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Physico-chemical characterization of the waters of the Taabo hydroelytric Dam (Bandama River, Côte d'Ivoire)

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Abstract

This study was carried out with the aim of determining the physico-chemical characteristics of the waters of the Taabo dam lake in order to evaluate the quality of the waters of this environment. To do this, water sampling and measurements were conducted in this lake from December 2018 to November 2019. The physico-chemical parameters determined were pH (7.22 ± 0.76), dissolved oxygen (5.82 ± 1.55mg/l), conductivity (91.71 ± 22.01 µS/cm), dissolved solids (47.21 ± 9.36mg/l), temperature (28.6 ± 0.81°C), orthophosphate (0.05 ± 0.07mg/l), ammonium (0.14 ± 0.12mg/l), nitrate (1.44 ± 1.11mg/l), nitrate-nitrogen (5.68 ± 5.5mg/l), nitrite (1.91 ± 1.16mg/l). The differences observed between the dry and rainy seasons are not significant according to the statistical test (ANOVA). The concentrations obtained indicate that the level of degradation of the lake waters is low.

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Introduction

On African rivers, dams are important tools for development through the production of electricity, water reserves for domestic needs and for agro-pastoral activities (Lévêque and Paugy, 1999). Various human activities such as agriculture with the use of fertilisers and pesticides contribute to the enrichment of aquatic environments in nutrients such as phosphorus, nitrates (Assougnon *et al.*, 2017). These aquatic environments thus become important receptacles for the pollutants used in their catchment areas (Lozo *et al.*, 2019). An increase in nutrient inputs can modify the evolution of the physico-chemical parameters of the environment (Lozo *et al.*, 2019), degrade the quality of watercourses and threaten aquatic life (Mama *et al.*, 2011 and Adou *et al.*, 2018).

The determination of surface water quality is based on the measurement of physico-chemical parameters as well as on the presence or absence of aquatic organisms and micro-organisms, which are indicators of water quality (Bli-Effert and Perraud, 2001). The Taabo dam lake created on the Bandama River in Côte d'Ivoire is located in an area of high anthropogenic activity. In fact, the local populations use chemical products as fertilisers in agriculture, dump household waste, waste water, faeces, etc. into the waters of the lake. All these activities could have an impact on the quality of the water of this lake. The objective of this study is to determine the physico-chemical characteristics of the waters of the Taabo dam lake in order to determine its quality.

Material and methods

Study area

The Taabo hydroelectric dam, established in 1978, is located on the main course of the Bandama River, about 110km downstream from the confluence of the Bandama Blanc and Bandama Rouge rivers and about 120km downstream from the Kossou dam (Kouassi *et al.*, 2007). The Taabo lake resulting from this dam is located between 06° 20' and 06° 40' north latitude and 5° and 5°30' west longitude. It covers an area of 69km² (Kouassi *et al.*, 2007; Aliko *et al.*, 2010). Lake Taabo has a transitional equatorial hydrological regime (Savané and Konaré, 2010). Sampling for this study was carried out at the Taabo-village station located at latitude 06°12' north and longitude 5°06' west. Located 1km from the village and at an altitude of 129 m, the station has a substrate composed of 10% sand, 60% mud and 30% dead wood, foliage and roots. The surface of the lake is 30% covered by aquatic plants and the canopy closure is zero (Fig. 1).

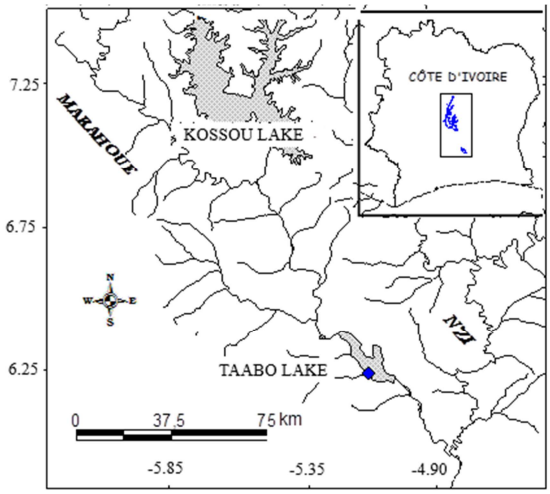

Fig. 1. Location of the sampling area on the Taabo dam lake (Côte d'Ivoire).

