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Qualité physico-chimique des eaux littorales de la partie Sud-Ouest du Lac Albert, RD Congo

Kasigwa Dieudonné CIWANINE^{1*}, Lonze Joël KATHO², Busanga Alodor KANKONDA³
et Jean-Claude MICHA⁴

¹Université Officielle de Bukavu, Faculté des sciences, Département de Biologie, RD Congo.

²Division d'Agriculture, Pêche et Elevage, Province d'Ituri, RD Congo.

³Université de Kisangani, Faculté des sciences, Département d'Hydrobiologie, RD Congo.

⁴Environmental Biology Research Unit (URBE), University of Namur, Belgium.

*Auteur correspondant; E-mail : cikwadiudonne@gmail.com

RESUME

Le lac Albert est moins étudié en ce qui concerne l'évolution de la qualité de ses eaux. L'objectif de cette étude était de contribuer à la connaissance de quelques paramètres physico-chimiques des eaux littorales de la partie Sud-Ouest du lac Albert. Pour y parvenir, nous avons utilisé un kit multi-parameter AZ8603 pour le prélèvement, *in situ*, du pH, de l'oxygène dissous, de la conductivité électrique et de la température pendant un cycle de 24 heures à intervalle de 3 heures durant une année. Il ressort de cette étude que les moyennes de température, conductivité, oxygène dissous et pH sont respectivement de 29,07 °C, 631,65 µs/cm, 4,8 mg/l et 8,01. La concentration en oxygène dissous était plus élevée le jour que la nuit. La différence non significative de température entre le cycle diurne et nocturne montre que l'activité photosynthétique est l'élément explicatif de l'augmentation du taux d'oxygène dissous. Les mois d'avril et de mai se sont distingués par une forte température et une baisse de la concentration en oxygène dissous. Ceux de mars, août, octobre et novembre ont été marqués par une conductivité élevée corrélée positivement à la température.

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Mots clés : Eaux, lac Albert, physico-chimie, variation nyctémérale.

Physico-chemical of coastal waters of the South-Western part of Albert Lake, DR Congo

ABSTRACT

The Albert Lake is barely investigated with regard to the evolution of the quality of its waters. The objective of this study was to contribute to the knowledge of some physico-chemical parameters of the coastal waters of the South-Western part of the Albert Lake. To reach the above objective, a kit multi AZ8603 parameter was used to record, *in situ*, the pH, the dissolved oxygen, the electric conductivity and the temperature during a cycle of 24 hours, with 3 hours interval. This was done during a year. This survey evidenced that the averages of temperature, conductivity, dissolved oxygen and pH were respectively 29.07 °C, 631.65 µs/cm, 4.8 mg/l and 8.01. The concentration of dissolved oxygen was higher during the day as compared to its concentration in the night. The slight difference of temperature between the diurnal and nocturnal cycle showed that the

photosynthesis activity was responsible of the increase of the dissolved oxygen rate. The months of April and May were characterized by relatively higher temperature and a lower concentration of dissolved oxygen. Those of March, August, October and November showed higher conductivity correlating positively to the temperature. © 2020 International Formulae Group. All rights reserved.

Keywords: Waters, Albert Lake, physico-chemistry, circadian variation.

INTRODUCTION

The Albert Lake is one of the biggest lakes of the rift Albertin with a surface estimated at 5600 km². It is classified among the polymictique lakes and is therefore provided with oxygen in depth (maximal depth 58 m). This type of structure implies notably that the planktonic biomass and the nutriments contained in the ecosystem are available in the whole column of water because of the dynamics of circulation of the water masses, mainly due to winds. This brewing should be responsible of the productivity increase of the lake.

An aquatic system is influenced by the surrounding biotic and abiotic factors which allow making the classification of a lake. Water quality is one of the major problems of environmental health which developing countries are facing (Montgomery and Elimelech, 2007). In a lake, the change in concentration of the dissolved oxygen, of the temperature and the pH during 24 hours, is strongly dependent on the autotrophic and heterotrophic activities, and it is in interrelationship with the contribution in nutriments during a diurnal cycle (Sabater et al., 2000).

In most studies, the physico-chemical parameters such as the dissolved oxygen, the temperature and the pH are taken in a punctual manner, and often only during the day while their concentration is increased due to the strong sunshine and photosynthetic activity (Wetzel, 2000; Moatar et al., 2009). To avoid having the skewed conclusions, Wetzel and Likens (2000), Villeneuve et al. (2006) recommend to make repeated and cyclic records (24 hours) of the O₂, the temperature and the pH in order to relativize the diagnoses established from punctual measurements and therefore to warn or to anticipate possible

contentious in the evolution of the ecological state of an aquatic system.

