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Spatio-temporal dynamics of the physical and chemical parameters of lake Ehuikro

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ABSTRACT

This study was conducted on lake Ehuikro, located in Bongouanou (Côte d'Ivoire) from April 2017 to March 2018. Each month, the physico-chemical parameters of the water were measured at three (3) identified stations. In order to analyse its ecological status, the following equipment was used: Conductivity meter Model Sx713; Model Sx711 pH meter; Model Sx716 oximeter and Secchi disk, which made it possible to determine the annual average values: The dissolved solids rate was 154.13 ± 1.22 mg/L (long dry season) and 181.67 ± 3.78 mg/L (short dry season). Conductivity 250 ± 3.07 Ms/cm (short rainy season) and 297.75 ± 2.66 MS/cm (long dry season). Hydrogen potential 7.35 ± 0.13 (long dry season) and 8.09 ± 0.55 (short rainy season). Temperature 27.06 ± 0.67 °C (main rainy season) and 28.45 ± 0.05 °C (main dry season). Oxygen saturation level 42.67 ± 3.77% (minor dry season) and 67.93 ± 6.96% (long dry season). The dissolved oxygen level was 3.07 ± 0.64 mg/l (short dry season) and 5.24 ± 0.45 mg/l (long dry season). The phosphorus concentration was 0.03 ± 0.01 mg/l (short rainy season) and 0.06 ± 0.01 mg/l (long rainy season). The nitrate concentration was 0.01 ± 0.1 mg/L (long dry season) and 0.02 ± 0.1 mg/L (main rainy season). Transparency 0.44 ± 0.02 cm (main rainy season) and 0.68 ± 0.05 cm (minor dry season). Depth 2.71 ± 0.36 m (main dry season) and 4.20 ± 0.51 m (main rainy season). The results obtained reveal that certain physico-chemical parameters show signs of disturbance probably linked to local anthropogenic activities.

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INTRODUCTION

The physical and chemical quality of surface water determines the functioning of aquatic ecosystems, potability and socio-economic uses in tropical countries. In the lakes and reservoirs of West Africa, it results from climatic forcing marked by alternating rainy and dry seasons and increasing anthropogenic pressure on watersheds (nutrient inputs, runoff, domestic waste), which causes sometimes rapid spatio-temporal variations in temperature, pH, dissolved oxygen, conductivity and nutrients. Recent studies confirm the existence of strong seasonal dynamics and spatial gradients in various tropical contexts and highlight the value of integrative tools (WQI), multivariate analyses (ACP/CA) and high-frequency monitoring to account for them (Hammoumi *et al.,* 2024).

In Côte d'Ivoire, several reservoirs (Kossou, Taabo, Buyo) have undergone physico-chemical assessments showing seasonal signatures and the influence of riparian uses, providing a regional framework for comparison with other water bodies. These studies report, for example, variations in conductivity, dissolved oxygen and nutrients between seasons and sectors, with implications for eutrophication and the services provided by these reservoirs (Koné *et al.,* 2022).

Beyond the biological components, a detailed understanding of the spatio-temporal variations in the physico-chemical parameters of Ehuikro remains incomplete: most of the available work focuses on limited time windows, or does not simultaneously cover all key stations and hydrological seasons. At the national level, monitoring indicators report good environmental quality for a significant proportion of water bodies, but these aggregates may mask marked local and seasonal dynamics in sensitive reservoirs such as Ehuikro. Hence the need for an updated, spatially explicit and seasonal diagnosis of the lake's physico-chemical parameters (Guy-Romain *et al.,* 2006).

The objective of this study is therefore to characterise the spatio-temporal variations in the physico-chemical parameters of Lake Ehuikro at the intra-lacustrine and seasonal scales, to identify the structuring factors (hydrometeorological forcings, anthropogenic pressures) and to discuss their ecological and management implications (risks of eutrophication, raw water quality). By using a recent dataset and multivariate analysis methods and synthetic indices, this work aims to fill the gap in recent local references and provide operational elements for monitoring and managing the water body (Wu *et al.*, 2025).

