Scholars Academic Journal of Biosciences (SAJB) **ISSN 2321-6883 (Online)**
Sch. Acad. J. Biosci., 2014; 2(3): 236-245 **ISSN 2347-9515 (Print)**

(An International Publisher for Academic and Scientific Resources)
www.saspublishers.com **DOI:** 10.36347/sajb.2014.v02i03.011

Research Article

A Preliminary Assessment of Physico-Chemical and Bacteriological Characteristics of Lake Edward and Majors Tributaries Rivers, Democratic Republic of Congo

Bagalwa M.*[1], Yalire M.[2], Balole E.[3] and Karume K.[2],
[1] Centre de Recherche en Science Naturelles de Lwiro, Bukavu, D. R. Congo
[2] Observatoire Volcanologique de Goma, D. R. Congo
[3] ICCN/Goma, D. R. Congo

***Corresponding author**
Jean Jacques Bagalwa M.
Email: mashibagalwa@yahoo.fr

Abstract: The physico-chemical and bacteriological parameters commonly used to determine water quality of lakes and rivers in tropical areas indicate declining trend of water quality, unsuitable for the growth of higher aquatic species. A study was carried out on lake Eduard water, streams water and rivers water in the Democratic Republic of Congo side to assess the physico-chemical and bacteriological characteristics. About 20 physicochemical and five bacteriological parameters were studied during the sampling period in September 2013 using standards techniques of water analysis. The results have shown that the different parameters varied from one river to another and from Lake water. There are a strong positive correlation between the Lake and the major tributaries rivers in general except Musenda River which is weak correlated with the Lake, Ishasha, Rutshuru, Semuliki and Kisaka rivers. The cluster analysis classified the samples in three classes according to selected physico-chemical parameters. The concentrations of most of the investigated parameters in the water sample from Lake Eduard and major tributaries river were in the permissible limit of WHO and UNECE water quality guidelines. Fecal bacteria were recorded in sampling water such as *Escherichia coli*, *Vibrio cholera* and Klesbiella. The presence of *Vibrio cholera* in water is dangerous to human and must be taken in account in management of the Lake Eduard. A regular monitoring of Lake Eduard and major tributaries rivers is required not only preventing the outbreak of diseases but also to check the water from further deterioration.
Keywords: Physicochemical, Bacteriological, Lake Eduard, Tributaries rivers, DRCongo

INTRODUCTION

Water plays an essential role in the ecosystem. Pollution of water sources in rural areas remains a challenge in many developing countries [1- 5]. Due to increased human activity, water pollution is widely spreading throughout the world. Lake Eduard has been identified as one of the most eutrophic lakes in the Western Rift valley. Its often pea-green color is due to the proliferation of unicellular algae resulting primarily from large amounts of nutrients [6- 10]. Fish kills, related to low oxygen conditions, are frequent [10]. Before, the hillsides of the catchment were once covered with forest vegetation. But known subsistence farming was practiced on the plains to grow crops. Deforestation in the hills over a period of time, along with agriculture, causes extreme erosion during heavy rainfall [11]. Sediments resulting from erosion are carried across plains and discharged into the rivers and Lake Eduard shoreline. This has led to severe stream bank erosion and sedimentation of the rivers and lake [11, 12].

Rivers are known to be vital and vulnerable freshwater systems that are critical for the sustenance of all life. However, the declining quality of the water in these systems threatens their sustainability and is therefore a cause for concern [13-14]. The maintenance of healthy aquatic ecosystem depends on the physico-chemical properties and biological diversity [15].

Very little information exists on the assessment of water quality in Lake Eduard catchment. According to Kilham, [16] and Lehman, [10], despite their ecological, evolutional and geological roles, the real ecology and chemistry of the rivers in the broad south-eastern plain, and others that flow across the western Mitumba escarpment into Lake Edward is essentially unknown and unmeasured. It is very necessary to understand the physico-chemical and bacteriological qualities of water in order to manage the ecosystem. Presence of coliforms, total dissolved solids, conductivity, pH, Hardness, DO, BOD, COD and nutrient are some of the significant parameters to study to determine the quality of water. Changes in the water quality of Lake Eduard or its tributaries could be a

contributing factor to the decline of ecosystem production and loss of biodiversity. However, no water-quality or water-quantity data exists for the tributaries Rivers and the lake itself except the work of Talling [9]. Significant spatial variation was observed in physico-chemical parameters of the study stations in this lake.

Microorganisms are widely distributed in nature, and their abundance and diversity may be used as an indicator for the suitability of water [17]. The use of bacteria as water quality indicators can be viewed in two ways, first, the presence of such bacteria can be taken as an indication of faecal contamination of the water and thus as a signal to determine why such contamination is present, how serious it is and what steps can be taken to eliminate it; second, their presence can be taken as an indication of the potential danger of health risks that faecal contamination posses. A wide range of pathogenic microorganisms can be transmitted to humans via water contaminated with faecal material. These include enteropathogenic agents such as salmonellas, shigellas, enteroviruses, and multicellular parasites as well as opportunistic pathogens like *Pseudomonas sp*, *Klebsiella* and *Vibrio spp* [17].

A basic understanding of the Lake Eduard watershed is necessary for park managers to preserve the high quality of water resources and the biodiversity using the water. This includes not only Lake Eduard, but the inflows to the lake as well. It is hypothesized that the quality of water in the catchment of the lake Eduard is deteriorate by anthropogenic activity taking place actually. Obtaining knowledge of the entire watershed could lead to a better understanding of the spawning habitat of fish and other unique biodiversity in the Lake but also in the entire Virunga National Park catchment. The overall aim of the study is to determine the status of the Lake Eduard and major tributaries water quality. Therefore the study intends: 1. To determine the physico-chemical and bacteriological characteristics of the Lake Eduard and major tributaries; 2. To recommend the efficient management practices of the Lake ecosystem to the Park Virunga manager for conservation of the biodiversity.