Only few studies have been done on the environmental parameters of the Albert Lake in its South Western part. The recent and general available data are those provided by Hecky and Kling (1987), Ssentongo (1987); they show that the conductivity of the Edouard lake varies between 900-925 Ms/bas, the pH between 8.5 to 9.3 with an average temperature of 26 °C while the Albert Lake has a temperature varying between 27.5 and 29 °C. These reports do not bring out the other parameters studied in the present work. Thus, this lake has a gap of information about water quality in its Congolese part because the available data were recorded in 1987 (Ssentongo, 1987) and were only for the Ugandan part.

Thus, this survey aimed at bringing out the diurnal and yearly variation of the physico-chemical parameters of the surface waters of the Albert Lake.

MATERIALS AND METHODS

Sampling site and methods

The Albert Lake is located in the Northern part of the West arm of the Rift valley in East Africa between 2°15' and 1°00' North of latitude, and also between 30°21' and 31°25' East of longitude. It borders Uganda and the D.R. Congo, an alluvial plain joins the Victoria Nile and the Albert Nile. The West coast, along the D R Congo, is characterized by 2 000 m of scarps. The coast South is marked by swamps, in particular of papyrus, that dominates the delta of the Semliki river joining the Edouard Lake to the Albert Lake.

The sampling site was in Kasenyi, situated in the coastal part of the lake, at a distance of 30 m from the strand (Figure 1). The sampling *in situ* was done at a depth of less than 1 m. This site was chosen because of the easy accessibility during the 24 hours of a day, the

safety of the equipment during the night experiments, and also its distance from the embarking and landing places of the fishers.

The record of the physico-chemical parameters was done two times a month (Wednesday of the first and the third weeks). The circadian cycle was subdivided by 8. Therefore, the record of the data was done *in situ* made every 3 hours (6 H, 9 H, 12 H, 15 H, 18 H, 21 H, 24 H, 3 H). During the working day, the probes of the multi-parameters device Mark AZ 8603 (Figure 2) were dived at 1 m of depth for some minutes until the numbers displayed on the screen of the device stabilized.

- Concentration of dissolved oxygen: expressed in mg/l and in percentage of saturation. It is considered as an important parameter of aquatic environment and is a limiting factor for every species. It also gives the idea on the working of the aquatic environment. According to Laboulle (2010), the concentration in mg/l corresponds to the expression of any other solution of water such as mineral salts, an indicative but raw value. The concentration in percentage is more expressive and is equivalent to the ratio between the concentration of oxygen really present and the theoretical maximal concentration of oxygen expected at the temperature of measurement. The concentration of the oxygen in water depends also on the air pressure, the temperature, and the photosynthesis.
- pH (potential in hydrogen): in the natural media, the weak pH corresponds to the deficit in oxygen and to the weak primary activities whereas the basicity generally superior to 8 denotes a strong photosynthetic activity. A good piscicultural water must have a pH ranging from 6.5 to 9 (Hade, 2003).
- The electric conductivity: gives an idea on the capacity of water to conduct the electric current. It is a function of degree of mineralization and depends on natural and

anthropogenic factors such as the geology of the basin, the temperature, the vaporization of the water, the variation in the flow of the inflows which feeds the lake, the pollution by wastewater (Gouasmia and al., 2016; Hade, 2003; Benin Chrystelle, 2018). Waters are soft when the conductivity is lower than 500 $\mu\text{s}/\text{cm}$, and mineral when the conductivity is over 600 $\mu\text{s}/\text{cm}$ (OBV, 2013).

- The temperature: is a physical parameter necessary in the classification of the lakes and its daily and seasonal variation influences the other physico-chemical parameters such as the concentration in dissolved oxygen. The stratification and the upwelling of the waters of the lakes are based on this parameter of water.

During the survey, the measured values of the dissolved oxygen (in mg/l and %), the temperature ($^{\circ}\text{C}$), the pH and the electric conductivity ($\mu\text{s}/\text{cm}$) were recorded in a field notebook prior to their transcription in an Excel leaf. The survey covered a period starting from August 2018 to July 2019, 12 months in total.

Data analysis

The field data were exported from the Excel leaf to specific software of analysis. One part of the data was processed using the software STATISTICA and the analysis of main components (ACP) was done by mean of XLSTAT. The descriptive analysis allowed calculating the average, the standard deviation, the minimum, and the maximum of every parameter according the month, the phase, and the hours of sampling for the circadian cycle. The analysis of correlation between the parameters was made through ANOVA and allowed to compare the variability of the data between months, phases and circadian cycles. The ACP helped to show the relationship between the environmental variables, and also to regroup the months according to the expression of these variables.

