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Water Physico-Chemical Characteristics of the Lakes Burera and Ruhondo, Rwanda

Valens Habimana[1] and Antoine Nsabimana[2]*

[1] Department of Chemistry, School of Science, College of Science and Technology, University of Rwanda;

[2]*Department of Biology, School of Science, College of Science and Technology, University of Rwanda**;** Po.Box 3900 Kigali, Rwanda. Tel: 0788435561

***Corresponding Author:** Antoine Nsabimana, antoine.nsabimana@gmail.com

ABSTRACT

Rwanda possesses multiple lakes, whose properties were rarely described. The present study assessed physico-chemical characteristics of water in Burera and Ruhondo lakes located in highly populated area with steep slopes, which are under extensive agriculture, thus water quality monitoring is important. Both lakes were alkaline with high content of Mg, while Ruhondo had higher electrical conductivity than Burera. Phosphorus and nitrogen exceeded Class III EPA standards indicating that both lakes are at risk of eutrophication.

Keywords: water quality, lakes Burera and Ruhondo, Rwanda

1. INTRODUCTION

Burera and Ruhondo lakes in Northern Rwanda are of volcanic origin and possess fish resources important for the surrounding population. Besides, both lakes provide water for two hydro-power plants, Mukungwa and Ntaruka, generating around 90% of the total electricity in Rwanda (Uhorakeye and Möller, 2018). However, little information is available on water quality in these lakes. Earlier studies reported about water pollution in other Rwandan lakes: high level of nutrients and heavy metals in lake Muhazi, rivers Akagera and Nyabarongo (Mupenzi et al., 2009; Usanzineza et al., 2011); pesticide residues in Lake Kivu and other Rwandan lakes (Houbraken et al., 2017).

Assessment of physico-chemical characteristics of a water body is the prime consideration for to assess the quality of water for its best utilization (Angagao et al., 2017). A regular monitoring of water quality is important for water resource management. Surface water quality is suspectible to deteriorate due to various anthropogenic activities (Masresha et al., 2011). This study assessed physico-chemical characteristics of surface water from the lakes Burera and Ruhondo.

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2. MATERIAL AND METHODS

Lake Burera is located at 1° 26' 56.4''S latitude and 29° 46' 12'' E longitude, and Lake Ruhondo at 1° 29' 13.2'' S latitude and 29° 44' 52.8''E longitude (Fig. 1). Lakes Burera and Ruhondo have area of 51.8 and 26.6 Km^2 (Isumbisho et al., 2011) and maximum depths of 179 and 68 m, respectively. Annual rainfall range is between 1400 and 1800 mm/year, and temperature between 10^oC and 25^oC (Musaninkindi, 2013). Surface water from both lakes was collected monthly from January to April 2019 from three sampling stations. Collected samples of 500 ml each were bottled and transported to the laboratory the same day. The pH, Dissolved Oxygen (DO), Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were recorded *in situ* using HACH 440d Multimeter. Calcium, Sodium and Potassium ions were determined using flame photometer. Magnesium and Total Alkalinity were determined using titration with Metrohm automatic Titrator. Magnesium was determined from the total hardness minus the pre-determined value of Calcium. The determination of total hardness was by titrating water samples with standardized EDTA using Eriochrome Black T indicator, which forms a stable wine-red complex with magnesium ion. This titration is carried out at a pH of 10 in NH_3/NH_4^+ buffer.

