Major Elements in Lake Muhazi, Rwanda, East Africa

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Abstract: The aim of this study undertaken at Lake Muhazi in Rwanda was to determine and analyze the major elements present in water. The presence of many major elements (Al, As, Ba, C, Ca, Cu, Fe, H^+, K, Mg, Mn, N, P, S, Si, and Zn) was determined by spectroscopic technique. The concentrations of the elements were measured in water samples taken from three different locations of the lake from May to August 2008. The lake is polluted by water flow from mountain sides surrounding the lake. Other causes of pollution could be the use of agrochemicals in the sugar land, which surrounds the lake, and human activities near the lake. Finally, we proposed the strategies that can be applied in order to ensure good conservation of the environment and to prevent augmentation of heavy materials into the lake.

Key words: major elements, environment, spectroscopic technique, water pollution, Muhazi Lake, Rwanda

1 Introduction

In the present study, we investigated surface water, an indispensable factor of the earth's layer and essential for all planetary living ecosystems. We studied the geochemistry of major elements from Lake Muhazi, Rwanda. The mineralogy of this region located in the east African rift valley may be similar in composition to the oceanic lithospheric mantle described by Damas (1954). Many studies have shown that the major elements are natural components of the hydrosphere, and many elements are essential in minute quantities for the metabolism of organisms (Ward, 1995). Some elements are important and necessary micronutrients for living organisms (e.g. Cd, Cu, Pb, and Zn) and they are toxic over a certain concentration for aquatic organisms and human health (Bowen, 1966; Nor, 1987; Timmermans, 1992; Silva et al., 2000). The dispersion and distribution of major elements in Lake Muhazi represent the result of the nature process. Their source is derived from volcanic lava, which represents a magmatic sampling of variations in the underlying continental lithosphere mantle; the source is beneath much of the east African rift valley system. This presence of volcanism in the east African rift valley system is caused by the melting of the lithospheric mantle; this volcanism began roughly in the eastern rift

~23 Ma, and in the western rift ~12 Ma (Kampunzu et al., 1986; Pastel et al., 1989). Many studies have described the diversity of magmatic volcanic rocks that have erupted along these two regions of the African rift (Holmes, 1940; Bell and Powell, 1969; Lloyd et al., 1991; Furman, 1995).

The problem of pollution was also a basis of our study. It was revealed that some metals are considered highly toxic (Demayo, 1980), and human activity, such as industrial development, agriculture, urbanization, and the expansion of infrastructure in most parts of the world, contribute to the contamination of the water surface (Rainbow, 1985). The pollution of water into the lake has many consequences on human health, compromising the quality of drinking water today.

Major elements in environmental pollution have gained the attention of different research institutions (Sharman et al., 1989). In Rwanda, human activity near lakes and valleys contributes to water contamination and causes a decrease in water transparency. The present study shows that a Secchi depth of 1.4–1.5 is a result of grazing by tilapia Randalli, which usually feed on large water plants (Damas, 1954a, b). Human activity may be a consequence of soil erosion, as the catchment areas become heavily cultivated (Ford, 1990). The study and management of Lake Muhazi started in 1985 by Henderson and Welcome (1974) in order to access a maximum sustainable fish yield in order to complete an absence of relevant information shown in the precedent research which an estimation of