The increasing urbanisation and industrialisation of cities is increasing the load of domestic and industrial effluents in terms of organic matter and dissolved substances. In most developing countries, these domestic and industrial effluents are generally discharged into aquatic ecosystems near cities without treatment or after only basic treatment. In the long term, this results in deterioration in the quality of these environments, a decrease in diversity, and even the disappearance of water bodies (Barroin, 1980) and consequently, organisms.

Human dependence on aquatic biodiversity and ecological services continues to increase due to population growth. This growth is inevitably accompanied by overexploitation of resources, pollution of all kinds, the introduction of exotic species, and the construction of dams, all of which have a huge impact on aquatic biodiversity (Lévêque, 1994; Yao, 2006).

To date, several studies have reported not only a reduction in fishery resources, but also increasing pollution of wetlands (Djiriéoulou *et al.,* 2014). Consequently, maintaining this aquatic biodiversity and the sustainability of ecosystem services is becoming a major concern.

MATERIALS AND METHODS

This study was carried out on Lake Ehuikro, located in Bongouanou, Côte d'Ivoire. The region experiences a tropical climate characterized by four distinct seasons: the long dry season (November–March), short rainy season (April–June), short dry season (July–August), and long rainy season (September–October). These alternating hydrological and climatic regimes strongly influence the physicochemical dynamics of the lake. Three sampling stations (Ehui 1, Ehui 2, and Ehui 3) were selected based on their hydrological positions and surrounding human activities. Ehui 1 represents the upstream zone influenced by domestic activities and aquatic vegetation; Ehui 2, the mid-lake area; and Ehui 3, the downstream section influenced by agricultural runoff and sediment inputs.

Monthly sampling was conducted at all stations from April 2017 to March 2018. In situ measurements of physicochemical parameters were taken using portable instruments: a Conductivity Meter (Model Sx713) for conductivity, a pH Meter (Model Sx711) for hydrogen potential, an Oximeter (Model Sx716) for dissolved oxygen and oxygen saturation, and a Secchi disk for water transparency. Water temperature, depth, and total dissolved solids were also measured directly in the field. Water samples were collected in clean polyethylene bottles and transported to the laboratory for nutrient analysis.

Laboratory analyses were conducted to determine nitrate (NO_3^-) and phosphate (PO_4^{3-}) concentrations following standard colorimetric methods. Phosphate levels were determined using the ascorbic acid method after digestion, and nitrate concentrations were obtained using the cadmium reduction method. All analyses were performed in triplicate, and results were expressed in milligrams per liter (mg/L).

The substrate composition of the lake was characterized at each sampling station through visual inspection and manual sampling to estimate the relative proportions of gravel–mud mixture, sand–gravel mixture, sand, and plant debris. Canopy closure and aquatic vegetation cover were visually assessed to evaluate the influence of macrophytes on water parameters.

Data were analyzed using descriptive statistics (mean ± standard deviation). Spatial and seasonal variations in physicochemical parameters were evaluated using analysis of variance (ANOVA) and Student's t-test at a significance level of $p < 0.05$. When appropriate, Tukey's post hoc test was used to identify significant pairwise differences among seasons. The results were illustrated through graphical representations to show the spatio-temporal dynamics of the measured parameters.

RESULTS

Physicochemical characterisation of lake Ehuikro

Spatial variations in physico-chemical parameters

Ten physico-chemical parameters (dissolved solids, temperature, dissolved oxygen, oxygen saturation, pH, conductivity, transparency, depth, nitrate and phosphate content) were monitored monthly during the study period (Figs 1, 2 and 3).