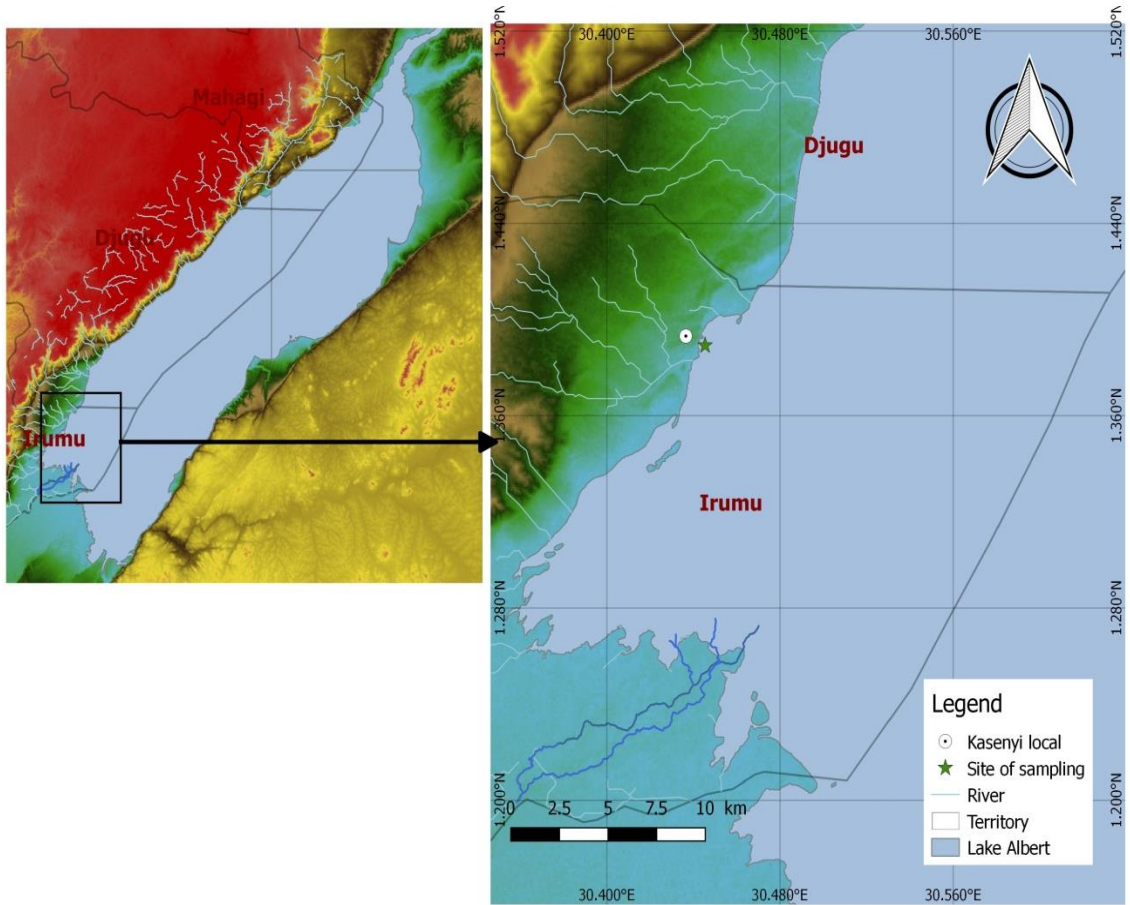


Figure 1: Localization of the sampling site for physico-chemical parameters.



Figure 2: The multi-parameter device used.

RESULTS

Variability of studied parameters during 12 months

At the sampling site, the temperature varied from 26.2 to 34.6 °C, the average being of 29.07 ± 1.24 °C (Table 1). Despite the dissolved oxygen concentration average being in the acceptable margin for the aquatic living being, it was observed certain variability (4.8 ± 2.09 mg/l and $54.48 \pm 23.99\%$) during one year. The pH average was good and slightly basic (8.01 ± 0.55), and the conductivity average was 631.65 ± 6 μ S/cms.