◆ = sampling station

▭ = Dam lake

Measurement of physico-chemical parameters

In this work, various parameters of the environment were measured monthly from December 2018 to November 2019. The variables measured during sampling were: hydrogen potential (pH), conductivity (µS/cm), dissolved solids (DS in mg/l), dissolved oxygen (mg/l) and water temperature (°C). Various WAGTECH digital display devices were used for this purpose. These devices are all coupled to a thermometer which allowed the measurement of the water temperature in the reservoir. The measurements were carried out in situ in the first 50 centimetres of water. The measuring devices were first switched on for about fifteen minutes and then their probes were immersed in the water. The value of each parameter is noted after display. With the conductivity meter, the selection of the derived functions (conductivity, DS) allows the automatic display of the value of the selected parameter.

Ionic compounds analysis

The ionic compounds measured are orthophosphate (PO_4^{3-}), ammonium (NH_4^+), nitrate (NO_3^-), nitrogen nitrate (NO_3^--N) and nitrite (NO_2^-). Every month, water samples from Taabo Lake are taken and kept cool in an icebox before being analysed in the laboratory. The determination of ionic compounds was carried out using a HANNA multiparameter photometer model HI 83200 series 2008. The measurement principle is based on Beer Lambert's law (Rodier *et al.,* 2009) which indicates the proportionality of the optical density with the thickness of the solution (sample under test) and the concentration of the chemical element searched. After addition of the appropriate reagent, the water sample-reagent mixture is introduced into the multiparameter photometer which displays the concentration of the ion (in mg/l) in comparison with the control.

The determination of orthophosphate was carried out with two reagents A and B composed respectively of sulphuric acid associated with ammonium molybdate and dimethylformamide combined with sodium bisulphate. Other reagents used are potassium iodide and mercury dichloride for ammonium; cadmium and sulphanilic acid for nitrate and nitrate nitrogen; and ferrous sulphate heptahydrated for nitrite.

Statistical Analysis

Analysis of variance (ANOVA) was used to determine the effects of seasons (dry and rainy seasons) on the different physico-chemical variables. Statistical analyses were carried out at the 5% significance level using *STATISTICA* software version 7.1.

Results

The annual and seasonal mean values of the physico-chemical parameters at the Taabo station are given in Table 1 and the monthly variations are shown in Fig. 2.

Hydrogen Potential (pH)

The pH values vary little from December to April, ranging from 6.69 to 7.03, before rising to 8.84 in May. A drop is then observed in June (7.9) and July (6.67) where the lowest value was recorded.

This parameter shows no significant seasonal variation ($p > 0.05$). However, the average of the rainy season is higher (7.36 ± 0.84) than that observed in the dry season (7.08 ± 0.72).

Table 1. Annual and seasonal mean values of physico-chemical parameters in the Taabo dam lake.

Parameters	Averages		
	Annual		Seasonal
pH	7.22 ± 0.76	Ds	7.08 ± 0.72
		Rs	7.36 ± 0.84
Dissolved oxygen (mg/l)	5.82 ± 1.56	Ds	5.81± 1.26
		Rs	6.24 ± 1.87
Conductivity (µS/cm)	91.71 ± 22.01	Ds	104.16 ± 21.55*
		Rs	79.26 ± 15.6*
Dissolved Solids (mg/l)	47.21 ± 9.36	Ds	51.98 ± 10.72
		Rs	42.45 ± 4.83
Temperature (°C)	28.6 ± 0.81	Ds	29.02 ± 0.69[a]
		Rs	28.28 ± 0.89[a]

Ds: dry season Rs: rainy season * Significant at $p < 0.05$

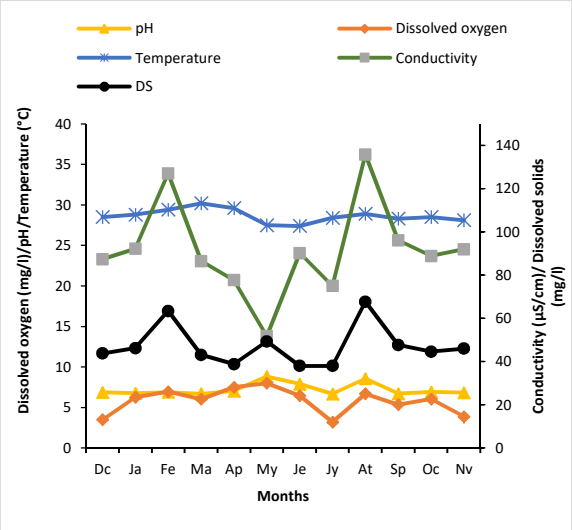

Fig. 2. Monthly variations of physico-chemical parameters of Taabo dam lake.