Description of study area

Lake Edward (0° – 0°40′ S, 29°20′–29°50′ E, 912 m a.s.l.) is located on the border separating Uganda from the Democratic Republic of Congo in the western arm of the East African Rift valley. Lake Eduard is bounded to the North by the Ruwenzori Mountains and to the South by the Virunga Volcanoes [18]. To the West lie steep mountains on the Lubero border fault, while the Kichwamba border fault rises more gently to the East to form a low topographic divide between lakes Eduard and Victoria (Figure 1).

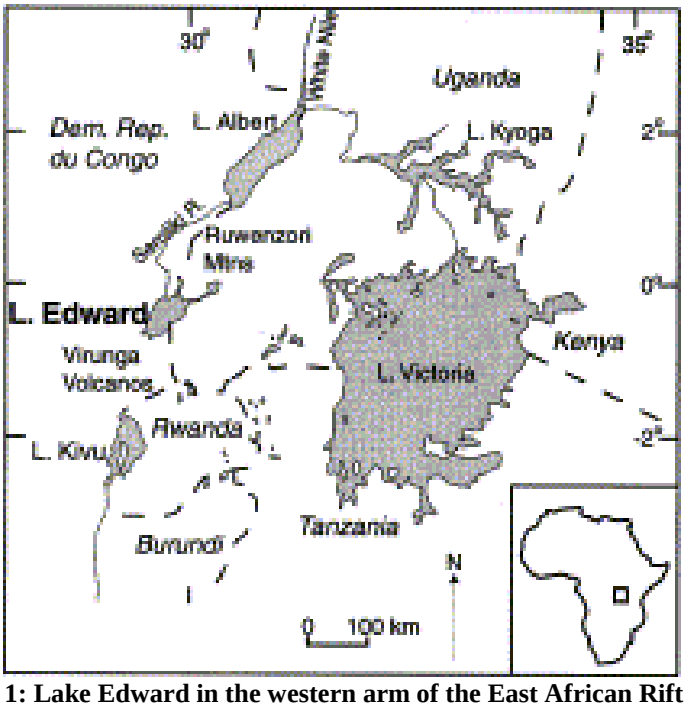

Figure 1: Lake Edward in the western arm of the East African Rift valley

Lake Edward has a surface area of 2325 Km^2 and a maximum depth of 117 m located just a few kilometers East of the Western shore. Lake Edward is connected to Lake George to the East by the Kazinga Channel [19]. It is presently an open system, draining to the North via the Semliki River (Beadle, 1981). Lake Edward's catchement, with a total area of 20374 Km^2, includes significant inflows from rivers draining the Ruwenzori highlands in the North (Nyamugasani and Lubilja rivers), the Rutshuru, Ishasha and Rwindi Rivers draining the Virunga Volcanoes in the South and Lake George via the Kazinga channel to the East.

Lake Edward is permanently anoxic below 80 m depth and periodically anoxic below 40 m depth and is considered a eutrophic system [20, 21]. Chemically, Lake Edward is a Na-Mg-HCO_3 system with a salinity of approximately 0.8 g/L and a pH averaging 8.9 [10, 20]. Their ionic composition appears to be out of balance with respect to reported inputs from the Northern and Eastern rivers, pointing to the dominance of alkaline inflows from the Virunga Volcanoes in Lake Eduard's salt budget [10, 20, 22]. The annual rainfall in the Lake Eduard catchment is averaging 900 mm/yr with two rainy seasons from October to December and March to May [10, 23].

During the investigation, 10 samples were taken in 8 rivers sites and 8 sites in the open Lake Edward were considered. These rivers are: Rutshuru, Ishasha, Semliki, Muko, Kisaka, Mosenda, Lubiriha and Lunyasenga as shown in figure 2 below.

