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Physico-Chemical Characterisation of the Waters of Lake M'bakre, South of Abidjan, Côte d'Ivoire

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ABSTRACT: Lake M'bakré, on the West African coast, south of Abidjan, is facing the consequences of eutrophication and recent developments in its surroundings. To assess the physico-chemical quality of its waters, the monitoring of physico-chemical parameters was carried out between June 2013 and March 2014. The results of the analyses show that its waters are neutral to alkaline, well oxygenated, not very mineralised, warm all year round, benefit from a good water quality and are little affected by the poor development of its surroundings. The lake's waters are not affected by the nutrient salts measured and these parameters remain below international standards.

KEYWORDS: Pollution, nutrient salts, M'bakré lake, Abidjan, Côte d'Ivoire.

1 INTRODUCTION

Surface waters are increasingly used in recent years for agriculture, food and industry [1]. Unfortunately, they are among the ecosystems most seriously threatened by the impact of human activities in the last century [2]. Perhaps the greatest problem in the world today is the accessibility and availability of freshwater in quality and quantity for all the thousands of diverse lives on earth [3]. In most developing countries, control and monitoring of the quality of surface water used for drinking water production is not systematic due to lack of resources [4]. Located in the southern periphery of the Ivorian megalopolis (Abidjan), Lake M'Bakré belongs to the lacustrine entity of the vast Ebrié hydrographic complex [5]. It has several uses, satisfying the drinking water needs of the local populations during shortages and contributing to their subsistence through the exploitation of these living resources. This body of water has long been preserved from the degradation caused by urbanisation and demographic pressure. This protection of the natural environment is based on the fact that it has been enclosed since the opening of the Vridi canal [6]. However, recent satellite images show that several socio-economic activities have developed around the lake and that its surface area seems to be shrinking. This reduction of the lake area is reflected in the extension of the grass beds and the permanent presence of macrophytes on its surface, which also attests to its tendency to eutrophication. These modifications are likely to disrupt its functions, particularly its biological potential and potential uses, and justify the need for a study of the environmental quality of the waters of Lake M'Bakré. Similarly, with the exception of two studies dating back more than thirty (30) years [5], [7] no study has been carried out on the physico-chemical characteristics of the lake. The present study therefore aims to evaluate the physico-chemical quality of the lake water and to measure the impact of socio-economic activities on the evolution of the water body.

2 PRESENTATION OF THE STUDY ENVIRONMENT

Lake M'bakré is located between 374830 and 383701 West longitude and 580251 and 581854 North latitude between the Atlantic Ocean to the South and the Ebrié Lagoon to the North (Fig. 1). It is about 9.058 km long and covers an area of 5.62 km2 [6], and is located in a catchment area of about 15 km^2 [7]. The geomorphology of its catchment area is made up of low plateaus (whose altitude varies from 8 to 12 metres) of continental origin, dating from the Ante-Holocene period and formed of sandy-clay sediments, and a

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plain formed by the barrier beaches in the east of its southern half [8]. Its tectonic structure is marked by a satellite fault parallel to the major fault (the lagoon fault) of the entire Ivorian sedimentary basin [9]. The climate is equatorial with four (4) seasons. The major rainy season runs from mid-March to mid-July and the minor rainy season from October to November, resulting in floods of unequal importance depending on the intensity and duration of rainy episodes. Indeed, May and June represent 22 to 64% of the total annual rainfall [10] with June being the wettest month of the year. As for the dry seasons, the longest extends from December to March and the shortest from mid-July to September, favouring the recession. The average air temperature varies very little, from 26°C to 33°C, the average annual rainfall is over 1800 mm [11] and its humidity rate is 80 to 90%.