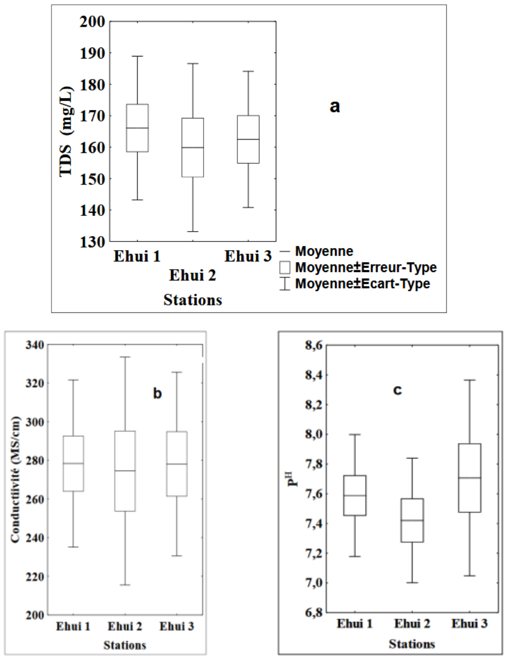
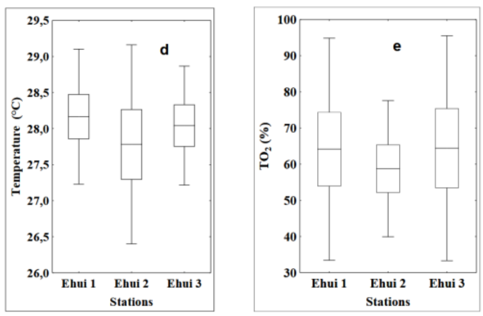


Fig. 1. Spatial variations in the physicochemical parameters measured in Lake Ehuikro (Ivory Coast) between April 2017 and March 2018. a) Dissolved solids content; b) Conductivity; c) pH



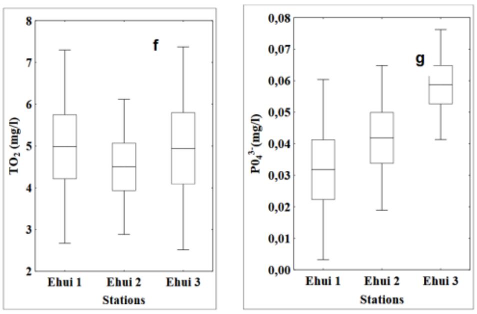


Fig. 2. Spatial variations in physicochemical parameters measured in Lake Ehuikro (Ivory Coast) between April 2017 and March 2018. d): temperature e): oxygen saturation level; f) dissolved oxygen level, g): phosphorus level

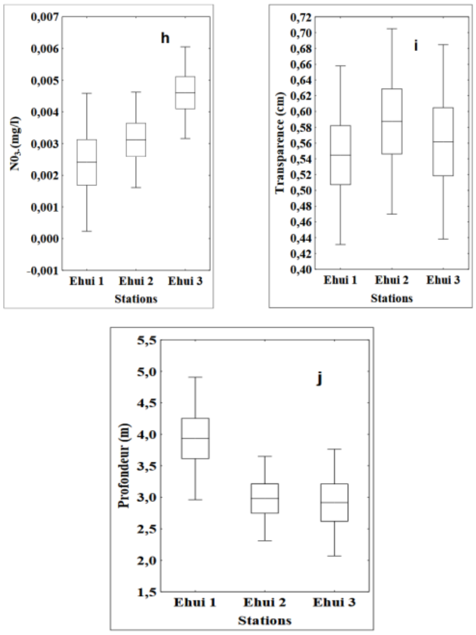


Fig. 3. Spatial variations in physicochemical parameters measured in Lake Ehuikro (Ivory Coast) between April 2017 and March 2018. h): nitrate level. i): transparency, j): depth

The dissolved solids content varied between 159.88 mg/L (Ehui 2) and 166.09 mg/L (Ehui 1). Conductivity varied between 274.45 mg/L (Ehui 2) and 278.33 mg/L (Ehui 1). The hydrogen potential (pH) values ranged from 7.42 (Ehui 2) to 7.70 (Ehui 3). The average water temperature at the sampling sites ranged from 27.78 °C (Ehui 2) to 28.16 °C (Ehui 1). The oxygen saturation level varies between 58.76% (Ehui 2) and 61.41% (Ehui 3). The dissolved oxygen level, which is, varies between 4.50 mg/L at (Ehui 2) and 4.98 mg/L at (Ehui 1). The extreme values for phosphorus range from 0.03 mg/L at (Ehui 1) to 0.06 mg/L at (Ehui 3). Nitrate ranges from 0.002 mg/L at (Ehui 1) to 0.004 mg/L at (Ehui 3). Transparency ranges from 0.54 m (Ehui 1) to 0.58 m (Ehui 2), while depth varies from 2.98 m at (Ehui 2) to 3.93 m at (Ehui 1).