The monthly averages of the studied parameters are given in the Table 2. The highest temperature was observed in April and the lowest in July. The concentration of dissolved oxygen in water was lower (2.95 ± 0.6 mg/l) in April; but in terms of percentage saturation, it was rather lower in May ($26.19 \pm 7.44\%$). The lowest conductivity was observed in June (619.69 ± 7.41 μ S/cms) followed by July (627.44 ± 4.32 μ S/cms). The pH varied during all months between 7.49 ± 0.9 (July) and 8.78 ± 0.15 (November). It was noted that all studied parameters varied significantly with months (Table 3).

Comparison of parameters between the day and the night phases

Table 4 shows the average values of the environmental variables taken in account in this study. The subdivision of the circadian cycle indicated that the difference was significantly noticeable ($F = 3.83$ and 9.75 , $p \leq 0.05$) for the dissolved oxygen between the day and the night phases (Table 5).

Although the temperature and the pH varied numerically between the two phases (slightly high temperature during the day with a lower pH than during the night), this difference remained non-significant.

Table 6 shows that during the sunrise, the temperature increased significantly in the same way with the concentration in dissolved oxygen and the conductivity of water. At night (Table 7), the significant link was observed only between the temperature and the electric conductivity of water.

Evolution of parameters with regard to the circadian cycle

While integrating the analysis of the parameter variations according to the hours of records, it was observed (Table 8) that the peaks of temperature and dissolved oxygen were gotten at around 15 H (30.22 ± 1.5 °C and 6.71 ± 2.89 mg/l) whereas during this time the pH was lower (7.71 ± 0.58) (Table 8).

Figure 3 shows that at the sunrise at around 6 H, the temperatures were lower and started increasing during the day to reach the peak at around 15 H, and then they decreased. The same phenomenon was observed for the concentration of dissolved oxygen. However, as opposite to the above two parameters, the pH was higher during the night as compared to that of the day.

Only the temperature, dissolved oxygen and pH varies significantly over time as shown by the result in Table 9.

The analysis of the main components (Figure 4) showed the quantum of 15 H to 18 H to be characterized by a positive relation between temperature and conductivity contrary to the other portions of time. From 21 H to 6 H in the morning, the pH was the main distinctive factor from the rest of sampling hours.

During this circadian cycle, the sampling of 12H was characterized by a particular concentration of dissolved oxygen (in mg/l and in percentage) and this parameter was in positive relationship with the temperature and the conductivity. It can be observed that the slice of 9H played buffer role between the day and the night phase. At this stage, it was difficult to discriminate the studied environmental factors.

The evolution of the parameters according to the months of sampling (Figure 5) showed that the months of April and May demarcated from other months in terms of temperature and pH whereas those of March, August, October and November rather showed a distinctive conductivity as compared to other months. It was also noticed that the dissolved oxygen was characteristic to the months of February, July and September. During the course of one year, when the temperature or the pH increased, it was observed that the

concentration in oxygen decreased sensibly (especially in terms of percentage). For the discriminated months based on the concentration in dissolved oxygen (February, July and September), it was observed a decrease of the temperature and the pH of water.

The months that differentiated themselves from others based on the relatively high conductivity (March, August, October and November), were followed by a general increase of the water temperature. The other three remaining months (December, January and June) could not be discriminated by the studied environmental factors.

Table 1: Annual averages, minima and maxima values of physico-chemical parameters during 12 months of study.

	N	Average	Minimum	Maximum	Scope	Variance	Standard deviation
T (°C)	192	29.07	26.20	34.60	8.40	1.55	1.24
DO (%)	192	54.48	10.50	127.70	117.20	575.41	23.99
DO (mg/l)	192	4.80	1.30	15.80	14.50	4.39	2.09
pH	192	8.01	6.20	9.00	2.80	0.31	0.55
Conductivity (µS/cm)	192	631.65	610.00	642.00	32.00	36.04	6.00

Table 2: Monthly averages of physico-chemical parameters during the study period.

	Temperature	DO %	DO (mg/l)	pH	Conductivity (µS/cm)
August	29.83±2.3	51.97±22.8	5.16±2.15	7.51±0.24	634.25±2.48
September	28.33±0.6	70.16±22.8	5.66±1.62	7.76±0.33	635.31±2.55
October	28.9±0.7	72.41±16.39	5.82±1.23	8.14±0.7	636.44±2.25
November	29.54±0.9	77.66±23.22	6.2±1.71	8.78±0.15	634.36±3.16
December	28.73±0.5	56.19±16.87	4.43±1.0	8.45±0.4	629.19±4.55
January	28.58±0.7	33.41±8.38	4.85±3.92	8.15±0.3	631.06±5.22
February	29.21±1.1	65.77±17.36	5.12±1.59	7.63±0.4	630.06±1.18
March	29.52±1.6	54.69±13.42	4.74±1.76	8.12±0.4	635.13±2.96
April	30.14±0.9	38.27±9.33	2.95±0.6	8.11±0.2	635.13±1.71
May	29.89±0.9	26.19±7.44	4.09±1.85	7.77±0.3	631.75±5.84
June	28.29±0.5	31.14±7.39	2.56±0.53	8.15±0.2	619.69±7.41
July	27.91±0.5	75.83±21.12	6.01±1.63	7.49±0.9	627.44±4.32
TsGrpes	29.07±1.24	54.47±23.99	4.8±2.1	8.01±0.6	631.65±6.0