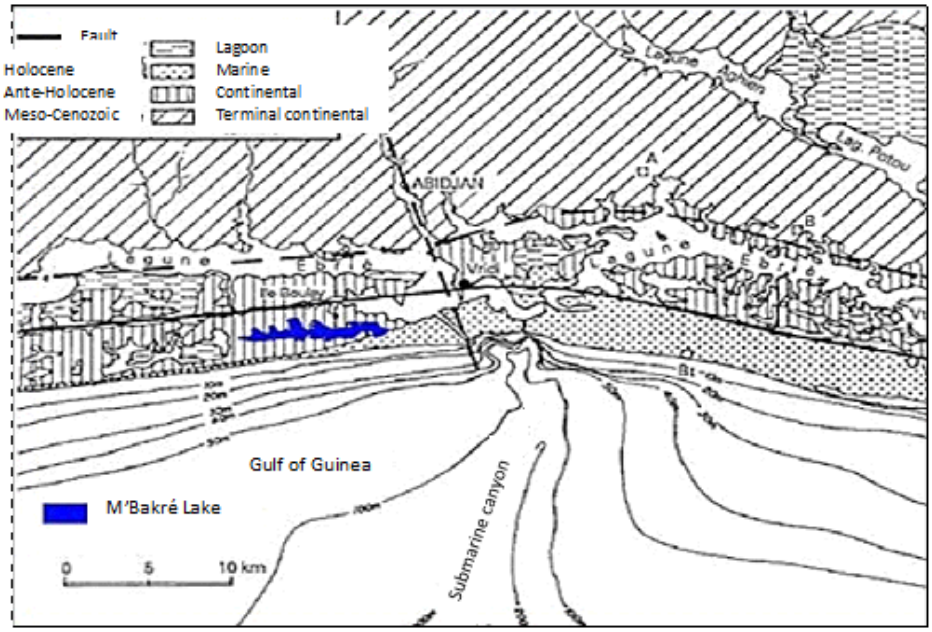

Fig. 1. Location of the study area

3 STUDY MATERIAL AND METHODS

3.1 CHOICE OF STATIONS AND SAMPLING FREQUENCY

In the absence of tributaries, the influences of external factors allowed the selection of ten surface stations across the lake. The sampling campaigns took place from June 2013 to March 2014 (Fig. 2).

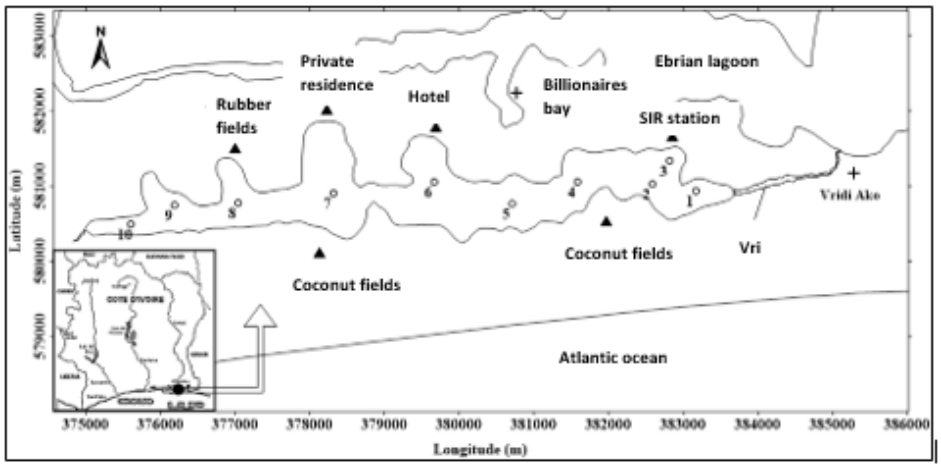

Fig. 2. Location and sampling stations of M'Bakré Lake

3.2 SAMPLES AND METHODS OF ANALYSIS

Samples are taken according to standardised techniques, using a two-litre Niskin type bottle. The samples were kept in coolers to ensure that the temperature was maintained at 4°C, and were then sent to the analysis laboratory of the Ivorian Anti-Pollution Centre (CIAPOL). Some measurements were carried out in situ: Temperature (T), Hydrogen Potential (pH), Electrical Conductivity (EC) and Dissolved Oxygen (DO) which were taken using a multi-parameter Hanna 9828 type. For the chemical parameters (Sulphates, Nitrates, Ammonium, Nitrites and Ortho phosphates), the analyses were carried out according to the so-called colorimetric methods, using the DR 6000 spectrophotometer. The processing of the data collected using the Surfer 11.0 software made it possible to produce maps of the distribution of chemical parameters on the surface. For the analysis and interpretation of the results, a study of the interdependence relationships was carried out using PCA with the XLSTAT Trial 2021 software. This statistical study required the use of the raw data matrix which includes 09 physico-chemical variables: electrical conductivity (EC), temperature (T°), hydrogen potential (pH), dissolved oxygen (O2), sulphates (SO4), nitrogen compounds (NO3, NO2, NH4), orthophosphate (PO4).