the production of this fish was at 74 kg ha^{-1}y^{-1} ;and its maximum sustainable yield at 24kg ha^{-1}y^{-1} (Beverton-Halt model 1957). Many studies were undertaken in region about water into the lake, but only few were oriented to access the major elements. The present study was undertaken to analyze the major elements in Lake Muhazi with a goal to establish a plan to protect the environment and water quality.
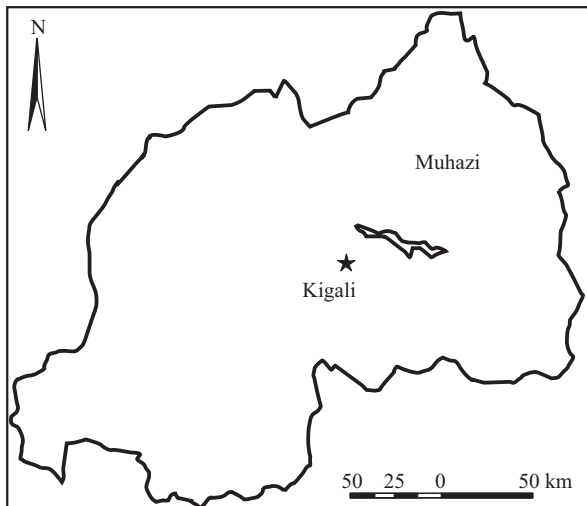
2 Materials and Methods

Fig. 1. Study area location.

2.1 Study area

Lake Muhazi is a small lake located in Rwanda (East Africa), in the upper part of the River Akagera Basin, which is also a part of the upper Nile Basin (Damas, 1953). Lake Muhazi is situated approximately 20 km northeast of Kigali at 1443 m above sea level. Its surface area is 34.6 km^2. Two different parts of the lake were distinguished: the western part, towards the lake outlet, is narrow, located on schists, and surrounded by steep hills; the maximum depth is less than 10 m and decreases slowly towards the outlet. The second part is the eastern part, which lies on granitic soil and is characterized by long side arms, most which are clogged by swamps (Damas, 1954; Beadle, 1981). Lake Muhazi (Fig. 1) is also characterized as a shallow lake with a rather unstable decanal stratification and with slight differences in the mixing regime between its eastern, deepest part and western, shallowest part (Ford, 1990).

Lake Muhazi borders the Gasabo district in south, the Gicumbi district in the northwest, Rwamagana and Kayonza in the east, and Gatsibo in the northeast. Its temperature varies between 10°C and 18°C; the prevailing

climate is tropical; it is very hotduring summer which starts from June to the end of August, and it's cold during winter which starts from September to December and from March to May. Many human activities are identified near the lake, which are fishing, the Muhazi Boulevard, Jambo Beach Restaurant, Rwesero schools, divers pastures, sugar plantation, and other kinds of agriculture, which pollute the lake.

2.2 Water sampling

Water samples were collected between May and August 2008, and three sampling stations were established: Rwesero (Fig. 2A), Nyarubuye (Fig. 2B), and Jambo Beach (Fig. 2C). Water samples were taken through a bottle of 1 L of polyethylene and rinsed three times with demonize-distilled water before use. The field measurements were also taken at the location, including water temperature, pH, air temperature, Eh electrode, and conductivity. We used YSI85D to determine conductivity and temperature, and the pH meter to determine the pH level. The filters cleaned with deionizers distilled for dissolving major elements by using 0.45-mM non-pyronenic sterile filters. the water samples were acidified to pH$_2$ by using concentrated HNO$_3$ after collection and storing at 4°C until analysis. The same methods were used in different studies (Ronald et al., 19 99 and Das et al., 2007). The water sample analyses were done through atomic mass spectroscopy following all procedures of typical MS: water samples were looked at through the MS instrument (4000 Q TRAP LC/ MS/ MS instrument, Applied Biosystems,Vernon Hills, Ullinois, USA, New in summer 2006). The water sample components were ionized and the ions were directed into the magnetic field, followed by the computation of the mass-to-charge ration (Sparkman, 2000). We then detected the ions. We then calculated particular elements by subtracting the dissolved value from the total element concentrations. Experimental
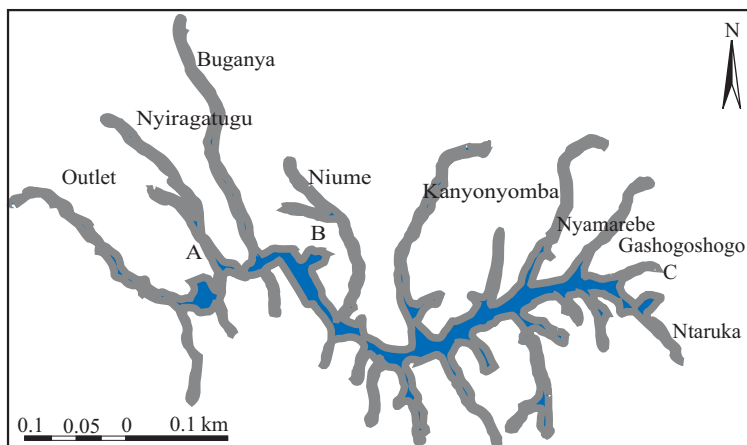