Overall, the average values for temperature, conductivity, saturated oxygen content, dissolved solids content and dissolved oxygen content gradually increase from station Ehui 2 (27.78 ± 0.81°C; 274.45 ± 23.94 ms/cm; 57.76 ± 7.62%; 159.88 ± 10 ms/cm; 4.50 mg/L ± 0.7 mg/L; respectively) to station Ehui 1 (28.16 ± 0.17°C; 278.33 ± 13.42 ms/cm; 61.41 ± 10.27%; 166mg/L ± 12.14mg/L; 4.98 ± 0.64 mg/L) respectively.

Conversely, the average values for transparency, phosphorus and nitrate increase from station Ehui 1 (0.54 ± 0.08 cm; 0.03 ± 0.01mg/L; 0.002 ± 0.001 mg/L respectively) to station Ehui 3 (0.56 ± 0.09 cm; 0.06 ± 0.009mg/L; 0.004 ± 0.0008 mg/L). The average hydrogen potential (pH) increases from station Ehui 2 (7.53 ± 0.19) to station Ehui 3 (7.89 ± 0.5).

Comparison of variations in the ten physicochemical parameters showed significant differences between stations for nitrate (ANOVA, $p < 0.05$).

Seasonal variations in physicochemical parameters

Conductivity, temperature, oxygen saturation and dissolved oxygen levels were higher during the long dry season (Table 1). Phosphorus and nitrate concentrations and depth were higher during the long rainy season. Dissolved solids and transparency peaked during the short dry season. The highest hydrogen potential value was observed during the short rainy season.

The average values for dissolved solids ranged from 154.13 ± 1.22 mg/L (long dry season) to 181.67 ± 3.78 mg/L (short dry season). Conductivity varies between 250 ± 3.07 Ms/cm (short rainy season) and 297.75 ± 2.66 MS/cm (long dry season).

The hydrogen potential has the lowest value (7.35 ± 0.13) during the long dry season and the highest value (8.09 ± 0.55) during the short rainy season.

The lowest average temperature was recorded during the major rainy season (27.06 ± 0.67 °C) and the highest during the major dry season (28.45 ± 0.05 °C). The oxygen saturation rate had average values ranging from 42.67 ± 3.77% (short dry season) to 67.93 ± 6.96% (long dry season). The lowest average dissolved oxygen level was recorded during the short dry season (3.07 ± 0.64 mg/l) and the highest during the long dry season (5.24 ± 0.45 mg/l).

The average phosphorus concentration values ranged from 0.03 ± 0.01 mg/l (short rainy season) to 0.06 ± 0.01 mg/l (long rainy season). Average nitrate concentrations ranged from 0.01 ± 0.1 mg/L (long dry season, short dry season and short rainy season) to 0.02 ± 0.1 mg/L (long rainy season).

In terms of transparency, the averages vary between 0.44 ± 0.02 cm (main rainy season) and 0.68 ± 0.05 cm (minor dry season). Depth values ranged from 2.71 ± 0.36 m (long dry season) to 4.20 ± 0.51 m (long rainy season).

Analysis of variance (ANOVA) reveals significant seasonal differences ($p<0.05$) for depth, temperature and transparency. In terms of temperature and depth, significant differences (Tukey's post hoc test, $p < 0.05$) are found between the long dry season and the long rainy season. For transparency, a significant difference was observed between the dry seasons (GSS and PSS) and the rainy seasons (GSP and PSP) (Tukey's post hoc test, $p < 0.05$).