4 RESULTS

4.1 TEMPERATURE

The seasonal evolution of the water temperature at Lake M'Bakré shows a seasonal variability of the water between 1 °C and 5 °C. The maximum values are observed in the dry season and exceed 32 °C (Fig. 3), precisely at sites 1, 2 and 3. The minimum values of 27.48 °C were measured in the rainy season (Figure 3). This temperature variation is related to local conditions.

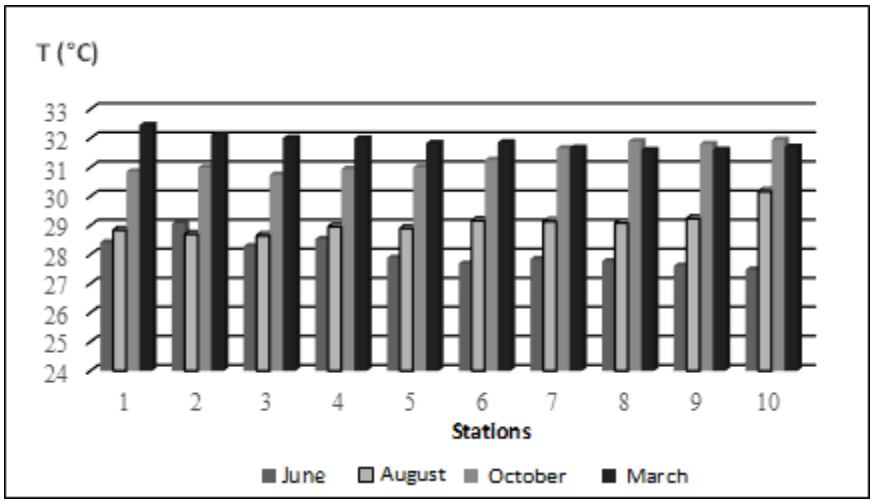

Fig. 3. Spatial and temporal variation of temperature values

4.2 HYDROGEN POTENTIAL

The evolution of the pH, which is generally neutral to alkaline throughout the study period in Lake M'Bakré, shows little variation. The pH values are generally between 6.7 and 8.5 (Fig.4).

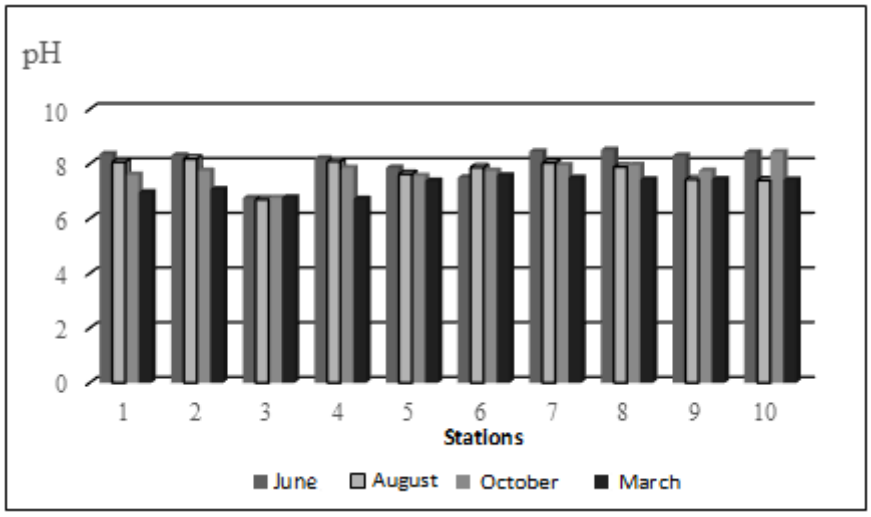

Fig. 4. Spatial and temporal variation of pH values

4.3 Electrical Conductivity (Ec)

The measurements of the electrical conductivity of all the ten (10) stations of Lake M'Bakré, show that they are between 62 and 58 µS/cm during the months of June to August (Fig. 5). This therefore indicates the presence of weakly mineralised water.