Table 3: Variance analysis of parameters in relationship with months.

	SC	Dl	MC	SC	dl	MC	F	p
T°	91.59	11	8.326	204.35	180	1.135	7.334	2.6e ⁻¹⁰
DO %	59992.39	11	5453.853	49911.06	180	277.284	19.669	1.3e ⁻²⁵
DO mg/l	232.41	11	21.128	605.84	180	3.366	6.277	9.8e ⁻⁹
pH	26.27	11	2.388	32.36	180	0.180	13.283	2.3 e ⁻¹⁸
Conductivity (µS/cm)	3911.31	11	355.573	2972.31	180	16.513	21.533	0.7 e ⁻²⁷

Table 4: Calculation of averages during the two phases.

Phase	N	T°C	DO %	DO mg/l	pH	Conductivity (µS/cm)
Day (6h to 15h)	96	29.18±1.34	57.83±26.92	5.26±2.32	7.95±0.57	631.39±6.57
Night (18h to 03h)	96	28.96±1.13	51.11±20.23	4.34±1.73	8.07±0.53	631.92±5.39
TsGrpes	192	29.07±1.24	54.48±23.99	4.80±2.09	8.0±0.55	631.65±6.0

Table 5: Analysis of parameter variance during the two phases.

	SC	DI	MC	SC	DI	MC	F	p
T°C	2.319	1	2.319	293.6	190	1.5453	1.500507	0.222110
DO %	2171.637	1	2171.637	107731.8	190	567.0095	3.829983	0.041808
DO mg/l	40.913	1	40.913	797.3	190	4.1965	9.749266	0.002074
Ph	0.676	1	0.676	58.0	190	0.3050	2.215184	0.138317
Conductivity (µS/cm)	13.547	1	13.547	6870.1	190	36.1583	0.374655	0.541210

Table 6: Correlation among parameters during the day phase (p-value < 0.05 in red).

	T°C	DO %	DO mg/l	pH	Conductivity (µS/cm)
T°C		0,077350	0,006966	0,105438	0,000377
DO %			0,000000	0,011234	0,013440
DO mg/l				0,009219	0,023137
pH					0,918895
Conductivity (µS/cm)					

Table 7: Correlation among parameters during the night phase (p-value < 0.05 in red).

	T°	DO %	DO mg/l	pH	Conductivity (µS/cm)
T°C		0,934007	0,117497	0,465342	0,000465
DO %			0,000000	0,271926	0,219527
DO mg/l				0,883725	0,095532
pH					0,997670
Conductivity (µS/cm)					

Table 8: Calculation of averages with regard to circadian cycle.

Hour	N	T°C	DO mg/l	DO %	pH	Conductivity (µS/cm)
6H	24	28,26±0,76	3,72±1,04	41,25±17,32	8,17±0,56	631,83±5,42
9H	24	28,55±0,7	4,51±1,45	51,18±22,36	8,09±0,53	630,46±6,83
12H	24	29,69±1,22	6,11±2,17	67,95±28,88	7,81±0,54	631,04±7,29
15H	24	30,22±1,5	6,71±2,89	70,98±27,19	7,71±0,58	632,21±6,87
18H	24	29,74±1,22	4,76±1,55	55,78±20,62	7,88±0,50	632,5±5,68
21H	24	29,19±0,95	5,06±2,18	52,61±22,75	8,07±0,53	631,88±5,28
0H	24	28,86±0,84	4,05±1,56	50,83±21,57	8,13±0,51	631,71±5,26
3H	24	28,06±0,82	3,48±1,12	45,24±14,87	8,18±0,55	631,58±5,66