Table 1. Values (means ± standard deviation) of physicochemical parameters measured during the short dry season (SDS), long dry season (LDS), short rainy season (SR) and long rainy season (LR) in lake Ehuikro (Côte d'Ivoire) between April 2017 and March 2018

Parameters	LSS	LSS	SSD	SR
TDS (mg/L)	154.13± 1.22^a	168.5± 8.01^a	181.67 ± 3.78^a	163 ± 2.02^a
Cond (MS/cm)	297.75± 2.66^a	252.14± 11.70^a	274 ± 2^a	250 ± 3.07^a
pH	7.35± 0.13^a	7.75± 0.01^a	7.53 ± 0.06^a	8.09± 0.55^a
Temp (°C)	28.45± 0.05^a	27.06± 0.67^b	28.24± 0.04^{ab}	27.9± 0.07^{ab}
Sat TO_2(%)	67.93± 6.96^a	61.42± 4.81^a	42.67± 3.77^a	65.63± 2.11^a
TO_2 (mg/l)	5.24± 0.45^a	5.08± 0.58^a	3.07± 0.64^a	4.53± 0.36^a
$Po^3{}_4{}^-$ (mg/l)	0.04± 0.01^a	0.06 ± 0.01^a	0.04± 0.01^a	0.03± 0.01^a
No_{3-} (mg/l)	0.01 ± 0.1^a	0.02 ± 0.1^a	0.01 ± 0.1^a	0.01 ± 0.1^a
Transp (cm)	0.62 ± 0.01^a	0.44 ± 0.02^b	0.68 ± 0.05^a	0.52 ± 0.03^{ab}
Depth (m)	2.71± 0.36^a	4.20 ± 0.51^b	3.18± 0.29^{ab}	3.43 ± 0.31^{ab}

TDS = Total dissolved solids; Cond = Conductivity; pH = Hydrogen potential; Temp = Temperature; Sat TO_2= Oxygen saturation level; TO_2= Dissolved oxygen level; $Po^{3-}{}_4$= Phosphate level; No^{3-}= Nitrate level; Transp = Transparency; Depth = Depth. For a given parameter, values in the same row with different superscript letters (a and b) show significant differences (ANOVA, $p<0.05$).

Seasonal variations in physico-chemical parameters by station in lake Ehuikro

At Ehui 1, the highest values for conductivity, temperature, oxygen saturation, dissolved oxygen and transparency were recorded during the dry season (Table 2). As for phosphorus, nitrate, depth, dissolved solids and hydrogen potential, the highest values were recorded during the rainy season. The seasonal differences noted at this station are significant (Student's t-test, $p < 0.05$) only for transparency and depth.

At the Ehui 2 station, dissolved solids, conductivity, temperature, and transparency are higher during the dry season (Table 2). In contrast, hydrogen potential, oxygen saturation, dissolved oxygen; phosphorus, nitrate, and depth had the highest values during the rainy season. At this station, no significant seasonal differences were observed for the physicochemical parameters (Student's t-test, $p > 0.05$).

At Ehui 3, the highest values were recorded during the dry season for dissolved solids, conductivity, temperature, hydrogen potential, and oxygen saturation. Dissolved oxygen, phosphorus, nitrate, and depth were higher during the rainy season (Table 2). The seasonal differences observed are only significant (Student's t-test, $p < 0.05$) for depth.

Table 2. Values (means ± standard deviations) of the physicochemical parameters measured during the dry (DD) and rainy (DR) seasons at the sampling sites in lake Ehuikro (Côte d'Ivoire) between April 2017 and March 2018