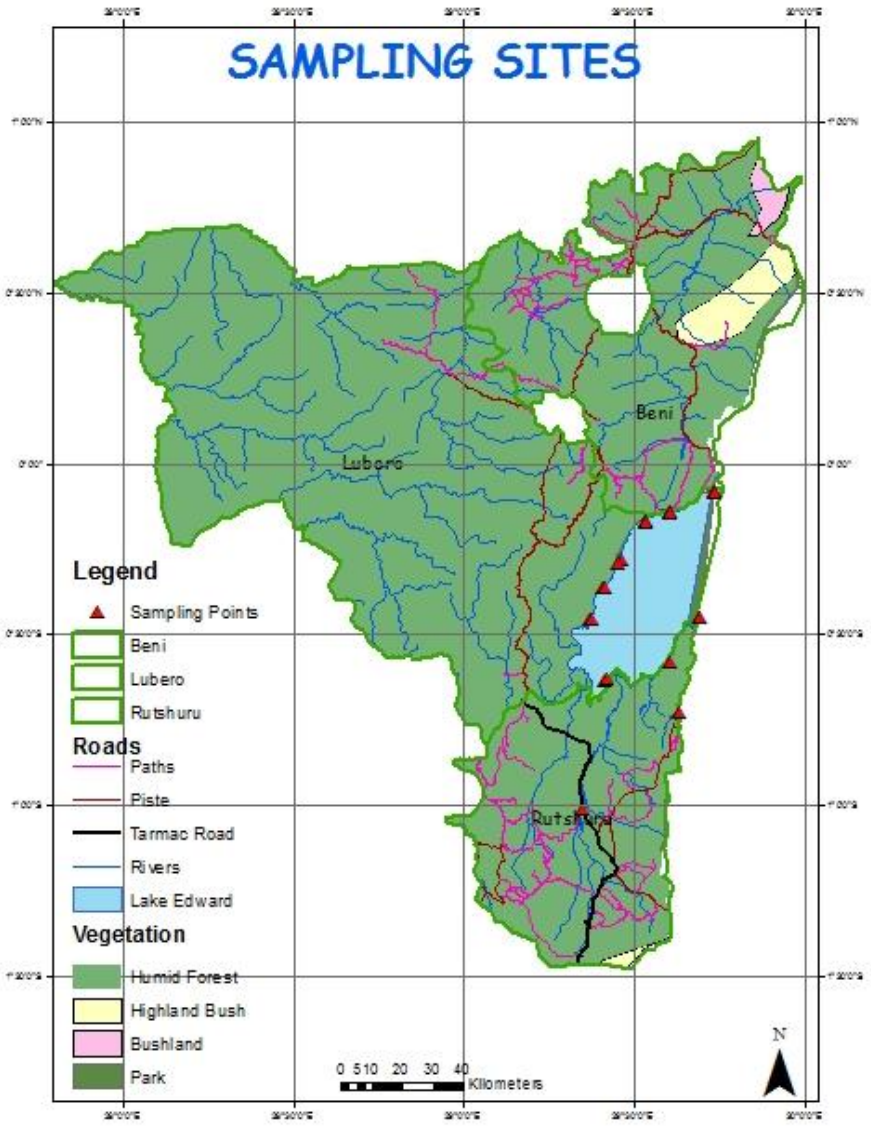

Figure 2. Sampling sites localization in Lake Edward catchment.

MATERIAL AND METHODS

Physico-Chemical Analysis

Surface water temperature, pH, Conductivity, Transparence, Dissolved Oxygen (DO), five-day Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Total Hardness, Calcium, Magnesium, Chloride, Sulphate, Fluoride, Hydro-carbonate, Free CO_2, Total phosphore, soluble reactive phosphore, Total nitrogen, Ammonium, Nitrate and SS were measured in the different sites and analyzed following the procedures described in Golterman *et al*. [24]; APHA [25]; Wetzel and Liken [26]. On each occasion, samples were collected at midmorning. Water was collected at a depth of 30 cm, near midstream. The temperature was measured using an YSI PROFESSIONAL PLUS. The meter sensor was dipped into the water and the temperature reading was recorded after the meter had stabilized. The pH was determined

in-situ using the same YSI PROFESSIONAL PLUS which was first standardized with two buffers (4 and 10). The conductivity was also measured in situ with the same equipment. Transparence of the lake water was determined with the aid of secchi disc. The calibrated disc was lowered into the water and the depth at which it disappeared was observed and recorded. At each station, two water samples were collected in pre-washed glass bottles. The level of DO in the Lake water and rivers was determine after fixation in the field, following the iodometric Winkler's method [24, 27]. BOD_5 was measured as the decrease in DO after incubation in the dark at 20°C for five days. The BOD_5 in mg/L of DO was calculated by subtracting the mg/L of DO in incubated sample bottles from the DO in initial bottles [28]. Other water samples were taken in 1l plastic bottles at the same time, for other chemical analyses. The plastic bottles were rinsed before overnight with 1M HCl and then with distilled water. The bottles were also rinsed thrice with sample water before final collection. The samples were placed in a cooler box with ice for transportation to the Goma Volcano Observatory laboratory. Analyses were not done immediately upon arrival at the laboratories; samples had to be stored in a refrigerator at 4^oC with preservation as appropriate. Hydro-carbonate (HCO_3^-) was estimated titrimetrically using 0.1 N HCl with phelphtalein and bromocresol as indicators (5 %). Total hardness was determined by complexometric method using EDTA after added a tampon and Eriochrome T indicator. Calcium also was determined by complexometric method using mirixid indicators. Magnesium was determined by subtracting the Total hardness and calcium. The Chloride was determined by titration with silver nitrate and potassium chromate indicator [24]. The sulfate was determined using gravimetrical method. Fluoride was determined using a spectrophotometer (DR/2500 ODYSSEY at 650 nm). TSS (mgl^{-1}) were estimated by filtration of 1l of water through analytical filter paper (Whatman 589, 185µm pore size), which was dried at 105°C and pre-weighed [25]. The nutrients (TN, NO_3^-, NH_4^+, TP and PO_4^{3-}) was determine using a spectrophotometer (UNICO 1200 at 630 nm for nitrogen and 850 nm for phosphorus) [26]. The hydrocarbon was identified by a mixed reactive acetic acid and sulfuric acid. The presence of hydrocarbon was identified by the presence of a red color of the sample [29]. All measurements were made in duplicate. Data were compared with UNECE, [30]; FEPA, [31] and WHO [32] standards.

Bacteriological Analysis

Samples were collected in clean, sterile polypropylene 200 mL bottles. Before the bottles were washed with deionized water and sterilized in the oven at 60 °C overnight. At the field bottle was washed thrice before collecting sample. All samples were kept in refrigerated cool box and transported to the laboratory. All analyses were completed at the Laboratory of Bacteriology at the "Centre de Recherche en Sciences Naturelles de Lwiro". Analyses for total coliform, fecal coliform and fecal streptococci were made in accordance with standard methods [33].