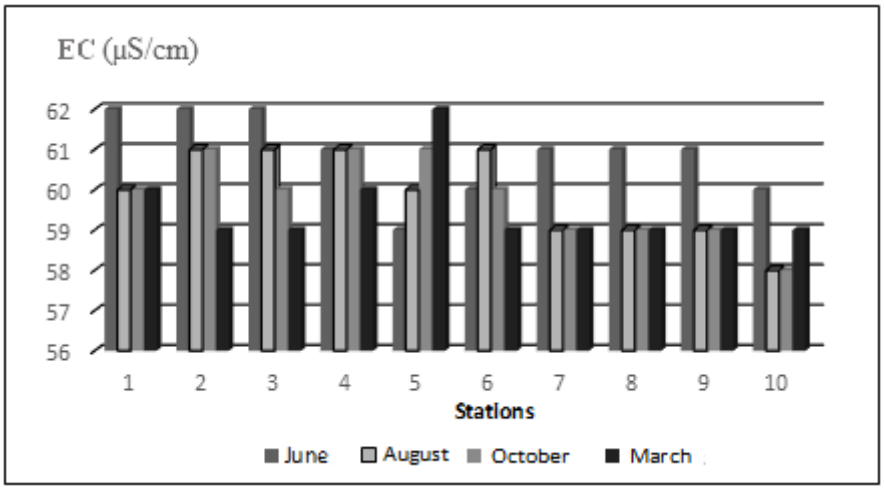

Fig. 5. Spatial and temporal variation of electrical conductivity values

4.4 Dissolved Oxygen

The distribution of dissolved oxygen at the surface is heterogeneous throughout the year and between sites. The seasonal evolution of dissolved oxygen shows higher concentrations in the rainy season than in the dry season. Indeed, the levels recorded vary between 6.8 mg/L and 14.88 mg/L in the dry and wet seasons respectively (Fig.6)

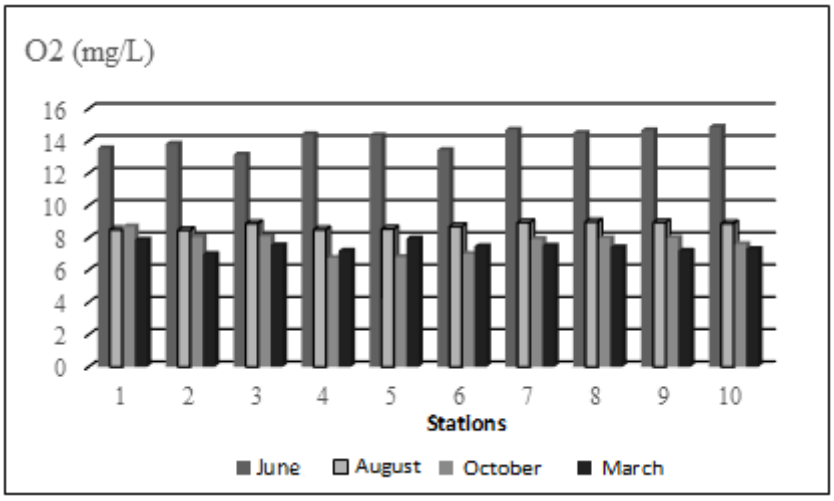

Fig. 6. Spatial and temporal variation of dissolved oxygen values

4.5 SULPHATES

Over the course of the different seasons observed, the evolution of the sulphate content shows very low values between 0 mg/L and 6 mg/L at all the sites studied. These remain well below the standards [12] set at 250 mg/L for drinking water. In addition, the spatial distribution of sulphates shows three distinct zones of distribution (Fig. 7). The first zone near the SIR station is represented by sites 1, 2, and 3. These sites are characterised by sulphate levels between 3 mg/L and 6 mg/L. The second zone is located in the middle of the lake. This second zone includes sites 7, 8, 9 and 10. These are characterised by sulphate levels of between 1 mg/L and 2 mg/L. Finally, the third distribution zone links stations 4, 5 and 6.

