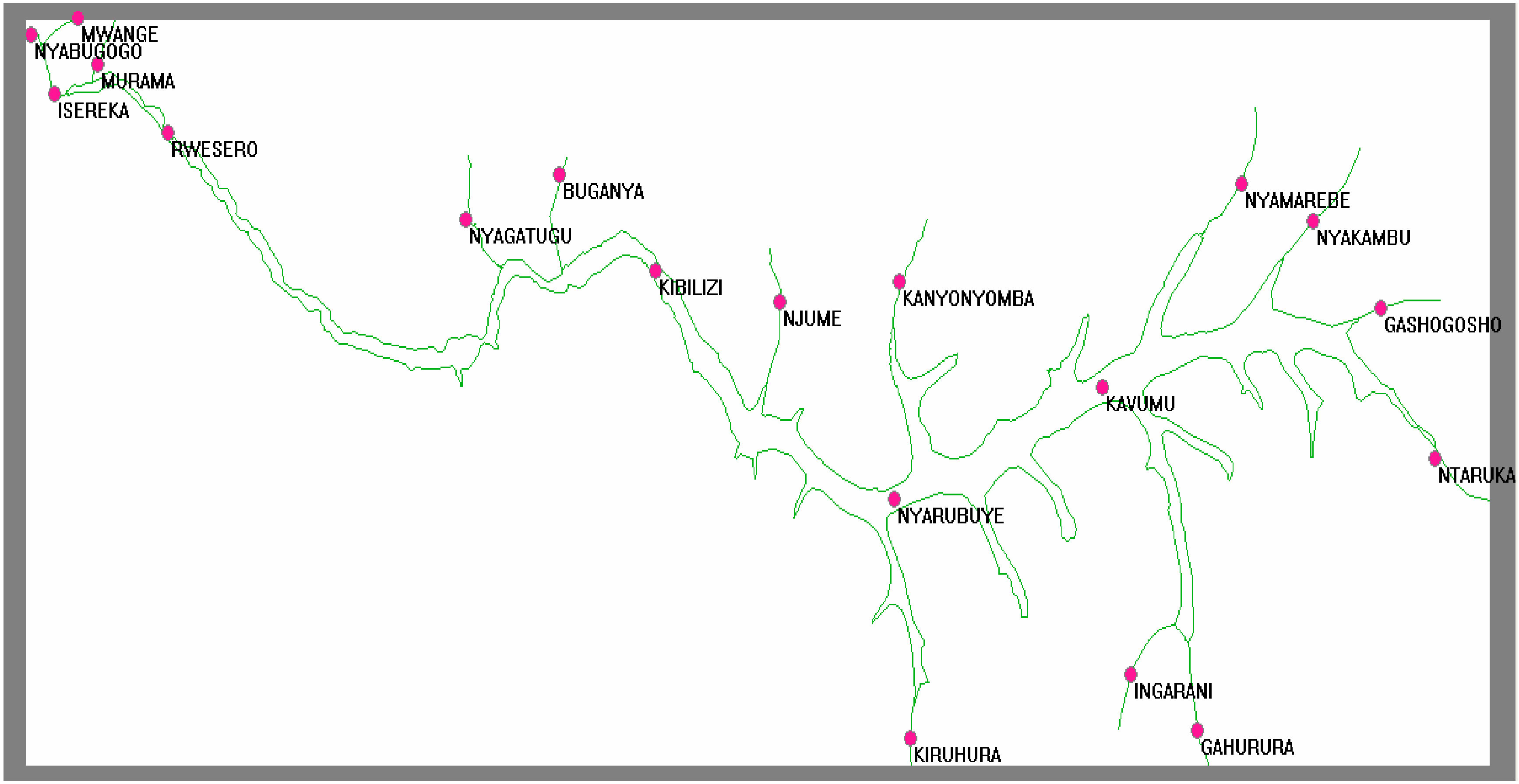

Figure 1. Sampling sites.