Fig. 2. Water sampling station. (A) Rwesero; (B) Nyarubuye; (C) Jambo Beach.

techniques used in other environmental studies (Filgueiras et al., 2002) helped us determine the standard solutions for the calibrations, which were prepared in aliquots of the calibration blank.

The standard stock reference material was obtained and run between every 10–50 samples. The typical precision was (1000 ug/mL). Water samples were taken four times from the site location in order to make determine the result. In the present study, we aimed to avoid pollution and concentration of elements, which often occurs during sample preparation and analysis. GIS software (ZIP, 104M, 2009-03-26, California, USA) was used for the map.

3 Results

The concentration of major elements(Al, As, Ba, C, Ca, Cu, Fe, H$^+$, K, Mg, Mn, N, P, S, Si, and Zn) in Lake Muhazi are shown in the following tables (Tables 1–3).

Table 1 Measurements of major elements at Rwesero (mg/L) in 2008

Date of samples	Al	As	Ba	C	Ca	Cu	Fe	H$^+$	K	Mg	Mn	N	P	S	Si	Zn
8 May	0.3	0.0	0.9	31.6	41.2	1.6	0.4	0.8	6.2	7.2	1.0	2.4	0.3	16.2	4.2	0.3
13 May	0.1	0.09	0.8	30.2	46.2	0.0	0.1	0.2	5.3	11.0	2.0	3.6	0.4	18.3	3.6	0.6
18 May	0.4	0.07	0.7	27.6	38.6	0.0	0.0	0.3	8.9	14.0	0.6	2.1	0.2	14.1	5.3	0.0
23 May	0.6	0.06	0.9	28.3	49.2	2.4	0.9	0.4	4.3	8.3	0.3	3.8	0.0	13.2	6.2	0.0
2 Jun	0.1	0.03	0.6	38.1	53.2	1.5	0.0	0.5	7.8	15.0	0.9	4.6	0.0	12.7	3.6	0.7
6 Jun	0.4	0.01	0.6	31.2	50.1	2.3	0.0	0.6	6.1	13.0	1.1	7.2	0.0	14.6	3.4	0.1
9 Jun	0.1	0.08	0.5	32.1	49.0	1.6	0.8	0.2	5.7	11.0	0.0	9.2	0.7	20.1	5.2	0.3
25 Jun	0.5	0.0	0.3	29	43.2	0.0	1.0	0.3	5.3	12.0	0.0	8.1	0.6	20.6	4.6	0.4
15 Jul	0.2	0.03	0.1	26.0	41.2	1.3	0.4	0.6	4.8	7.8	0.1	3.2	0.3	18.1	3.7	0.0
21 Jul	0.2	0.0	0.6	27.2	56.2	2.2	0.5	0.1	4.9	8.9	0.3	3.6	0.4	13.2	6.3	0.0
22 Jul	0.4	0.0	0.8	28.6	32	0.9	0.5	0.3	5.6	9.2	0.8	3.9	0.0	15.3	5.8	0.3
24 Jul	0.8	0.02	0.7	34.3	28.3	0.7	0.3	0.4	8.1	12.0	1.1	4.8	0.0	16.1	6.2	0.6
2 Aug	0.1	0.04	0.3	32.1	29.1	0.8	0.0	0.2	7.9	13.0	0.0	6.3	0.0	13.2	4.3	0.8
3 Aug	0.6	0.01	0.2	30.1	36.2	2.3	0.0	0.8	8.1	14.0	0.6	8.4	0.6	19.2	4.8	0.4
22 Aug	0.3	0.03	0.3	36.2	51.2	1.4	0.8	0.6	3.8	15.0	0.4	2.1	0.3	17.2	3.7	0.0
23 Aug	0.1	0.01	0.3	28.1	49.1	2.1	0.1	0.4	6.4	14.0	0.3	7.8	0.4	12.1	5.2	0.6
Average	0.33	0.0	1.0	31	43	1.0	0.0	0.0	6.0	12.0	1.0	5.1	0.3	16.0	5.0	0.3