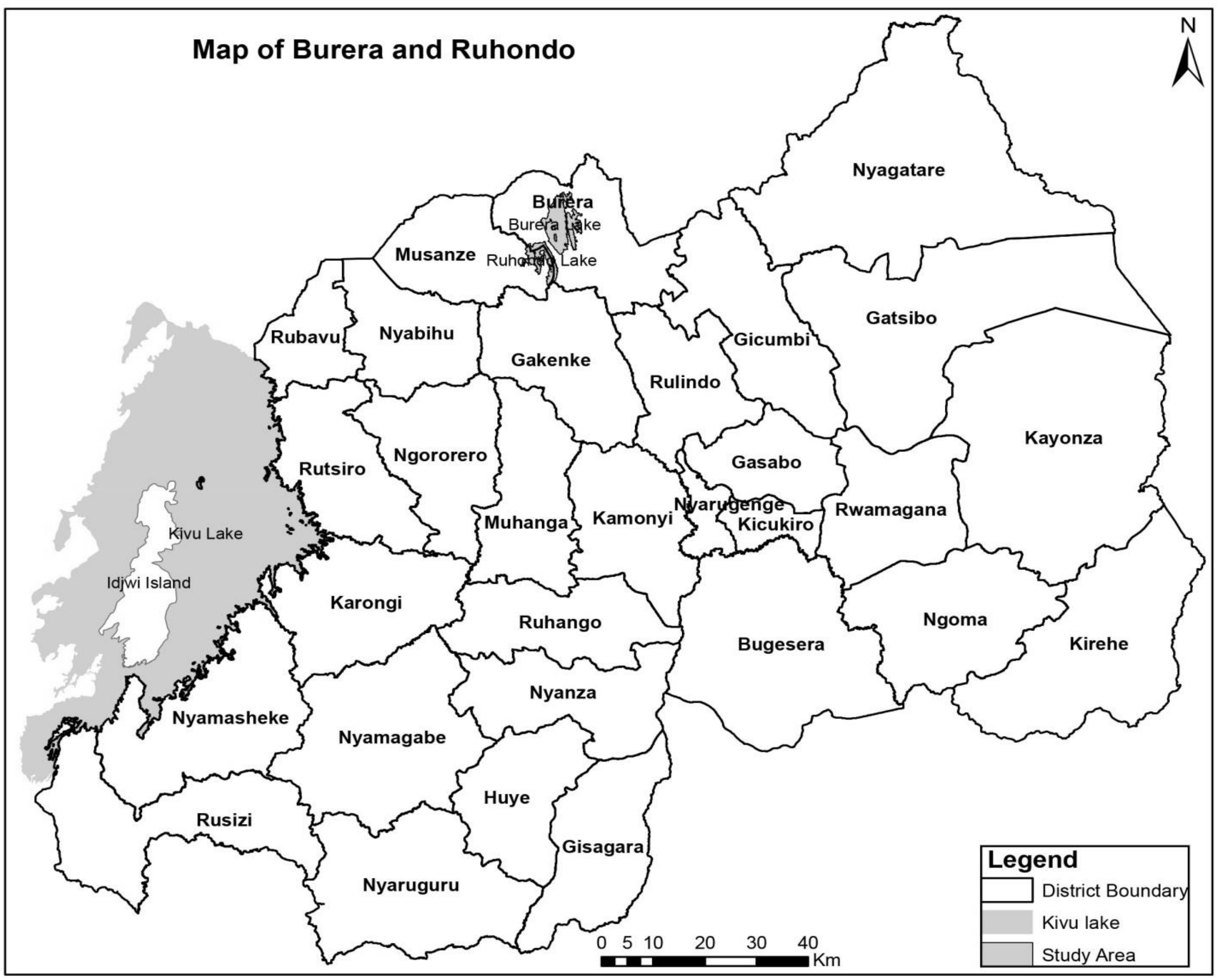

Figure 1: Location of lakes Burera and Ruhondo on Rwanda map

Organic matter was determined by mixing the samples with potassium dichromate in sulfuric acid in the presence of silver sulfate as oxidation catalyst for straight chain hydrocarbons and mercuric sulfate as complexion agent for halides. The samples were then digested for two hours on a block digester at 150ºC and analyzed using SHIMADZU UV-Vis-NIR Spectrophotometer. Nitrogenous and phosphorus forms in water were measured using SHIMADZU UV-Vis-NIR Spectrophotometer. For determination of phosphorus, ammonium molybdate and antimony potassium tartrate react with orthophosphates in acid medium for form antimony-phospho-molypdate complex, which is reduced by ascorbic acid to form a blue color complex. The absorbance of standards and the sample are measured with UV-visible spectrophotometer at 650 nm and the concentration of phosphorus in the sample is determined from the standard curve. Organic phosphorus compounds were converted to orthophosphate by per-sulfate digestion and polyphosphates are converted to the orthophosphates by sulfuric acid hydrolysis so that they can be analyzed. Samples for determination of dissolved forms of phosphorus were filtered before the analysis. Nitrate was estimated using phenol disulfonic acid method, Total Nitrogen was calculated as the sum of Nitrate and Nitrogen determined using Kjeldahl method. Analysis of variance (ANOVA) under General Linear Model was performed using MINIAB 17 to compare water characteristics in both lakes and their dynamic during the period of long rains (from January to April). Prior to ANOVA, variables deviating from normal distribution were checked for outliers and square root or log (x+1) transformed.