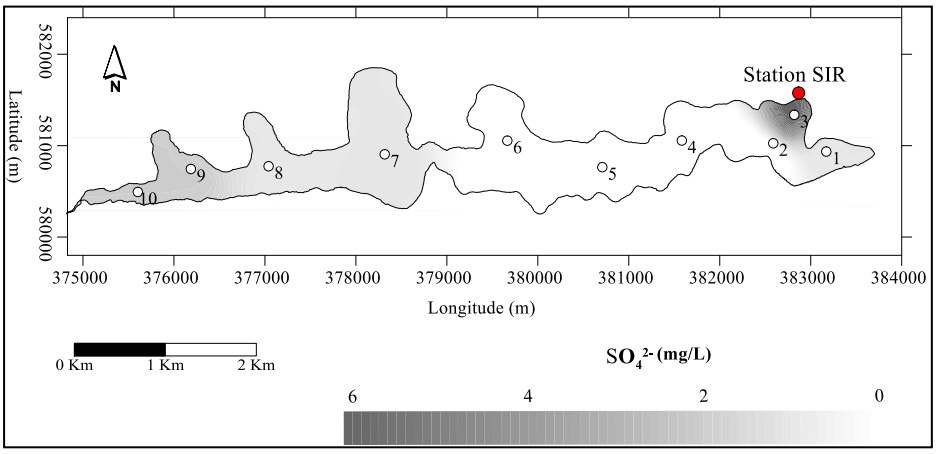

Fig. 7. Spatial distribution of sulphate levels in Lake M'Bakré

4.6 AMMONIUM

The seasonal ammonium concentration recorded at the various sampling locations is low. They range from 0.02 mg/L to 0.19 mg/L. These results are below the standards [12] set at 0.5 mg/L for drinking water. The spatial distribution of ammonium ions shows two zones of distribution (Fig. 8). The first zone corresponds to the eastern half of the lake and is represented by sites 1 to 6 with ammoniacal nitrogen levels below 0.1 mg/L. The second zone, corresponding to the western half of the lake, groups together sites 7 to 10 with levels between 0.16 mg/L and 0.19 mg/L.

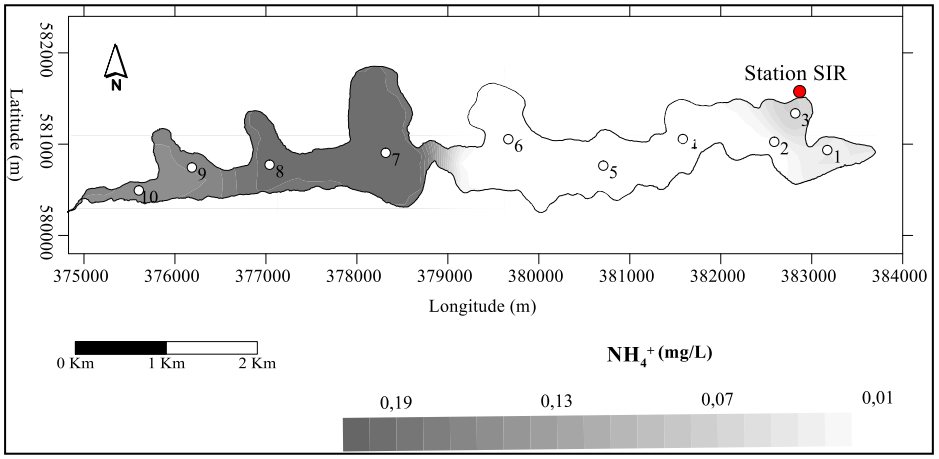

Fig. 8. Spatial distribution of ammonium levels at Lake M'Bakré

4.7 NITRATES

The evolution of the nitrate content shows very low values, which are recorded during all seasons and at all study sites. The lake waters are not subject to a risk of nitrate pollution, as the values recorded during the analyses oscillate between a minimum of 2 mg/L and a maximum of 4.2 mg/L, and are still below the value admissible by the standards [12] set at 50 mg/L for drinking water. The lateral distribution shows two zones of distribution (Fig. 9). The first zone is close to the SIR station and is represented by sites 1, 2, and 3. These sites are characterised by nitrate levels between 3 mg/L and 4.2 mg/L. The second zone includes sites 4 to 10 with nitrate levels below 3 mg/L.