Table 2 Measurements of major elements at Nyarubuye (mg/L) in 2008

Date of samples	Al	As	Ba	C	Ca	Cu	Fe	H$^+$	K	Mg	Mn	N	P	S	Si	Zn
9 May	0.1	0.01	0.6	32.1	51.2	0.0	0.5	0.8	7.9	11.0	2.0	3.7	0.0	16.8	4.8	0.0
16 May	0.3	0.03	0.6	29	49.1	0.0	0.5	0.2	8.2	12.0	2.0	3.2	0.0	17.8	4.6	2.0
24 May	0.8	0.01	0.5	30.2	36.2	1.2	0.3	0.7	5.3	8.2	1.0	4.2	0.2	15.1	3.6	0.0
25 May	0.6	0.04	0.3	27.1	29.7	1.4	0.4	0.9	6.3	7.2	0.6	2.4	0.0	14.1	6.1	0.6
13 Jun	0.1	0.03	0.1	38.1	32.0	2.5	0.1	0.6	8.2	8.6	0.5	9.1	0.2	13.6	3.9	0.9
14 Jun	0.2	0.0	0.6	27.0	28.3	2.3	0.0	0.2	6.2	8.3	0.2	7.6	0.3	21.0	3.8	0.7
28 Jun	0.2	0.0	0.8	26.0	56.2	2.2	0.0	0.1	6.1	9.2	0.3	3.9	6.0	19.2	4.9	0.0
29 Jun	0.4	0.02	0.7	27.8	41.2	1.7	0.0	0.7	3.9	14.0	0.9	7.3	0.3	16.7	5.3	0.0
4 Jul	0.8	0.0	0.3	35.4	41.2	0.0	0.8	0.8	4.2	14.0	1.2	8.2	0.2	15.6	6.7	0.3
8 Jul	0.5	0.0	0.9	32.3	49.2	0.0	0.4	0.6	4.9	8.6	1.3	7.8	0.1	15.3	6.3	0.3
9 Jul	0.4	0.09	0.8	30.1	38.6	1.2	0.0	0.7	4.7	7.3	0.3	7.6	0.0	15.2	6.3	0.6
27 Jul	0.1	0.07	0.7	34.0	46.2	1.3	0.0	0.3	5.6	13.0	0.5	5.4	0.0	20.1	4.5	0.7
2 Aug	0.3	0.06	0.9	28.1	53.1	2.5	0.9	0.3	8.2	13.0	0.6	9.1	0.0	19.2	4.8	0.8
3 Aug	0.1	0.03	0.3	30.2	50.6	0.8	0.4	0.2	7.3	13.0	0.3	8.2	0.2	21	3.7	0
22 Aug	0.6	0.08	0.3	36.4	49.9	0.9	0.0	0.8	7.6	13.0	0.0	7.8	1.0	14.3	5.4	0.9
23 Aug	0.4	0.01	0.2	29.2	43.7	1.6	0.1	0.6	8.1	12.0	0.0	6.3	3.0	17.6	5.6	0.5
Average	0.37	0.0	1.0	31.0	44.0	1.0	0.0	1.0	6.0	11.0	1.0	6.4	0.8	17.0	5.0	0.5