3. RESULTS

Both lakes were alkaline, but Ruhondo had significantly ($p<0.001$) higher alkalinity and pH than Burera with values of 87.2 and 165.2 mg/l for alkalinity and 7.88 and 8.36 for pH, respectively (Table 1). Organic matter and calcium did not differ in water between both lakes (Table 1).

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Table 1. Mean surface water characteristics of Burera and Ruhondo lakes, Rwanda (Jan.-Apr. 2019)

Parameters Units	Alkalinity, mg/l $CaCO_3$	pH	Ca, mg/l	Mg, mg/l	Na, mg/l	K, mg/l	Electrical Conductivity µs/cm	Total Dissolved Solids, mg/l	Dissolved oxygen, mg/l	Organic matter, mg/l
Burera	87.2	7.88	12.8	30.6	17.9	13.2	113.2	57.3	7.53	2.68
Ruhondo	165.2	8.36	11.1	74.3	32.1	32.2	221.3	116.6	7.77	2.74
P	*<0.001*	*<0.001*	*NS*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*0.01*	*NS*
USEPA max acceptable concentration limit, mg/l	*50-120*	*6.5-8.5*	*NA*	*NA*	*NA*	*NA*	*700*	*350*	*11*	*NA*
	Nitrogen-nitrate, mg/l	Total N, mg/l	Total P, mg/l	TN:TP	Orthophosphates, mg/l		Organic P, mg/l		Condensed P, mg/l	Hydrolysable P, mg/l
					Total	Dissolved	Total	Dissolved	Total	Insoluble
Burera	0.48	8.28	0.177	46.59	0.0293	0.0285	0.1317	0.0018	0.167	0.0052
Ruhondo	0.42	8.38	0.184	45.56	0.0268	0.0252	0.1437	0.0062	0.136	0.0032
P	*NS*	*NS*	*NS*	*NS*	*0.001*	*<0.001*	*NS*	*<0.001*	*<0.001*	*<0.01*
US EPA limit, mg/l	*10*	*0.67*	*0.06*	*22*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*

US EPA limit - maximum permissible concetration limit for US EPA surface waters; NR – Not regulated.

Table 2. Water quality characteristics means from two lakes (Burera and Ruhondo, Rwanda) from January to April 2019

	Alkalinity, mg/l $CaCO_3$	pH	Ca, mg/l	Mg, mg/l	Na, mg/l	K, mg/l	Electrical conductivity, µs/cm	Total dissolved solids, mg/l	Dissolved oxygen, mg/l	Organic matter, mg/l	Nitrogen-nitrate, mg/l	Total N, mg/l	Total P, mg/l	Total organic P, mg/l	Total dissolved P, mg/l
January	119.8	7.75	10.0	45.97	22.11	17.88	134.1	65.8	*7.7*	*2.37*	*0.424*	*7.86*	*0.181*	*0.139*	*0.139*
February	116.0	7.87	10.9	47.58	22.59	18.56	131.0	63.02	*7.65*	*2.38*	*0.423*	*8.26*	*0.179*	*0.136*	*0.136*
March	123.7	8.26	12.0	52.95	25.04	23.67	158.0	81.12	*7.58*	*2.70*	*0.475*	*8.62*	*0.185*	*0.142*	*0.142*
April	145.5	8.60	14.76	63.10	30.4	30.12	246.0	138.0	*7.66*	*3.27*	*0.474*	*8.68*	*0.178*	*0.134*	*0.134*
P	*<0.01*	*<0.01*	*0.05*	*<0.01*	*0.001*	*0.001*	*<0.001*	*<0.001*	*NS*	*0.001*	*<0.01*	*<0.05*	*NS*	*NS*	*NS*

NS- not significant at P<0.05.