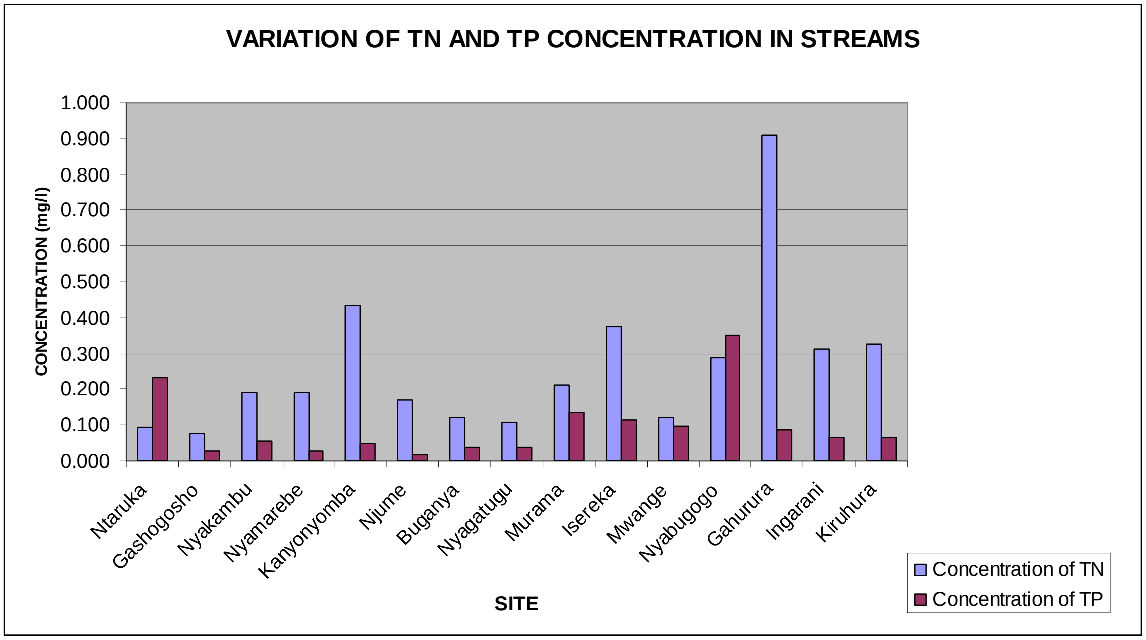

Figure 2. Concentration of TP and TN in streams

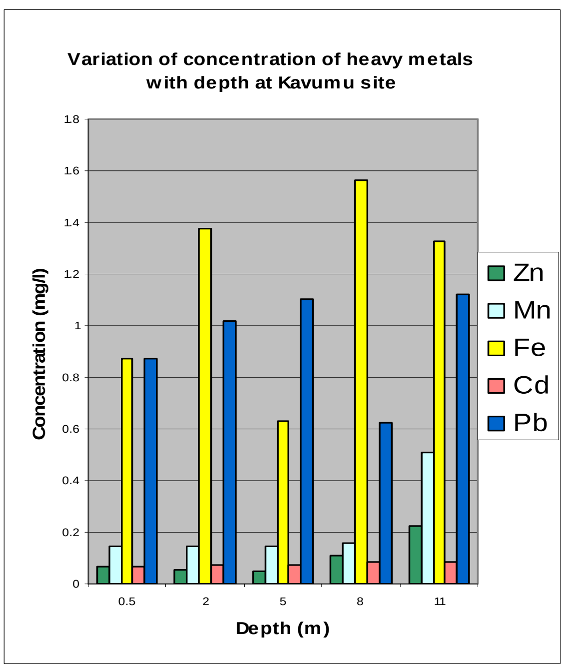

Figure 4. Concentration of heavy metals at KAVUMU

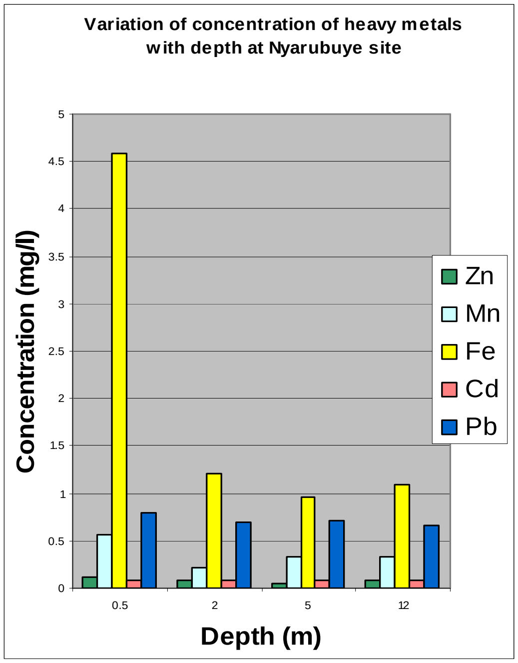

Figure 5. Concentration of heavy metal at NYARUBUYE

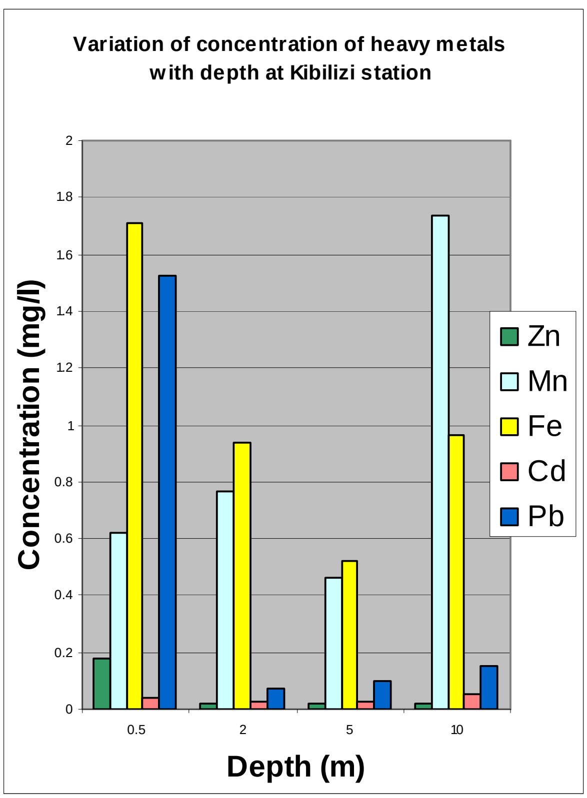

Figure 6. Concentration of heavy metals at KIBILIZI