Coliforms were detected by inoculation of samples into tubes of MacConkey broth and incubation at 37 ± 1 °C for 48 h. The positive tubes were sub-cultured into brilliant green bile broth (BGBB) and were incubated at 44.5 ± 1 °C. Gas production in BGBB at 44.5 ± 1 °C was used for the detection of faecal coliform after 48 h incubation [34, 35]. Cultures showing no production of gas in 48h were considered negative. The tubes showing gas were inoculated on endo or eosine-methylene-blue agar; and one or more typical colonies were picked off into Brilliant Green Bile broth [36] and studied microscopically to see whether the contained organisms had the morphological and staining properties of coliform bacilli. Faecal streptococci were detected by inoculation of water samples into Azide Dextrose broth and incubation at 37.5 ± 1 °C for 24–48 h [25]. Nutrient agars (NA), Salmonella- shigella agar, Thiosulphate citrate bile salt sucrose agar were used to determine heterotrophic bacterial, *Salmonella* and *Shigella*, *Vibrio cholerae* respectively. All plates were incubated at 35°C for 24hrs. Presumptive colonies were confirmed by gram staining and biochemical reactions and each plate was given a positive or negative score. Isolates were confirmed by some conventional biochemical test [37].

RESULTS AND DISCUSSION

Physico-chemical Parameters

The physico-chemical parameters of Lake Eduard and the major tributaries rivers in the catchment are present in table 1.

The rivers water was in normal *p*H range (pH between 7.65 and 9.1) and the Lake water in the range of 8.6 ± 0.17. The *p*H was within the range of 6.5 – 9.5, which indicates that the water is made for drinking and domestic purposes [32]. The UNECE [30] also sets slightly protection limits of *p*H from 6.5 to 8.5 for fisheries and aquatic life. Based on these guidelines, the *p*H of Lake Eduard and the major tributaries rivers water would not adversely affect its use for domestic and the aquatic ecosystem. The well buffered nature of the Lake Eduard and the major tributaries rivers water can be attributed to the nature of deposits over which it flows [16]. Water temperatures ranged from 26.4 ±1 ^oC to 23.76 ±1.71 ^oC, respectively for Lake and rivers water which are within the temperature ranges. Temperature has a pronounced effect on the rate of chemical and biological processes in water; no other single factors affect development and growth of fish as much as water temperature [38].

Table 1: Physico-chemical parameters of Lake Eduard and the major tributaries rivers

	Lake	Ishasha	Rutshuru	Semuliki	Kasindi	Muko	Lunyasenge	Kisaka	Musenda
Temperature	26.40	22.20	22.15	27.20	23.30	22.40	24.80	26.10	21.90
pH	8.68	7.65	8.11	8.90	7.90	9.10	8.80	8.78	9.06
Conducuctivity	685.85	907.55	1588.50	817.00	134.70	96.50	100.80	610.00	39.90
Transparance	79.90	20.00	0.20	100.00	5.00	25.00	5.00	160.00	20.00
DO	4.63	5.00	1.18	5.59	9.71	6.04	8.65	7.43	7.43
BOD	2.95	1.02	0.37	1.55	5.59	4.98	5.63	4.24	5.06
COD	32.30	50.40	26.40	18.80	42.00	26.80	4.40	2.80	14.80
TP	0.30	0.15	0.22	0.13	0.52	0.89	0.46	0.69	0.64
SRP	0.05	0.29	0.11	0.06	0.11	0.33	0.07	0.02	0.03
TN	10.01	17.64	7.53	4.31	6.88	15.80	19.85	16.07	3.10
NH4+	0.58	2.13	0.23	1.70	1.06	0.36	0.63	0.17	0.22
NO3-	5.01	2.86	1.32	5.43	6.34	5.11	6.37	3.26	7.17
CL-	122.75	65.00	137.00	100.00	26.00	36.00	72.00	72.00	60.00
Hard	21.61	35.26	28.37	17.90	22.55	10.74	14.14	15.04	15.22
Ca	19.02	33.65	27.21	15.75	22.20	7.16	12.17	15.04	13.60
Mg	2.60	1.61	1.16	2.15	0.36	3.58	1.97	0.00	1.61
HCO3-	114.50	10.50	268.50	118.00	26.00	28.00	23.00	19.00	15.00
CO2	1.83	0.00	0.00	2.30	0.00	0.00	0.00	0.00	0.00
TSS	0.85	1.45	1.20	2.02	0.30	0.96	0.38	0.52	0.46
SO4--	20.13	9.50	86.50	0.00	2.00	0.00	9.00	0.00	0.00
F-	0.36	0.05	1.15	0.00	0.02	0.58	0.01	0.52	0.09

Conductivity values varied between 685.85±150.73 µS/cm and 536.87 ± 443.83 µS/cm respectively in the Lake water and in the major tributaries rivers. According to Umeham [39] a high surface electrical conductivity of about 400 µS/cm of a water body coupled with its shallow depth be used to assign a high morphoedaphic index to it and therefore a high fish production potential. For running water, the guide limit [40] of water conductivity is 400 µS/cm. Thus with respect to electrical conductivity, the lake water is running.

DO concentrations in unpolluted water are normally about 8 – 10 mg/L at 25 ^{o}C [32]. Concentrations below 5.0 mg/L adversely affect aquatic life. DO is one of the important parameters in water quality assessment. It reflects the physical and biological processes prevailing in the water. The concentration of DO in the rivers is ranged between 6.38 ± 1.93 mg/L and 4.63± 0.55 mg/L from the Lake water. Thus, the river water is suitable for use in the aquatic ecosystem. These values indicate relatively moderated organic pollution. The high temperature and low DO in the Lake water create favorable conditions for development of blue-green algae [41]. The low DO values were also recorded in other ecosystems as in lake Kivu water [42], Ujjani reservoir in India [43] and rivers Ciranyobowa and Kahuwa rivers tributaries of lake Kivu [44, 45].