Magnesium had the highest concentrations in both lakes (Table 1) reflecting its abundance in underlying basalt from volcanic deposits (Bhateria and Jain, 2016). Ruhondo samples contained almost double values of Mg, Na, K, electrical conductivity and total dissolved solids as compared to Burera samples (Table 1). Higher Magnesium, Sodium and Potassium in Lake Ruhondo than in Lake Burera would be the main cause of the difference in electrical conductivity between Ruhondo and Burera. Dissolved oxygen was significantly higher in Ruhondo samples (Table 1). Nitrogen nitrate, total N, total and organic P, and total N to total P ratio did not differ between the two lakes (Table 1). Orthophosphates (total and dissolved), condensed and hydrolysable P were higher ($p<0.01$ or $p<0.001$) in Burera than Ruhondo (Table 1), but dissolved organic P was higher ($p<0.01$) in Ruhondo (Table 1). Among the parameters exceeded EPA maximum permissible limits (USEPA, 2018) were: mean alkalinity in Ruhondo (slightly higher), total N (exceeded 12 times), total P (exceeded three times), and N:P ratio (two times) (Table 1). For the period from January to April, there was a trend of significant ($p<0.05$ or less) increase in alkalinity, pH, Ca, Mg, Na, K, electrical conductivity, total dissolved solids, organic matter, nitrogen nitrate and total nitrogen (Table 2). However, dissolved oxygen, total P, total organic and dissolved P did not change significantly with wet season (Table 2).

4. DISCUSSION

Lakes have more complex and fragile ecosystem as they do not have a self-cleaning ability and therefore readily accumulate pollutants (Watson et al., 2016). The pollutants accumulate along food chains and finally threat human health, or water in the lake may become of inadequate quality and unusable for drinking. One of the environmental threats to African lakes is the high level of nutrients from various sources (Mavuti et al., 1996). Algae feed on those nutrients and grow faster, dying of algae bloom produces high amount of organic matter in water bodies (Liu et al., 2019). Microorganisms use high amount of oxygen in the decomposition of organic matter, a process, which reduces dissolved oxygen in water and results in bad odor production. Low oxygen in water bodies results in stress or even death of while aquatic organism or some species, e.g. fishes used for consumption (Chaudhry and Malik, 2017).

Alkalinity is important parameter of water quality as it indicates the acid neutralizing power of the lake. Based on United States Environmental Protection Agency (USEPA) classification of lakes based on alkalinity, lakes Burera and Ruhondo could be classified as non-sensitive lakes. In acid non-sensitive lakes, the pH of the lakes is stable as they have the ability to neutralize acid pollution.

Phosphorus in aquatic systems may come from external sources or internally by sediment re-suspension. Among different P compounds, the main was organic P. Cattle and human feces and runoff from surrounding steep slopes may be the sources of organic phosphorus (Leytem et al., 2013). High level of organic phosphorus in lakes Burera and Ruhondo indicates that the lakes receive significant quantity of sewage from animal or human waste. Organic phosphorus is also an indication of a possible increase in the phytoplankton in water bodies. The possible source of dissolved organic phosphorus is the discharge of waste water in the lakes (Qin et al., 2015).

Physico-chemical quality of water body is one of the determinants of the types and quantity of aquatic organisms living in. Biochemical reactions, metabolism and immune system of aquatic organisms are affected by the quality of water, in which they live (Paturej et al., 2017). Thus, the change in water quality has negative impact on lakes ecosystem components.

High levels of Nitrogen and Phosphorus witness about important water pollution. Increase in these nutrients accelerates the proliferation of algal blooms and eutrophication , which is a slow natural process but anthropogenic activities have accelerated this process with excess nutrient discharged in water bodies (Liu et al., 2017) It is also possible that the examined lakes receive high amount of waste water due to the high density of population around lakes.

Among the human activities contributing to change in water quality include nutrients coming from agricultural activities, urbanization around the water bodies and rapid increase in population using water bodies as dumping sites. In addition to the mentioned causes of the water quality changes, climate change is another factor accelerating the change in water quality (Bondarenko et al., 2019). Like in other parts of the world, pollution from human activities is also a threat to water bodies in Rwanda, especially lakes (Mukanyandwi et al., 2018).

5. CONCLUSION

Our finding revealed high concentrations of Ca, Mg, Na, N and P, which increased during the long rains period (January – April). Consistent presence of N and P contamination irrespective of month is witnessing important levels of water pollution, which may originate from mineral fertilizers, human and animal waste. Increased N and P in water could accelerate increased algae growth and thus, lead to rapid eutrophication of the lakes. The findings of this paper inform scientific audience and policy makers about the need to enforce protection measures for both lakes and introduce water quality monitoring.

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