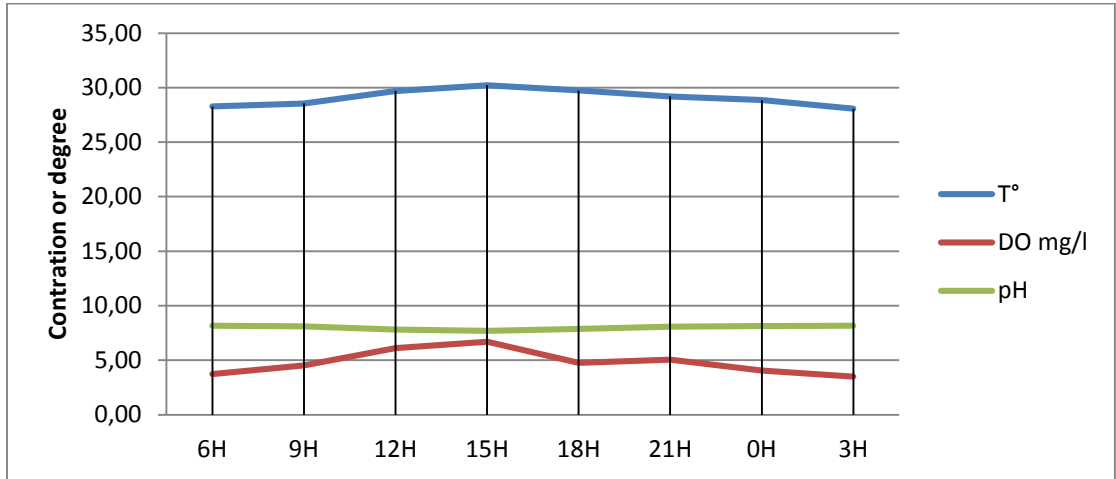


Figure 3: Curve of the evolution of the T°, the DO and the pH during the circadian cycle.

Table 9: Analysis of parameter variance with regard to circadian cycle.

	SC	DI	MC	SC	dl	MC	F	p
T°C	98,81	7	14,116	197,12	184	1,071	13,177	0,0000001
DO %	17845,61	7	2549,373	92057,84	184	500,314	5,096	0,000026
DO mg/l	215,13	7	30,733	623,12	184	3,387	9,075	0,0000001
pH	5,48	7	0,783	53,15	184	0,289	2,712	0,010652
Conductivity (µS/cm)	69,99	7	9,999	6813,63	184	37,031	0,270	0,964861

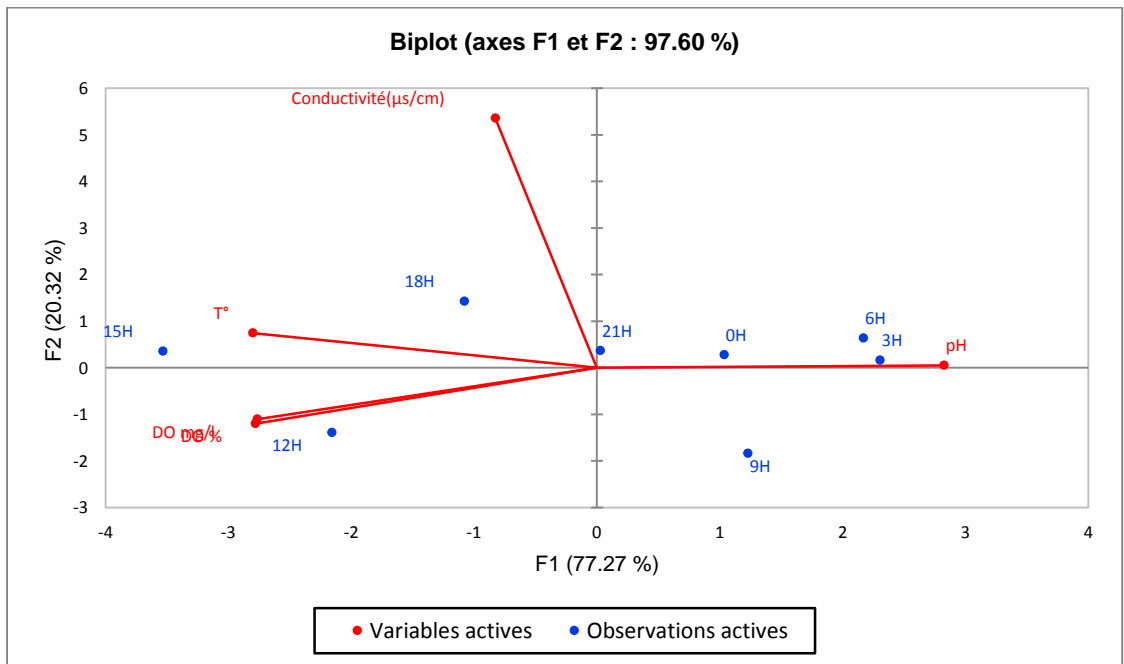


Figure 4: Main components of the parameter differences according to the circadian cycle.