Stations	Seasons	TDS (mg/L)	COND (Ms/cm)	pH	Temp (°C)	Sat TO_2 (%)	TO_2 (mg/l)	Po^{3-}_4 (mg/l)	No_{3-} (mg/l)	Transp (cm)	Depth (cm)
Ehui 1	SS	165.225± 10.78^{a}	284.25± 13.25^{a}	7.4425± 0.01^{a}	28.34± 0.11^{a}	54.405± 17.41^{a}	3.735± 1.64^{a}	0.055± 0.01^{a}	0.0035± 0.01^{a}	0.65± 0.04^{a}	2.725± 0.48^{a}
	SP	168± 2^{a}	254.55± 0.05^{a}	8.3375± 0.58^{a}	27.575± 0.43^{a}	63.595± 0.31^{a}	5.145± 0.55^{a}	0.06± 0.01^{a}	0.0045± 0.01^{a}	0.47± 0.03^{b}	3.635± 0.24^{b}
	Avg.	166.6125± 1.39	269.4± 14.85	7.89± 0.45	27.9575± 0.38	59± 4.60	4.44± 0.71	0.0575± 0.01	0.004± 0.01	0.56± 0.09	3.18± 0.46
Ehui 2	SS	169.75± 14.25^{a}	287.88± 13.88^{a}	7.39 ± 0.24^{a}	28.41± 0.11^{a}	50.25± 7.25^{a}	3.83± 0.73^{a}	0.03± 0.01^{a}	0.01 ± 0.01^{a}	0.68± 0.07^{a}	2.69 ± 0.05^{a}
	SP	158.25± 1.75^{a}	240± 5.40^{a}	7.68± 0.08^{a}	26.93± 0.88^{a}	65.48± 0.68^{a}	4.67± 0.67^{a}	0.05± 0.01^{a}	0.01± 0.01^{a}	0.51± 0.05^{a}	3.38± 0.38^{a}
	Avg.	164± 5.75	263.94± 23.94	7.54± 0.14	27.66± 0.74	57.86± 7.61	4.25± 0.42	0.04± 0.01	0.01± 0.01	0.6 ± 0.08	3.04± 0.34
Ehui 3	SS	168.73± 16.28^{a}	285.5± 8.5^{a}	7.49± 0.05^{a}	28.29± 0.09^{a}	61.25± 13.25^{a}	4.9± 0.9^{a}	0.034± 0.01^{a}	0.01± 0.001^{a}	0.62± 0.02^{a}	3.43± 0.18^{a}
	SP	171± 8^{a}	258.66 ±8.66^{a}	7.75± 0.01^{a}	27.94± 0.04^{a}	61.5± 7.3^{a}	4.61± 0.39^{a}	0.04 ± 0.02^{a}	0.01± 0.002^{a}	0.46± 0.04^{a}	4.44± 0.54^{b}
	Avg.	169.86 ±1.14	272.08 ±13.42	7.62± 0.13	28.11± 0.18	61.37 ± 0.13	4.76 ± 0.15	0.03 ± 0.01	0.01± 0	0.54± 0.08	3.93 ± 0.51

Within the same station, values in the same column with different superscript letters (a and b) indicate significant differences (Student's t-test, $p < 0.05$).

Substrate canopy closure rate at Lake Ehuikro

The substrate at lake Ehuikro is composed of fine and coarse sand, dead wood, plant debris, a mixture of gravel and mud, sand and gravel (Table 3).

Table 3. Average values for substrate rates in lake Ehuikro

	Stations	MGB (%)	MSG (%)	S (%)	DV (%)
Ehuikro	E1	82	0	0	18
	E2	0	68	0	32
	E3	0	0	67	33

MGB: Gravel-Mud Mixture; MSG: Sand-Gravel Mixture; S: Sand; DV: Plant Debris

Aquatic plants are also found on the lake at Ehui 1, the substrate consists of a mixture of gravel and mud and plant debris, while at Ehui 2, it is more of a mixture of sand, gravel and plant debris. At Ehui 3, the substrate is dominated by sand and plant debris. The canopy is 20% covered at Ehui 1 and 0% covered at Ehui 2 and 3. The coverage rate of aquatic plants is 16% at Ehui 1, 30% at Ehui 2 and 34% at Ehui 3.