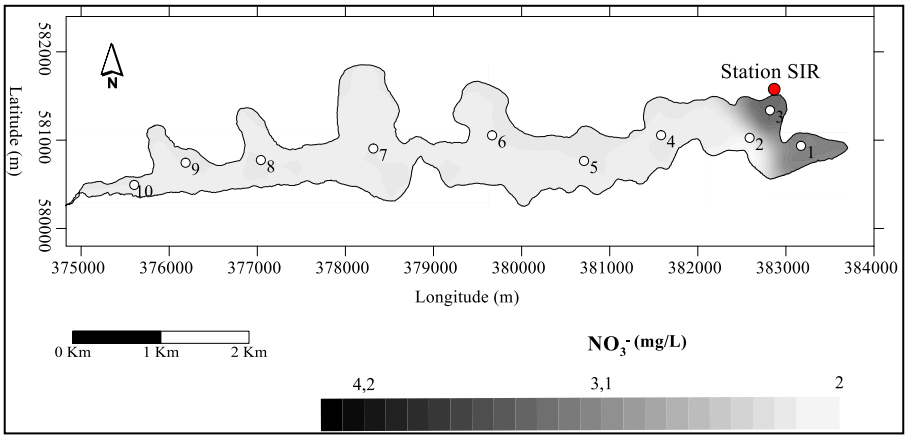

Fig. 9. Spatial distribution of nitrate levels at Lake M'Bakré

4.8 NITRITES

The evolution of the nitrite content shows zero values, which are recorded during all seasons and at all study sites except at the SIR station. The waters of the lake are not subject to a risk of pollution by nitrites because the values recorded during the analyses oscillate between a minimum of 0 mg/L and a maximum of 0.03 mg/L and which remain moreover lower than the admissible value by the standards [12] fixed at 0.2 mg/L for drinking water. The spatial distribution of Nitrites shows two zones of distribution (Fig. 10). The first zone is close to the SIR station and represented by site 3 with average levels of 0.03 mg/L. The second zone includes sites 2 to 10 with zero levels.

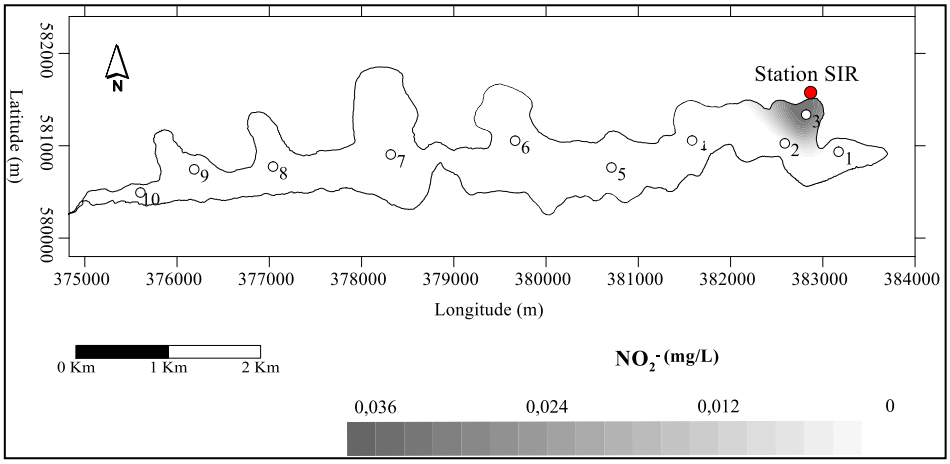

Fig. 10. Spatial distribution of nitrite levels in Lake M'Bakré

4.9 PHOSPHATES

The evolution of the phosphate content shows very low values, which are recorded during all seasons and at all study sites. The levels are in the range of 0 mg/L to 0.09 mg/L. These levels remain well below the standards [12] set at 5 mg/L for drinking water, which proves that the lake is not subject to the risk of phosphate pollution. The spatial distribution of phosphates shows three zones of distribution (Fig. 11). The first zone is represented by sites 2 to 6. These sites are characterised by phosphate levels between 0.05 mg/L and 0.09 mg/L. The second zone is represented by sites 1, 7 and 8. These sites are characterised by phosphate levels between 0.02 mg/L and 0.05 mg/L. The third zone includes sites 9 and 10.