Dissolved oxygen

The highest value was recorded in May (8.01mg/l), while the lowest was in July (3.2mg/l). The dissolved oxygen content observed during the seasons indicates a higher value in the rainy season (5.85 ± 1.93mg/l) than in the dry season (5.80 ± 1.26mg/l). The difference observed between the seasons is not significant ($p > 0.05$).

Conductivity

The evolution of conductivity shows two important peaks: one in February (127µS/cm) and the other in August (135.8 µS/cm). The lowest value for this parameter was reached in May with 51.80µS/cm. The conductivity observed in the dry season (104.16 ± 21.55 µS/cm) is higher than that recorded in the rainy season (79.26 ± 15.6µS/cm). Statistical analysis showed that this difference is significant ($p < 0.05$).

Dissolved solids (DS)

The evolution of the dissolved solids rate shows a similar pattern to that of the conductivity. The highest level was measured in August with 67.7mg/l. The lowest level was recorded in June and July (38mg/l). The dry season has the highest TDS value (51.98 ± 10.72) and the rainy season the lowest (42.45 ± 4.83). The ANOVA did not show any significant difference between the seasons.

Temperature

The highest temperature was recorded in March (30.2°C) and the lowest in June (27.4°C). Regarding the seasonal variation of this parameter, no significant difference was found by statistical analysis between the rainy and dry seasons. Nevertheless, the highest average temperature was observed in the dry season (29.02 ± 0.69°C).

Ionic compounds

The monthly variations of ionic compounds at the Taabo station are shown in Figs. 3 and 4 and the annual and seasonal mean values o are given in Table 2.

Table 2. Annual and seasonal mean values of ionic compounds in Taabo dam lake.

Parameters (mg/l)	Averages Annual		Seasonal
PO_4^{3-}	0.05 ± 0.07	Ds	0.05 ± 0.08
		Rs	0.05 ± 0.08
NH_4^+	0.14 ± 0.12	Ds	0.14 ± 0.12
		Rs	0.14 ± 0.13
NO_3^-	1.44 ± 1.11	Ds	1.6 ± 0.98
		Rs	1.28 ± 1.29
NO_3^--N	5.68 ± 5.25	Ds	6.65 ± 5.03
		Rs	4.71 ± 5.75
NO_2^-	1.91 ± 1.16	Ds	1.66 ± 0.81
		Rs	2.16 ± 1.47

Ds: dry season, Rs: rainy season

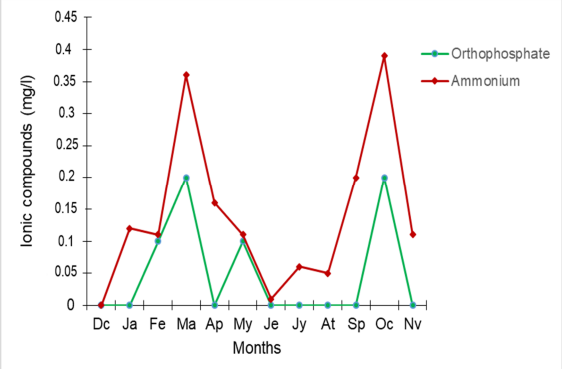

Fig. 3. Monthly variations of orthophosphate and ammonium concentration in Taabo Lake.