The high value of TSS (2.54 mg/L) was recorded at Rutshuru River and the lowest was recorded in Kasindi River. Low concentration of TSS was recorded in the Lake water samples. TSS recorded in the major rivers of Lake Eduard catchment indicated a zone of sedimentation. Soil erosion and runoff from agriculture activities contributed to high TSS in the river water. TSS is a common indicator of polluted waters. His levels and fluctuations influence aquatic life, from phytoplankton to fish. A river with high sedimentation would decrease light penetration into the water column and hence, reduce photosynthesis. TSS is closely linked to land erosion and to erosion of river channels. It is an important measure of erosion in river basins and also closely linked to the transport through river systems of nutrients (especially phosphorus), metals and a wide range of industrial and agricultural chemicals.

BOD_5 was low in the Lake water (2.95 ± 1.06 mg/L) than in the rivers (3.55 ± 1.93 mg/L) wherever COD was high in the Lake water (32.30 ± 19.50 mg/L) and low in the rivers (23.30 ± 13.0 mg/L). The concentration of Chloride varied between 26 mg/L

(Kasindi River) and 137 mg/L (Rutshuru River). It was also found in Lake Eduard water with about 122.75 ± 30.94 mg/L of Chloride. The desirable chloride level is 200 mg/L, while the permissible limit is 600 mg/L. All the concentrations recorded are below the limit [46]. Chlorides are relatively harmless to organisms [46]. Calcium concentration was high in all samples compared to Magnesium even from Lake Eduard as well as from river water. The total hardness in the major rivers is between 21.61 ± 8.89 mg/L in the Lake water and 19.9 ± 6.62 mg/L in the rivers. Water has been classified on the basis of hardness as follows [47, 48]: water having 0 - 75 mg/L as soft, 75 – 150 mg/L as hard, while samples having total hardness of over 300 mg/L was hard. Lake Eduard and major tributaries rivers have hardness in the range of soft water, level below the desirable and permissible limit of WHO. Hydrocarbonate, Sulfate and Fluoride were high in the Rutshuru River comparatively to other rivers and Lake Eduard water. The concentration of Fluoride ranged from (0.30 ± 0.34 mg/L in the rivers) to (0.36 ± 0.33 mg/L in the Lake water). Based on the WHO standard the fluoride desirable level should be 1 mg/L and the permissible limit 1.5 mg/L [46]. The sulfate ranged from (20.13 ± 9.06 mg/L) to (13.38 ± 18.28 mg/L) respectively in Lake water and major tributaries rivers. The high concentration of sulfate (100 mg/L) was recorded in the Rutshuru River in the Virunga National Park. WHO standards indicate highest desirable limit of sulfate 200 mg/L and the maximum permissible limit being 400 mg/L. The sulfate recorded in the Rutshuru River his probably due to the thermal water flowing in the river in the Virunga National Park. It was reported that thermal water contained high quantity of sulfate [16, 49].

Hydrocarbonate values ranged from 114.5 ± 10.75 mg/l in Lake water to 63.50 ± 64.88 mg/l in the major tributaries rivers. The absence of sufficient carbonic acid in the lake water and the Semuliki River at the inlet caused the dissociation of the bicarbonate ion and form additional carbon dioxide [50]. Carbone dioxide measured in the Lake Eduard (1.83 ± 0.92 mg/L) and in the inlet of Semuliki river (2.3 mg/L). Algae readily exploit this carbon dioxide for their photosynthetic needs, at the cost of allowing a build-up of hydroxide ions to such an extent that the water becomes quite alkaline [50].

TP and TN were respectively about 0.30 ± 0.20 µmole/L and 10.01 ± 7.41µmole/L for the Lake water and 0.46 ± 0.22 µmole/L and 11.40 ± 5.94 µmole/L for rivers. The high TP was recorded in Muko river (0.86 µmole/L) and the lowest in Semuliki river (0.132 µmole/L) the outlet of Lake Eduard. It is well known that the main natural origin of phosphate is due to erosion, which is the chemical and mechanical weathering of rocks. During the erosion process, phosphate is mobilized partly as dissolved inorganic phosphate and partly adsorbed on or even into clay particles [51]. The Muko river comes from mountain where erosion is occurring due to inappropriate agricultural practice done in slope of mountains. And also as the river pass through Virunga National Park, the used of the river by wide animals and their excreta can increase the phosphorus concentration [51]. Most of Nitrogen is possibly come from nitrate (NO_3^-) washed with the TSS into the river but also from decay of dead vegetation. The values obtained for the TN is in agreement with general values for African rivers [52]. Phosphorus and Nitrogen are required to sustain life but excess loads can upset the nutrient cycle balance resulting in change in water quality harmful to aquatic organisms [53].

Person's r correlation of selected physico-chemical parameters of the Lake Eduard and the major tributaries rivers are present in table 2. The physicochemical parameters used in the correlation were temperature, pH, conductivity, DO, TP, TN, Cl-, Hardness, CO2, TSS, SO4—and F-. Theses parameters are the main considered in this study which are ecological important for aquatic life.

Table 3: Person's r correlation of physicochemical parameters of Lake Eduard and the major tributaries rivers

	Lake	Ishasha	Rutshuru	Semuliki	Kasindi	Muko	Lunyasenge	Kisaka	Musenda
Lake Eduard	0								
Ishasha river	0.99	0							
Rutshuru river	1.00	1.00	0						
Semuliki river	1.00	1.00	1.00	0					
Kasindi river	0.98	0.98	0.97	0.98	0				
Muko river	0.96	0.94	0.94	0.95	0.97	0			
Lunyasenge river	0.87	0.82	0.83	0.85	0.88	0.95	0		
Kisaka river	1.00	1.00	1.00	1.00	0.98	0.95	0.85	0	
Musenda river	0.59	0.50	0.51	0.55	0.62	0.74	0.88	0.54	0

Table 3 shows that there is a strong positive correlation between the Lake and the major tributaries rivers in general except Musenda river which is weak correlated with the Lake, Ishasha, Rutshuru, Semuliki and Kisaka rivers. This Person's correlations concern the selected physicochemical parameters. The cluster analysis confirms the classification of the different tributaries rivers as indicated in figure 3.