Table 3 Measurement of major elements at Jambo Beach (mg/L) in 2008

Date of Samples	Al	As	Ba	C	Ca	Cu	Fe	H$^+$	K	Mg	Mn	N	P	S	Si	Zn
8 May	0.2	0.2	6.0	27.0	53.1	1.6	0.0	0.3	5.7	14.0	0.6	5.4	0.0	19.2	3.7	0.1
13 May	0.2	0.4	0.8	26.0	49.9	0.0	0.8	0.4	5.3	14.0	0.5	9.1	0.0	16.7	6.3	0.3
18 May	0.4	0.8	0.9	27.8	41.2	1.3	1.0	0.2	4.8	8.6	0.2	8.2	0.0	15.6	5.8	0.4
23 May	0.4	0.5	0.8	35.4	49.2	2.2	0.4	0.8	4.9	7.3	0.3	7.8	0.7	15.3	6.2	0.0
2 Jun	0.1	0.4	0.7	32.3	38.6	0.9	0.5	0.6	5.6	6.3	0.9	6.3	0.6	15.2	4.3	0.0
6 Jun	0.3	0.1	0.9	30.1	46.2	0.7	0.5	0.4	8.1	13.0	1.2	2.4	0.3	16.1	4.8	0.3
9 Jun	0.1	0.3	0.6	34.0	53.1	0.8	0.3	0.7	7.9	13.0	1.3	3.6	0.4	13.2	4.2	0.8
25 Jun	0.6	0.1	0.6	28.1	50.6	2.3	0.0	0.3	8.1	13.0	0.3	2.1	0.0	19.2	3.6	0.0
15 Jul	0.2	0.6	0.7	30.2	49.9	1.4	0.0	0.3	3.8	12.0	0.5	3.8	0.0	17.2	5.3	0.9
21 Jul	0.4	0.0	0.3	36.4	46.2	2.1	0.8	0.2	6.4	7.2	1.0	2.4	0.6	15.3	6.2	0.5
22 Jul	0.6	0.09	0.1	29.2	38.6	0.0	0.5	0.8	5.1	11.0	2.0	9.1	0.3	16.8	6.1	0.0
24 Jul	0.1	0.07	0.6	32.1	49.2	0.0	0.5	0.6	4.6	14.0	0.6	7.6	0.4	17.8	3.9	0.0
2 Aug	0.4	0.06	0.8	29.0	53.2	1.2	0.3	0.7	7.2	8.3	0.3	3.9	0.3	15.1	3.8	0.3
3 Aug	0.1	0.03	0.7	30.2	50.1	1.4	0.4	0.6	5.1	15.0	0.9	7.3	6.0	14.1	4.9	0.3
22 Aug	0.5	0.01	0.3	27.1	49.0	2.5	0.1	0.8	5.3	13.0	1.1	8.2	0.3	13.6	5.3	0.6
23 Aug	0.4	0.08	0.9	27.2	43.2	2.3	0.0	0.9	8.9	11.0	0.0	7.8	0.2	21	6.7	0.6
Average	0.31	0.23	1.0	30.0	48.0	1.0	0.0	1.0	6.0	12.0	0.7	5.9	0.6	16	5.1	0.3

4 Discussion

The present study was undertaken at Lake Muhazi in order to determine the average concentrations of major elements contaminating the surface water. They were (in mg/L): Al 0.33, Ba 1, C 31, Ca 43, Cu 1, K 6, Mg 12, Mn 1, N 5.1, P 0.3, S 16, S i5, and Zn 0.3 at Rwesero station; the average concentrations of As, Fe, and H^+ were negligible and estimated at 0. At Nyarubuye station, the average concentrations of major elements (in mg/L) were: Al 0.37, Ba 1, C 31, Ca 44, Cu 41, H^+ 1, K 6, Mg 12, Mn 1, N 6.4, P 0.8, S 17, Si 5, and Zn 0.5. The average concentrations of As and Fe were also insignificant and were estimated at 0. The average concentrations of major elements (in mg/L) at Jambo Beach were: Al 0.31, As 0.23, Ba 1, C 30, Ca 48, Cu 1, H^+ 1, K 6, Mg 12, Mn 0.7, N 5.9, P 0.6, S 16, Si 5.1, and Zn 0.3; the average concentration of Fe was estimated at 0.