DISCUSSION

The water temperature of Lake Ehuikro fluctuates with an average of 27.78 °C (Ehui 2) and 28.16 °C (Ehui 1). These data are similar to those recorded by Kouassi *et al.* (2007) and Aliko *et al.* (2010) in Lake Taabo; by Yté *et al.* (1996) and Ossey *et al.* (2008) in the Buyo dam lake and by Brunel and Bouron (1992) in Lake Kossou. These authors gave temperature values ranging from 25°C to 33°C. According to Iltis and Lévêque (1982), the temperature of Ivorian watercourses rarely falls below 25°C. In tropical areas, during the period from February to April (dry season), the air temperature, linked to solar radiation, is at its maximum, while it is at its minimum during the period from June to July (rainy season) to August to September (dry season), with overcast weather (Dufour and Durand, 1982). These seasonal variations are small within a given station (less than 1°C difference) and the differences observed are not significant. Nevertheless, these variations may be linked, among other things, to the climatic conditions on the days when this parameter was measured. The factors that determine temperature variations in aquatic ecosystems are atmospheric conditions, hydrology, exchanges at the water/sediment interface, geomorphology and vegetation cover (Lery, 2009). The intensity of insolation would also explain the maximum values of this parameter recorded during the dry season.

pH is a measure of the acidity, alkalinity or neutrality of water. The pH values measured vary between 7.42 (Ehui 2) and 7.70 (Ehui 3), with an annual average of 7.57. These results show that the waters of these lakes are slightly alkaline. Kouassi *et al.* (2007) noted an average pH of 7.36 in the waters of Lake Taabo. This value is of the same order of magnitude as that obtained in our study. According to Iltis and Lévêque (1982), pH values are generally very slightly alkaline, with an average of 7.35 in the Bandama River basin. Seasonal variations in this parameter are thought to be linked to the life cycle of organic matter. The drop in pH observed during the dry season is thought to be the result of a significant process of organic matter decomposition (Ekou *et al.*, 2011). Indeed, a large proportion of the lake's aquatic vegetation dies periodically. The decomposition of biomass (macrophytes) adds organic matter to the water body, which increases oxygen consumption and makes the environment reductive. Thus, the decomposition process could lead to a decrease in hydrogen potential. Consequently, in the absence of aquatic plant decomposition, the pH of the water would tend to increase.

Spatio-temporal variations in saturated oxygen content are commonly observed in other lake environments, such as Lakes Ayamé 1 and 2 by Galy-Lacaux *et al.* (1999); Lake Taabo by Kouassi *et al.* (2007) and Aliko *et al.* (2010); Lake Kossou by Traoré (1996); the Canet Pond (Pyrénées-Orientales, France) (Wilke, 1998a); and the Salses Leucate Pond (France) (Wilke, 1998b). According to Dufour and Slepoukha (1975) and Dufour and Durand (1982), several factors could explain these spatio-temporal variations in oxygen content, in particular exchanges with air-water interfaces (atmosphere, marine and fresh water) on the one hand, and consumption and production through photosynthesis *in situ* on the other. In the lake waters of Bongouanou, our results show seasonal variation in oxygen content, with maximum levels during the rainy seasons (April, May, June, July, September and October) and minima during the dry seasons (November, December, January, February, March and August). This could be explained by a drop caused by the enrichment of the waters with organic matter (particulate and dissolved) and nutrients. The bacteria responsible for decomposing organic matter increase the biochemical demand for oxygen and release carbon dioxide into the environment through respiration (Wilcock *et al.*, 1995). In addition, the high concentration of suspended matter, reflected in the low transparency of the lakes, combined with the macrophytes covering the water surface, considerably limits the penetration of light into the lower layers of the lakes. This has the effect of reducing photosynthetic activity and increasing the rate of algal and bacterial respiration, thereby causing a decrease in the oxygen concentration in the environment (Barillier *et al.*, 1993).