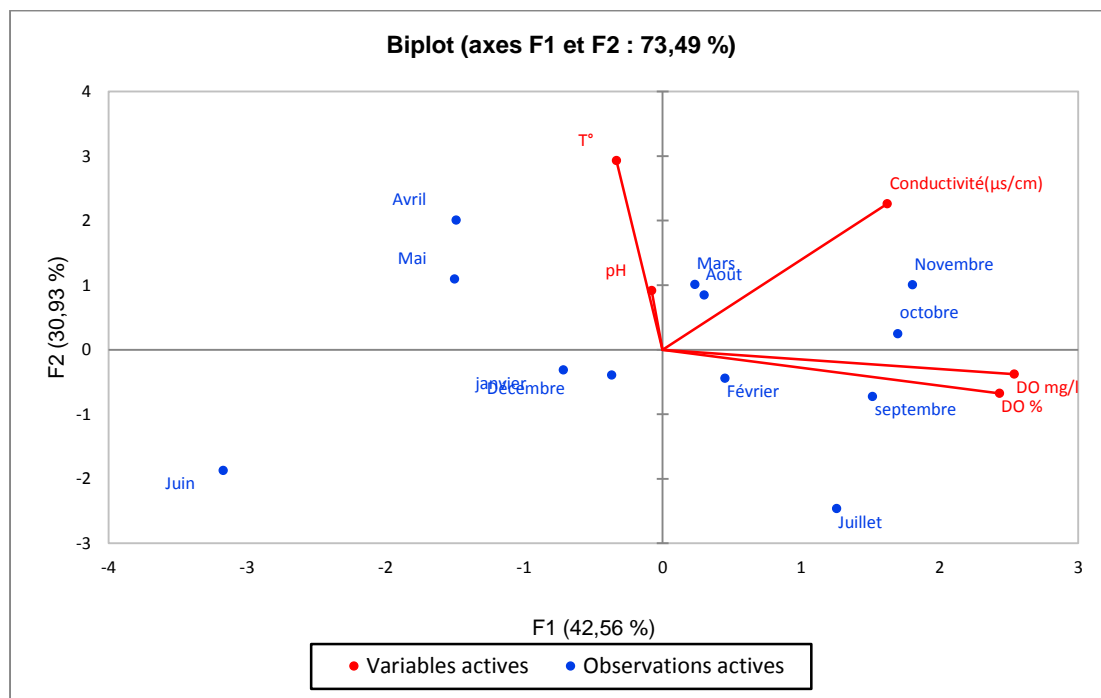


Figure 5: Main components of the parameter differences according to the months.

DISCUSSION

Temperature is a key factor in the biological process and regulates the growth of several aquatic species (Kadlec and Reddy, 2001).

. During the course of this survey, the temperature varied daily and monthly, with a yearly average of 29.07 ± 1.24 °C. It was higher in April (30.14 °C) and lower in July (27.91 °C).

Many authors (Hade, 2003 ; Atinkpahoun, 2018 ; Gouasmia et al., 2016) agree on the facts that when there is increase of the temperature, the ions influencing the determination of matter in suspension in water increase, with as consequence the increase of the water conductivity, whose value depends on the nature of the substratum and exogenous and endogenous contributions (Schneider, 2001; Yapo Ossey et al., 2008; Tang et al., 2014). The average temperature of the Albert Lake was higher than that of the other three lakes found in the Eastern part of the DRC, in the Albertin rift. In the Tanganyika Lake, it varied between 23.5 to 25.0 °C, but in the

coastal zone, it was comprized between 24 and 27 °C (Ntakimazi, 2005; Sigels and Colter, 1996; Nyangya, 2013). About the Edouard Lake, it was about 26 °C (Ssentongo, 1987), and finally, in the Kivu Lake where the values were lower (23 to 24.5 °C) (Sarmanton, 2006). This difference would be due to the altitude on the one hand, (Lake Albert being around 610 meters above sea level) and the reproach with the equator on the other hand.

In the coastal part of the Albert Lake, the conductivity (631.65 ± 6 µS/cms) was higher than what was reported by Nyangya (2013) in the same part of the Tanganyika Lake (543.8 ± 54.8 µs/cms). Nevertheless, it was lower than that of the Edouard Lake (around 900 µs) which receives waters from the Semliki river (Ssentongo, 1987). This hinted at higher conductivity of the Semliki delta waters as compared to other parts of the lake.