In general, the analysis of the major elements in Lake Muhazi show that the average concentration of those elements (in mg/L) were: Al 0.33, As 0.07, Ba 1, C 30.6, Ca 45, Cu 1, H^+ 0.6, K 6, Mg 11.6, Mn 0.9, N 5.8, P 0.5, S 16.3, Si 5, and Zn 0.3; the average concentration of Fe was insignificant and was estimated at 0.

The concentrations of Ca, C, and S in the water sample analysis were higher than those of other elements in Lake Muhazi; their average concentrations (in mg/L) were: 45, 30.6, and 16.3, respectively. Elements, such as Mg, K, N, and Si, have an average between 11.6 and 5. Another group is composed of elements concentration <5, including Ba, Cu, Mn, H^+, P, Al, Zn, As, and Fe. The results of the study reveal that several ongoing physical and chemical processes influence the water quality in Lake Muhazi; the water in the lake has a pH level between 5.3 and 8.5, and conductivity (umho/cm) =2300–2460. The dominance of Ca, C, and S can influence the metal toxicity in Lake Muhazi. The origin can be founded in domestic activities of the houses surrounding the lake carried, for example, in sewage water, and other human activities, such as agriculture and fishing, which are believed to be source of water contamination. The study by Samecka–Cymerman and Kampers (2001) showed that the level of heavy metals in the water of anthropogenic lakes differ in acidification. They found high concentration of the following elements: K, Ca, Mg, Fe, Mn, Ni, Zn, and Cu.

Lake Muhazi gets its water from different rivers and ground water percolating into the lake (pH=8). It is one of the reasons of lower dissolved metal concentration which is low pollutant input from local industries in the surrounding area (Chen et al., 2000; Nguyen et al., 2005). The lake's geological source (it is located in a rift valley near a volcanic region) might influence the element concentration. Other studies have analyzed freshwater systems (Förstner and Wittmann, 1998; Hamilton-Taylor and Davison, 1995; An and Kampbell, 2003), but Talling (1965) explained this peculiar composition. Lake Muhzazi is not atypical and its position in the scale of tropical Africa influences the saline water. Dissolved oxygen and pH levels usually have typical clinograde profiles. Damas (1954) showed that in the mixed layer of the stratified water column, which extends down to 4 m, the pH level is approximately 8.5 times its means. The nutrients in water dissolved inorganic from the presence N, P, and K are very lower in the mixed layer, but the presence of Fe are estimated insignificant, because of those causes, the distribution and concentrations of major elements in Lake Muhazi are very high and other big cause might be the water from soil erosion which carried many contamination sediments into the Lake from neighbors mountains and from many human activities like agriculture used agrochemical near the lake.

5 Conclusion and Recommendations

This study was undertaken in Rwanda, Africa, in order to analyze of major elements in Lake Muhazi. The result of the water samples collected through the three sites showed that the lake has been contaminated by major elements, and this contamination might be as a result of its geology, as the lake is located in the east African rift near a volcanic channel. Human activity near the lake, such as agriculture, where large quantities of fertilizer are used, and fishing, has contaminated the lake, as well as soil erosion from the nearby mountains, which deposits many sediments into the lake, and domestic toxic water, causing water pollution. These observations suggest that more needs to be done to tackle this problem (e.g. prevent erosion) in order to protect the lake and its environment.

Acknowledgements

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