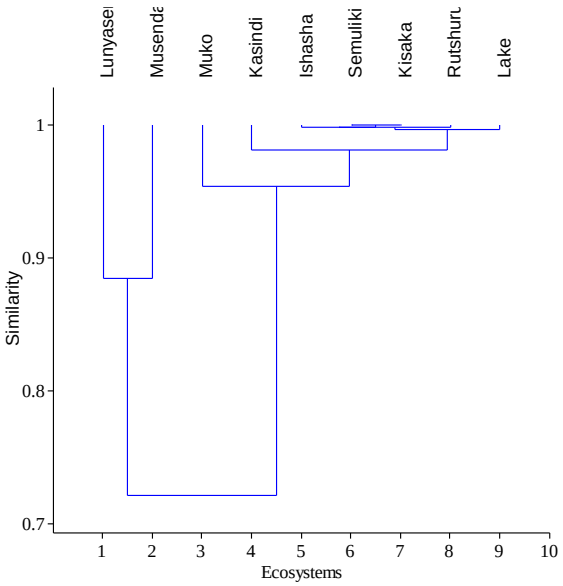

Figure 3: Cluster analysis of Lake Eduard and major tributaries rivers for selected physico-chemical parameters

Three classes are observed in the cluster analysis for the correlation, the first class which governs the quality of Lake Eduard water composed by the big tributaries Ishasha, Kisaka, Rutshuru and the Semuliki River. The second class is composed by the Kisaka and Muko rivers which has a slight influence on Lake Eduard water quality. The last group is constituted of the Lunyasenge and Musenda which have no influence on Lake Eduard water quality according to the selected physico-chemical parameters.

Bacteriological parameters

Faecal coliforms represented 93–99% of coliform bacteria in faeces from humans and animals [54]. Three type of bacterial were found in the water during the sampling period (Table 4).

Table 4: Bacteriological parameters of Lake Eduard water and the major tributaries rivers

	Escherichia coli (col/ml)	*Klesbiella* (col/ml)	*Vibrio cholera* (col/ml)
Ishasha Lake	5600	0	0
Ishasha river outlet	500	0	0
Ishasha river Park	2000	0	0
Rutshuru Lake	3600	0	0
Rutshuru river outlet	5000	0	0
Rutshuru river Park	20000	0	0
Semuliki Lake	0	0	0
Semuliki river inlet	4300	500	500
Kasindi Lake	8000	0	0
Kasindi river	600	0	0
Muko Lake	1700	0	0
Muko river	0	0	0
Lunyasenge Lake	8000	0	0
Lunyasenge river	2400	0	0
Kisaka Lake	9200	0	0
Kisaka river	0	0	0
Musenda Lake	0	500	0
Musenda river	2800	0	500

The most common is *the Escherichia coli* in the major sampling sites except the site of Semuliki Lake, Muko river, Kisaka river and Musenda river. The count number of *Escherichia coli* varied from 0 – 20000 col/mL (Rutshuru river Park). The high counts of faecal coliforms *Escherichia coli* can be attributed to the indiscriminate defecation along the river banks by both humans and other animals grazing along the river banks [55]. Lake Eduard and the major tributaries rivers investigated pass through the Virunga National Park were animals use the water for washing but also the population living within the Park as well as soldiers and can be a source of contamination of water with faecal coliforms. One site at Semuliki river inlet was infected by *Klesbiella* and two sites with *Vibrio chole*ra (Semuliki river inlet and Musenda Lake). The presence of *Vibrio cholera* identified in the water at the two sites can directly be linked to the human source of pollution of water. The counts of faecal coliforms in almost all occasions of sampling indicate significant and increasing risk of infectious disease transmission. As faecal coliform levels increase beyond 20 cfc/100 ml, the amount of water ingested required to cause infections decreases [54]. The high coliforms recorded (faecal and total coliforms) was also observed in other rivers such as Oti River in Ghana [56].

CONCLUSION

The study has provided useful baseline information on the water quality of the Lake Eduard and the major tributaries rivers in the Democratic Republic of Congo side for the management of the Lake as well as the ecosystem of the entire Lake Eduard watershed. The study presents the actual physic-chemical and bacteriological conditions of the Lake Eduard and the major tributaries rivers, and provides basis information for determining cause-and-effect relations of these parameters selected. Lake Eduard water and some major tributaries rivers (except Kisaka and Muko rivers) water are not suitable for direct human consumption in view of the high counts of both faecal coliforms and total coliforms. For physico-chemical parameters all water quality parameters investigated were within the limits of WHO or UNECE standards. A regular monitoring of Lake Eduard and major tributaries rivers is required not only to prevent the outbreak of diseases but also to checks the water from further deterioration.

Acknowledgements

We are grateful to the UNESCO for providing the funds for the study and ICCN-PNVi for support the realization of this study. We are also appreciative of the role of technician of the Centre de Recherche en Sciences Naturelles and OVG Goma.