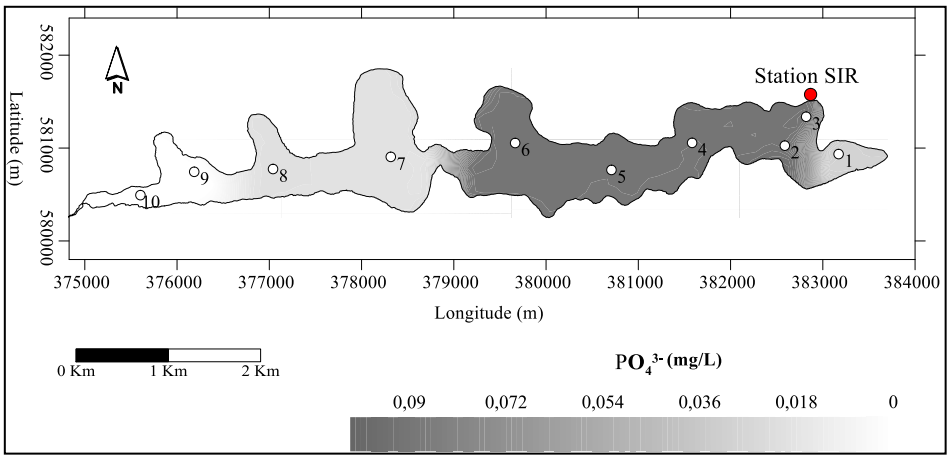

Fig. 11. Spatial distribution of phosphate levels in Lake M'Bakré

4.10 PRINCIPAL COMPONENT ANALYSIS

The principal component analysis (PCA) of the results of the physico-chemical analysis of the waters of Lake M'bakré, allowed us to know the different degrees of linkage between the parameters. The percentages of information expressed for the most important factors are F1 (51.14%) and F2 (30.47%) (Fig. 12). These first two factors express 81.01% of the information and are therefore sufficient to inform about the hydrochemical interactions in Lake M'bakré.

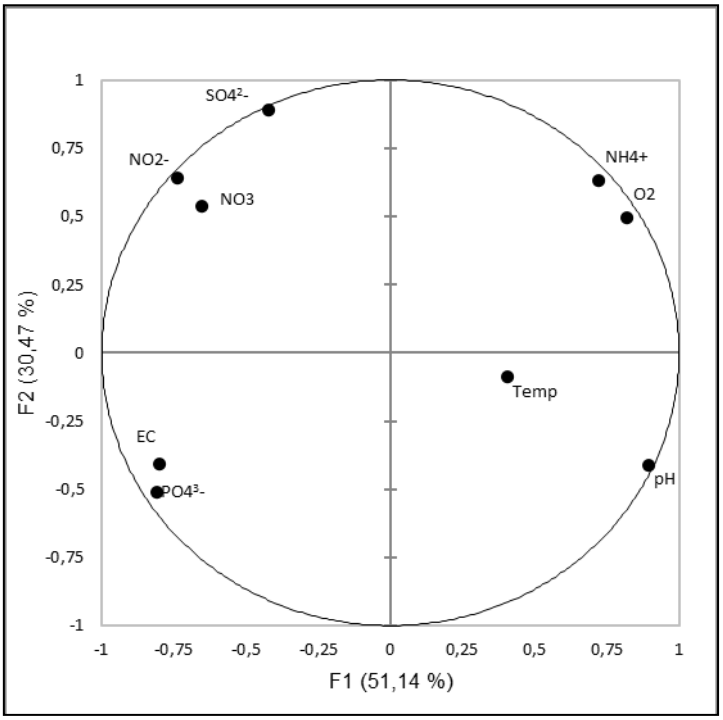

Fig. 12. Projection of variables into the F1-F2 factorial plane

The analysis of the results shows that the first and most important component F1 is defined by the parameters NH_4^+, O_2 and pH in its positive part and the parameters NO_2^-, NO_3^-, PO_4^{3-} and conductivity in its negative part. The F1 factor expresses the oxygenation gradient which facilitates the nitrification phenomenon and an enrichment of the water in phosphate, which would come from the decomposition of the organic matter expressed by the good correlation between the electrical conductivity and the phosphates. The second component F2 is made up of NH_4^+, NO_2^-, NO_3^- and SO_4^{2-} which are descriptors of anthropogenic pollution and rainfall. The F2 factor expresses the anthropogenic origin of nutrient salts through surface inputs.