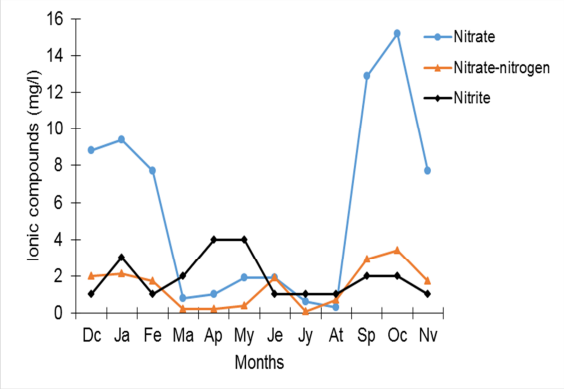

Fig. 4. Monthly variations of nitrate, nitrate-nitrogen and nitrite concentration in Taabo Lake.

Orthophosphate (PO_4^{3-})

The orthophosphate concentration shows two major peaks during the year in the reservoir. These peaks are recorded first in March (0.20mg/l), then in October (0.20mg/l). The concentration of this compound did not vary between the two seasons. It is 0.05 ± 0.08mg/l.

Ammonium (NH_4^+)

The highest ammonium concentrations are observed in March at 0.36mg/l and in October at 0.39mg/l. In December the concentration is zero and in June it is only 0.01mg/l. The concentration of ammonium in the dry season (0.14 ± 0.12mg/l) is equal to that observed in the wet season (0.14 ± 0.13mg/l).

Nitrates (NO_3^-)

The highest concentration of nitrate is recorded in October with a value of 15.02mg/l. The lowest content is recorded in August (0.30mg/l).

The nitrate-nitrogen (NO_3^--N) content of the Taabo lake water decreases from January (2.10mg/l) to March-April (0.20mg/l) before increasing slightly in June (1.90mg/l). In July, the nitrogen nitrate concentration drops to its minimum value (0.10mg/l). An increase in the concentration of this parameter is then recorded from August to October when the maximum (3.4mg/l) is reached. The seasonal mean values of the different nitrate compounds are higher in the dry season than in the rainy season. However, the differences observed are not significant.

Nitrite (NO_2^-)

The concentration of nitrite changes irregularly during the year. The highest concentration (4mg/l) is observed in April and May. The concentration then gradually decreases and stabilizes at the minimum value (1mg/l) from June to August. The seasonal mean values are 1.66 ± 0.81mg/l (dry season) and 2.16 ± 1.47mg/l (rainy season).

Discussion

The pH is a measure of the acid, basic or neutral character of water. The pH values measured in Lake Taabo range from 6.67 to 8.84 with an annual average of 7.22 ± 0.76. This result shows that the waters of this lake are slightly alkaline. Work by Aliko *et al.* (2010) showed that the waters of Taabo Lake have a pH between 6.29 and 7.23. The annual average recorded in this environment during our work is included in this interval. According to Iltis and Lévêque (1982), the pH is generally very weakly alkaline, with an average of 7.35 in the Bandama River basin. Seasonal variations in this parameter are related to the life cycle of organic matter. Indeed, the death of a large part of the aquatic plants in the lake occurs periodically. The decomposition of the biomass (macrophytes) brings 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. The drop in pH observed in the dry season would therefore be the result of an important process of decomposition of organic matter.

In the absence of decomposition of aquatic plants, the pH of the water would tend to increase (González *et al.*, 2004; Ekou *et al.*, 2011).

The annual average dissolved oxygen measured in the surface layers of the waters of Taabo Lake is 5.82 ± 1.55mg/l. This value is higher than those noted by Kouassi *et al.* (2007) and Aliko *et al.* (2010) in the same environment (3.85mg/l to 5.30mg/l). The oxygen levels recorded in the surface zones are due to the photosynthetic activities of the phytoplankton, which generally take place with greater intensity in these zones due to the high light penetration (Kouassi *et al.*, 2007). Variations in dissolved oxygen levels are influenced by a number of factors including wind, stream depth, current velocity and the presence of reducing deposits (Matthes, 1964). Other authors, such as Durand and Guiral (1994), have reported that the level of dissolved oxygen in the water is also dependent on exchanges with the atmosphere, which are favoured by the agitation of the water, which is itself a function of wind, tide and currents.