Transparency is a measure that allows us to assess the amount of suspended matter in the environment. Our study shows a clear seasonal variation in the transparency of the lake waters of Bongouanou. Maximum transparency values are observed during the dry seasons (periods of low water levels in the lakes), while minimum values are obtained during the rainy seasons (periods of high water levels in the lakes). This seasonal variation is consistent with the results obtained by Kouassi (2013) in the Adzopé reservoir. It also follows the same trend as the variations observed in the Ebrié lagoon by Dufour and Durand (1982) and in Lake Togo by Millet (1986). Indeed, the stagnant nature of the water promotes the settling of suspended matter, which results in increased transparency (Diomandé, 2001) . On the other hand, during the rainy season, the water carries mineral and organic particles, thus increasing its turbidity (Diomandé, 2001).

According to Martin (1987), phosphate plays a very important role in the development of Aquatic plants. This is an important parameter in the fertilisation of water bodies, playing a major role in planktonic growth. This nutrient is a relevant indicator for assessing the trophic level of water bodies (Mama *et al.*, 2011). According to this author, most phosphorus inputs come from point sources: urban or industrial discharges, animal waste from traditional or industrial livestock farming, and runoff from rainfall in river basins. The values for this compound are much higher than those obtained by Mama *et al* (2011) in Lake Nokoué in Benin. This difference can be explained by the drainage of rainwater, which is rich in phosphorus from the use of fertilisers on fields. Phosphorus is an essential nutrient for plant growth; however, above a certain concentration and when conditions are favourable, it can cause excessive growth of algae and higher aquatic plants. This growth may be followed by an accumulation of plant biomass and detritus, which generally leads to a deterioration in water quality (Ekou *et al.*, 2011). Levels above 0.5 mg/L should be considered an indication of pollution (Ahonon, 2011).

According to Welcomme (1985), conductivity provides a better assessment of the chemical richness of a given environment. The conductivity results indicate that the waters of Lake Socotè have a higher conductivity than those of Lakes Kaby and Ehuikro. Our results are higher than those recorded in Lake Taabo by Kouassi *et al.* (2007) and Aliko *et al.* (2010).

These authors observed average values between 85.16 µS/cm and 90.45 µS/cm. The average conductivity recorded by Yté *et al.* (1996) in Lake Buyo Dam ranges from 20 to 100 µS/cm. Ossey *et al.* (2008) recorded conductivity values in the same environment ranging from 47.50 to 102.20 µS/cm. These average values are close to those obtained in the Kossou dam lake (75.63 µS/cm). According to Edia (2008), seasonal fluctuations in conductivity are likely to be related to the seasonality of mineral salt concentrations, as these elements are responsible for the mineralisation of water and, consequently, its conductivity. Welcomme (1985) indicates that in the natural environment, variations in water conductivity are influenced by a number of factors, including precipitation, evaporation and the type of substrate. Other work carried out by N'Goran (1989) has shown that during the dry season, evaporation combined with a lack of water supply causes an accumulation of ions, which increases conductivity. This could explain the increase in conductivity observed at the stations during the dry season.

Nitrate (NO_3-) is an ion that occurs naturally in the environment. It is the result of the nitrification of ammonium ions (NH^{4+}), which are present in water and soil (Chaussée, 2003). The highest concentrations of nitrate nitrogen were observed in Kaby and Socotè. This increase in nitrate concentration in these environments may be associated with agricultural areas, which are probably the main source of fertilising elements after leaching from cultivated land enriched with fertilisers during the rainy season. These results are higher than those obtained in the lakes of Taabo and Kossou by Koné (2012).

The nitrate concentrations obtained in this study are significantly higher than those given by the Nitrates Directive (11.30 mg/L) as an indicator of water pollution (Ekou *et al.*, 2011).

CONCLUSION

In summary, the study conducted on Lake Ehuikro highlights significant seasonal variability in the physico-chemical parameters of its waters. While some indicators, such as temperature, pH and conductivity, remain within acceptable ranges for an aquatic environment, others, notably low dissolved oxygen levels and reduced transparency, point to a gradual deterioration in water quality. These disturbances appear to be closely linked to anthropogenic pressures around the lake, highlighting the need to implement environmental management and monitoring measures in order to preserve the ecological balance of this body of water.

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