REFERENCES

1. Mwendera EJ; Rural Water Supply and Sanitation (RWSS) coverage in Swaziland: toward achieving millennium development goals. Phys. Che. Earth, 2006, 31: 681-689.
2. Zhu K, Zhang L, Hart W, Liu M, Chen H; Quality issues in harvested rainwater in arid and semi-arid Loess Plateau of Northern China. J. Arid Environ., 2004, 57(4): 487-505.
3. Sadeghi GH, Mohammadian M, Nourani M, Peyda M, Eslami A ; Microbiological quality assessment of rural drinking water supplies in Iran. J. Agri. Soc. Sci., 2007, 3(1): 31-33.
4. Traichaiyaporn S, Chitmanat C; Water quality monitoring in upper ping river, Thailand. J. Agri. Soc. Sci., 2008, 4: 31-34.
5. Gamedze K, Tevera DS, Fadiran AO; Water Quality Assessment of Various Sources in Rural Areas in the Lowveld Region of Swaziland. Current Research Journal of Social Sciences, 2012, 4(2): 99-102.
6. Damas H; Exploration du Parc National Albert. Mission H. Damas (1935- 1936) Fascicule 1. Recherches hydrobiologiques dans les Lacs Kivu, Edward et Ndalaga. Institut des Parcs Nationaux du Congo Belge. Bruxelles, 1937.
7. Marlier G ; Recherches hydrobiologiques dans les rivières du Congo Oriental. Composition des eaux. La conductivité électrique. Institut pour la Recherche Scientifique de l'Afrique Centrale, Laboratoire du Tanganyika, Uvira. Hydrobiologia, 1951.
8. Marlier G; Recherches hydrobiologiques dans les rivières du Congo Oriental. Etude écologique. Laboratoire d'Uvira. Institut pour la Recherche Scientifique de l'Afrique Centrale, Hydrobiologia 1954, 2, (6).
9. Talling JF; Origin of stratification in an African rift lake. Limnol. Oceanogr.,1963, 8: 68-78.
10. Lehman J; Application of AVHRR to water balance, mixing dynamics, and water chemistry of Lake Edward, East Africa. In: Odada, E.O., Olago, D. (Eds.), The East African Great Lakes: Limnology, Palaeolimnology, Biodiversity. Kluwer Academic, Dordrecht, 2002 : 235–260.
11. Plumptre AJ, Kayitare A, Rainer H, Gray M, Munanura I, Barakabuye N, Asuma S, Sivha M, Namara A; The Socio-economic Status of People Living Near Protected Areas in the Central Albertine Rift. Albertine Rift Technical Reports, 2004, 4.
12. Hylkema; Haiti Soil Fertility Analysis and Crop Interpretations for Principal Crops in the Five WINNER Watershed Zones of Intervention. Thesis report, Soil and Water Science, University of Florida, 2011.
13. Maitland PS, Morgan NC; Conservation management of freshwater habitats: Lakes, rivers and wetlands. Chapman & Hall. London. Weinhein. New York. Tokyo. Melbourne. Madras, 1997.

14. Arunachalam M, Manimekalan A, Johnson JA, Sankaranarayanan A; Fishes of rain forest streams/rivers of India. A research Overview. Chapter 10, 2002.
15. Venkatesharaju K, Ravikumar P, Somashekar RK, Prakash KL; Physico-chemical and bacteriological investigation on the river Cauvery of Kollegal stretch in Karnataka. Kathmandu University Journal of Science, Engineering and Technology, 2010, 6(1):50-59
16. Kilham P; Sulfate in African inland waters: Sulfate to chloride ratios. Verhandlungen der internationale Vereinigung fur Limnology, 1984, 22: 296 – 302.
17. Sati A, Sood A, Sharma S, Bisht S, Kumar V; Bacterial indicators of faecal pollution and physiochemical assessment of tributaries of Ganges River in Garhwal Himalayas, India. RMZ – Materials and Geoenvironment, 2011, 58(2): 129–142
18. Russell JM, Johnson TC, Kelts KR, Laerdal T, Talbot MR; An 11 000-year lithostratigraphic and paleohydrologic record from Equatorial Africa: Lake Edward, Uganda–Congo. Palaeogeography, Palaeoclimatology, Palaeoecology , 2003, 193(1) : 25–49
19. Lærdal T, Talbot MR, Russell JM; Late Quaternary sedimentation and climate in the Lakes Edward and George area, Uganda-Congo. In: Odada, E.O., Olago, D. (Eds.), The East African Great Lakes: Limnology, Palaeolimnology, Biodiversity. Kluwer Academic, Dordrecht, 2002: 429–470.
20. Beadle LC; The Inland Waters of Tropical Africa. Longman, London, 1981: 433 .
21. Hecky RE, Degens ET; Late Pleistoncene-Holocene chemical stratigraphy and paleolimnology of the Rift Valley Lakes of central Africa. Woods Hole Oceanogr. Inst. Tech. Rep., 1972, 73: 93 .
22. Talling JF, Talling IB; The chemical composition of African lake waters. Int. Rev. Gesamten Hydrobiol., 1965, 50: 421–463
23. Nicholson SE; A review of climate dynamics and climate variability in Eastern Africa. In: Johnson, T.C., Odada, E.O. (Eds.), The Limnology, Climatology, and Paleocliamtology of the East African Lakes. Gordon and Breach, Amsterdam, 1996: 25–56.
24. Golterman HL, Clymo RS, Ohnstad M; Methods for Physical and Chemical Analysis of Fresh Waters. Blackwell, London, 1978: 213
25. APHA (American Public Health Association); Standard methods for the examination of water and wastewater. 18th edition, Washington DC, USA, 1989: 1587.
26. Wetzel RG, Likens GE; Limnological analysis. Springer, 2000: 429
27. Olapande OJ, Omitoyin BO ; Anthropogenic pollution impact on physico-chemical characteristics of Lake Kivu, Rwanda. Scholarly peer reviewed, 2012, 12(5): 6517 – 6536.
28. Olapande OJ ; Trace metal pollution and physicochemical characteristics of Lake Kivu, Rwanda. Global Journal of Environmental Research, 2011, 5(2) : 56 – 64.
29. CENTRE D'EXPERTISE EN ANALYSE ENVIRONNEMENTALE DU QUÉBEC ; Détermination des huiles et graisses totales dans les eaux; Méthode gravimétrique. MA. 415 – HGT 1.0, Ministère de l'Environnement du Québec, 2001 : 14 .
30. UNECE; Standard Statistical Classification of Surface Freshwater Quality for the Maintenance of Aquatic Life. In: Readings in International Environment Statistics, United Nations Economic Commission for Europe, United Nations, New York and Geneva, 1994.
31. FEPA (Federal Environmental Protection Agency); Guidelines and Standards for Environmental Pollution Control in Nigeria, Federal Environmental Protection Agency Regulation 1991 on pollution abatement in industries and facilities generated wastes. 1991, 78(42): 38.
32. WHO; Guidelines for Drinking Water Quality. World Health Organization, Geneva, Switzerland, 1993: 489.
33. American Public Health Association; Standard Methods for the Examination of Water and Wastewater, 19th ed. American Public Health Assoc, Washington, DC, 1995.
34. Collins CH, Lyne MP; Microbiological Methods. Butterworth and Co publishers Ltd., London, Boston. 1976: 524.
35. Bakare AA, Lateef A, Amuda OS, Afolabi RO; The Aquatic toxicity and characterization of chemical and microbiological constituents of water samples from Oba River, Odo-oba, Nigeria. Asian J. Microbiol. Biotechnol. Environ. Sci., 2003, 5: 11-17.
36. Coyne MS, Howell JM; The faecal coliform/faecal streptococci ratio (FC/FS) and water quality in the Bluegrass Region of Kentucky. Soil Sci. News and Views, 1994, 15.
37. SCA (Standing Committee of Analysts); The microbiology of drinking water. Part 1-Water quality and public health methods for the examination of waters and associated materials. Environment Agency, 2002.
38. Babalola OA, Agbebi FO; Physico-chemical characterisitics and water quality assement from Kuramo Lagoon, Lagos, Nigeria. International journal of advanced biology research, 2013, 3(1): 98-102.
39. Umham SN; Some aspects of the physico-chemical limnology of Lake Tchad (Southern Sector). Journal of aquatic Sciences, 1989, 4: 21 – 26
40. EEC (European Economic Community); European community standards for surface waters used for