The results indicate that the water in Taabo Lake has a higher conductivity in the dry season (104.16 ± 21.55µS/cm) than in the rainy season (79.26 ± 15.6µS/cm) with an annual average of 91.71 ± 22.01 µS/cm. Our results are similar to those obtained in Lake Buyo by Ossey *et al.* (2008). These authors observed mean values ranging from 47.50µS/cm to 102.20µS/cm. According to Edia (2008), seasonal fluctuations in conductivity are likely to be an implication of the seasonality of the concentration of mineral salts as these elements are responsible for the mineralisation of water and therefore its conductivity. Since conductivity and dissolved solids content are two positively correlated parameters, the observations made on conductivity apply to dissolved solids content. Welcomme (1985) indicates that in a natural environment, variations in water conductivity and dissolved solids are influenced by a number of factors including rainfall, evaporation and substrate type. Further work by N'Goran (1989) showed that during the dry season, evaporation combined with lack of water supply, causes an accumulation of ions

that would increase conductivity. This could explain the increase in conductivity and TDS observed in the dry season in the waters of Taabo Lake.

The monthly water temperature values for Lake Taabo range from 27.4°C to 30.2°C. These data are of the same order of magnitude as those recorded by Yté *et al.* (1996) and Ossey *et al.* (2008) in the Buyo dam lake and by Brunel and Bouron (1992) in Kossou lake. These authors gave temperature values varying between 25°C and 33°C. According to Iltis and Lévêque (1982), the temperature of Ivorian rivers rarely falls below 25°C. The water temperature is higher in the dry season than in the rainy season. These seasonal variations are small and the differences observed are not significant. Nevertheless, these variations can be linked, among other things, to the weather on the days when this parameter was measured. Indeed, various factors influencing variations in the temperature of water in aquatic ecosystems have been noted by Welcomme (1985). These include latitude, degree of insolation, substrate composition, precipitation, wind and especially plant cover.

Nitrogen and phosphorus compounds are considered indicators of trophic level and are likely to favour the development of macrophytes (Hadj *et al.*, 2008). Orthophosphate is an important parameter in the fertilization of water bodies and plays an important role in plankton growth (Martin, 1987). It is a relevant indicator for assessing the trophic level of waters (Mama *et al.*, 2011). According to these authors, the majority of phosphorus inputs come from point sources: urban or industrial discharges, animal waste from traditional or industrial livestock farms, and leaching water following rainfall in the river catchment. The concentration of orthophosphate in Lake Taabo is 0.05mg/l. The values of this compound are much lower than those obtained by Lozo *et al.* (2019) in Kossou Lake (2.15mg/l). Iltis and Lévêque (1982) report orthophosphate levels in the transitional equatorial regime ranging from 0.01 to 1mg/l. Phosphorus is an essential nutrient for plant growth; however, above a certain concentration and under favourable conditions, it can cause excessive growth of algae and higher aquatic plants. This may be followed by an accumulation of plant biomass and detritus, which generally leads to a degradation of water quality (Ekou *et al.*, 2011). Levels above 0.5mg/l should be a pollution index (Ahonon, 2011).

Nitrates (NO_3^-) and nitrites (NO_2^-) are naturally occurring ions in the environment. They are the result of nitrification of the ammonium ion (NH_4^+), present in water and soil (Chaussée, 2003). Among the nitrogen compounds, the highest concentration is nitrogen nitrate (5.68 ± 5.25mg/l). According to Groga (2012), Taabo Lake is a water reservoir whose catchment area is dominated by agricultural areas which are probably the main source of nutrients after leaching from fertiliser-enriched croplands during rainy periods. The nitrate concentrations obtained in the present work are well below those given by the Nitrate Directive (11.30mg/l) as an indicator of freshwater pollution (Ekou *et al.*, 2011).

Conclusion

The study of the physico-chemical parameters of Taabo Lake showed that the pH is 7.22±0.76 and that the lake water is oxygenated (5.82±1.55mg/l). The conductivity was 91.7±22.01 µS/cm and the dissolved solids level was 47.21±9.36mg/l. The water temperature was 28.6±0.81°C. The seasonal values recorded are not significantly different. The ionic composition showed nitrate nitrogen ($NO3^-$-N) concentrations of 5.68±5.25mg/l and 1.91± 1.16mg/l for nitrite (NO_2^-). These values are nevertheless below those given by the nitrate directive (11.30mg/l) as an indicator of freshwater pollution. The concentration of orthophosphate (PO_4^{3-}) is 0.05 ± 0.07mg/l. This value indicates that the waters of Taabo Lake are of a low trophic level.

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