This would be justified by the fact that the conductivity of Lake Edward is 900 µs / cm and that the water of the latter is spilled in the southern part of Lake Albert by the Semliki River.

Based on the criteria of the quality of the water destined to aquaculture and the good function of an aquatic ecosystem such as a lake, the pH of 6.5 to 9 is better for the development of the aquatic biodiversity (Hade, 2003). The pH found during this survey was within this interval (8.01 ± 0.6 of average). From the above findings, it appeared that the degradation process was accelerated and the lake was susceptible to be a lake with high primary productivity. In August 2005, WWF (2005) found a pH relatively higher (8.9) as compared to that gotten in this work (7.51 ± 0.24). However, the yearly averages were similar (8.01 ± 0.6).

Generally, in an aquatic ecosystem, when the temperature increases, the dissolved oxygen decreases (Figure 2). The lowest temperature was observed in July (27.91 ± 0.5 °C) while the concentration in dissolved oxygen was higher ($75.83 \pm 21.12\%$). However, this dissolved oxygen was $38.27 \pm 9.33\%$ in April whereas the temperature was higher (30.14 ± 0.9 °C). The yearly average temperature (29.07 °C) was similar to that reported by Lehman et al., in 1995 although their survey was done during the only month of March 1995.

Although the concentration in dissolved oxygen varied relatively through months, the observed averages (54.47% and 4.8 mg/l) classified the water of the Albert Lake in the category of good waters for the ichthyofauna, with regard to the requirements for species living in that lake and is higher than most waters with high primary and secondary productivity (Buhungu, 2018; Fermont, 2007). During the circadian cycle, it was noticed that all studied environmental factors varied daily except for the conductivity whose variability was non-significant (Table 9).

Figure 3 shows that at the sunrise, the temperature of water increased to reach the peak at around 15 H and decreased thereafter. A similar tendency was observed for the concentration in dissolved oxygen. However, the pH showed an inverse tendency in relation with the two precedents parameters. This tendency seemed to be in contradiction with the theory which stipulates that when the

temperature increases, the concentration in dissolved oxygen decreases.

The analysis of the day and night phases (Tables 4, 5 and 6) shows that the temperature was not the factor influencing the difference of the dissolved oxygen concentration observed between the two phases. In report published by Zuntz (1900) cited by Secondat (1951), it was said that in summer, in the pool having a rich vegetation, the concentration in dissolved oxygen increased during the day reaching up to 22 cm³/litre and decreased at night till 2 cm³/litre. This demonstrated that the explanation about the variation of the dissolved oxygen concentration followed the same understanding in the Albert Lake. In the coastal zone where sampling was done, the increase of the dissolved oxygen concentration was probably due to the process of photosynthesis during the day with as consequence the reduction of the water pH. During the night, there was no photosynthesis process by absence of the sun light, the oxygen was then consumed by the primary and secondary producers, which had as consequence the reduction of the dissolved oxygen concentration and the increase of water pH. The dissolved oxygen concentration in surface waters of the coastal part of the Albert Lake was lower (4.8 ± 2.1 mg/l) following high primary and secondary productivity as compared to that of the Tanganyika Lake (6.34 ± 2.48 mg/l) reported by Nyangya (2013). However, it remains higher than that found in waters with high eutrophication of 1.879 ml / g, value found by Affloua et al. (2019).

Conclusion

The working of an ecosystem is based on the abiotic and biotic conditions of the media. Our survey was done on the circadian and the yearly evolution of four physico-chemical parameters of the Albert Lake waters allowing to make a first appreciation of the living conditions of the fish. Of all studied parameters, the conductivity of water underwent fewer fluctuations during the months, and its daily variation was less affected by the temperature, the pH and the dissolved oxygen concentration of water. In the

coastal part of the lake where the survey was done, the variation of the dissolved oxygen concentration (% and mg/l) was independent of the circadian variation of the temperature, but rather depended on the activity of the primary producers (the action of the photosynthesis) although it was observed a slight difference of temperature between the day and the night phases. This also explained the increase water pH at night (21 H to 6 H morning).

The analysis of the main components allowed determining that, all along of the year, April and May were characterized by the highest temperature, which was favorable for high conductivity of waters resulting in a decrease of the dissolved oxygen concentration. The months with higher dissolved oxygen concentrations had slightly lower temperatures (February, July and September).

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

KDC organized the data collection, analyzed and wrote the article manuscript; LJK contributed to the data collection; BAK and J-CM guided the tests and corrected the manuscript.

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