portable abstractions. Directive 76/464/EEC. EEC, Brussels, 1976.
41. Jayaraju PB, Prasadrao GDV, Sharma SV; Seasonal variation in Physico-Chemical parameters and diversity in the flora and fauna of the river Munneru, A tributary to river Krishna, (A.P.) India. Aqua. Biol., 1994, 9: 19-22.
42. Isumbisho M, Sarmento H, Kaningini B, Micha JC, Descy JP; Zooplankton of Lake Kivu, East Africa, Half a century after the Tanganyika sardine introduction. Journal of Plankton Research, 2006, 28(11): 971-989.
43. Sangpal RR, Kulkarni UD, Nandurkar YM; An assessment of the physico-chemical properties to study the pollution potential of Ujjani reservoir, Solapur District, India. ARPN Journal of Agricultural and Biological Science, 2011, 6(3): 34 - 38
44. Bagalwa M, Karume K, Bayongwa C, Ndahama N, Ndegeyi K; Land-use Effects on Cirhanyobowa River Water Quality in D.R. Congo. Greener Journal of Environment Management and Public Safety, 2013a, 3(1): 21 - 30.
45. Bagalwa M, Majaliwa JBM, Mushagalusa N, Karume K; Estimation of Transported Pollutant Load from Small Urban Kahuwa River Micro-catchment in Lake Kivu, Democratic Republic of Congo. Journal of Environmental Science and Engineering B 2013b, 2: 460 – 472.
46. WHO; Guidelines for drinking water quality. Health Criteria and other supporting information, Genera; WHO, 1990, 2.
47. Adeyeye EI, Abulude FO; Analytical assessments of some surface and ground water resources in IleIfe, Nigeria. J. Chem. Soc. Nig., 2004, 29: 98 - 103.
48. Helen PAM, Jayasree S, Johnson JA, Edith BJ, Chittarasu IH, Seasonal Variations In PhysicoChemical Parameters Of Water In Coconut Husk Retting Area, Parakkani, Tamil Nadu. International Journal of Environmental Sciences, 2011, 1(6): 1056 – 1061.
49. Trabelsi S, Bouri S, Ben Dhia H ; Contribution des approches hydrochimiques et géothermométriques à l'étude des eaux thermales de la province fluorée tunisienne (Nord-Est Tunisien). Revue des Energies Renouvelables CER'07 Oujda, 2007, 85 – 88.
50. Baird C ; Environmental Chemistry, 2nd edn. W.H. Freeman and Company. New York, 2000: 557.
51. Golterman HL; Aquatic ecosystems, physiological Limnology, IHE, Delft, The Netherlands, 1993.
52. UNEP; GEMS Water Quality of World River Basins, UNEP Environment Library No. 14, Nairobi, 1995.
53. Aldous A, McCormick P, Graham S, Craft C; Hydrologic regime controls soil phosphorous fluxes in restoration and undisturbed wetlands. Restoration ecology, 2005, 13(2): 341 – 347.
54. WRC (Water Resources Commission); Ghana Raw Water Criteria and Guidelines, Vol. 1. Domestic Water. CSIR-Water Research Institute, Accra, Ghana, 2003.
55. Jones F, White WR; Health Amenity Aspects of Surface Water. Wat. Pollut. Control 1994, 83: 215–225.
56. Abdul-Razak A, Asiedu AB, Entsua-Mensah REM, deGraft-Johnson KAA; Assessment of the Water Quality of the Oti River in Ghana. West African Journal of Applied Ecology, 2009, 15: 12