5 DISCUSSION

The seasonal evolution of the water temperature at Lake M'Bakré shows a seasonal variability of the water between 1°C and 5°C. In the study area, the temperature does not vary greatly from one site to another and remains close to the local temperature. This temperature variation is related to local conditions. This temperature distribution has already been highlighted in several studies [13], [14] in Cameroon and Mauritania respectively. The pH values across the lake range from 6.7 to 8.5. These different values are related. Seasonally, the minimum values are observed in March during the long dry season and the maximum values during the long rainy season in June. This seasonal variation is attributable to biological and physicochemical reactions related to the presence of aquatic plants [15], which are favoured by summer conditions and hindered by high temperatures in the dry season, causing phytoplankton mortality and reducing their activity. As for the specificity of site 3 (SIR station) where low pH values are observed, this is due to the mixing of the water column by industrial activity [16]. The measurements of the electrical conductivity of all the ten (10) stations of the M'Bakré lake show that they are weakly mineralised. Moreover, the maximum and minimum values are found respectively in the rainy and dry seasons, contrary to what is observed in the waters of the Ain Dalia dam in Algeria studied by [17]. Beyond the effects of temperature, the seasonal variation of electrical conductivity is also influenced by additional mineral inputs during the rainy seasons due to ion-enriched waters leaching from the catchment soils, and dilution by lightly loaded rainfall during other seasons [18]. The distribution of dissolved oxygen at the surface is heterogeneous throughout the year and between sites. Indeed, the levels recorded vary between 6.8 mg/L and 14.88 mg/L in dry and wet periods respectively. These levels, which are higher than the natural oxygen saturation level, indicate eutrophication of the environment, resulting in intense photosynthetic activity. The changes in dissolved oxygen values are due to the decrease in water temperature, as cold water contains a greater amount of dissolved oxygen than warm water [19]. In terms of nutrient salts, at all stations and for all periods of the study, the values obtained remain below the standards [12]. As far as sulphates are concerned, these levels, which are well below the norms, could be explained on the one hand by the nature of the soil and on the other hand by the poor drainage of mineral elements and waste water from domestic activities by the populations living near Lake M'bakré and the watercourses that feed it [20]. The ammonium content of the water in Lake M'bakré is very low in all the sites studied. This low ammonium content of the lake water is attributable to the presence of organic

silt, the result of the decomposition of macrophytes [19]. Nitrates are found at all the study stations at low levels. This low presence of nitrates is explained by an origin due mainly to the oxidation of ammoniums into nitrites and then into nitrates. Nitrous ion is unstable. It is transformed into nitrates which are the final state of ammonium oxidation. According to [2], the presence of nitrates in watercourses is due either to leaching from agricultural soils or to the oxidative reactions of ammoniacal nitrogen and nitrites. Nitrite (NO2-) is present in low concentrations in the waters of Lake M'bakré. This low content of nitrite during the study period can be interpreted by the fact that nitrite is an intermediate form that tends to oxidise into nitrate or to reduce to ammonium [21]. The evolution of the phosphate content shows very low values, which are recorded during all seasons and at all study sites. These relatively low levels could be explained by a change in form (precipitation of phosphates to calcium phosphates) or by adsorption by particles in the soil [20].

6 CONCLUSION

The results of the physico-chemical characterisation of Lake M'bakré from July 2013 to March 2014 show that the water quality of Lake M'bakré is good. This characterisation highlighted neutral to basic pH values, between 6.7 and 8.51, a dissolved oxygen level above 11 mg/L in the rainy season which tends to be reduced in the absence of rain (7 mg/L). A temperature of between 27.48°C and 32.45°C is related to sunshine, which fluctuates during the day and does not exceed 2°C. Similarly, the electrical conductivity, which is influenced by the geology of the catchment area, varies little, ranging from 58 to 64 µS/cm. The water of the lake according to the measured nutrient salts is little affected and these parameters remain below the international standards. However, this does not necessarily mean that the lake is spared from the risks of alteration. Indeed, it suffers from shoreline modifications caused by agricultural practices and human settlements along its shores. However, the waters of the lake could serve as a freshwater resource for drinking water supply. For the best monitoring of this lake system, which is a potential source of drinking water supply, studies on metallic contamination and microbiology are necessary.

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