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RESEARCH ARTICLE

ESTIMATION OF CHLOROPHYLL *a* CONTAINED IN PHYTOPLANKTON FROM BAYS OF ABIDJAN EBRIE LAGOON - CÔTE D'IVOIRE

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ABSTRACT

The present work is focused on the evaluation of Chlorophyll *a* contained in phytoplankton from some bays of Abidjan district (Ebrie lagoon, Côte d'Ivoire). The sampling campaigns took place on August and October 2016. The study was interested successively in the physicochemical characterization of bays of Ebrie lagoon system, and the quantification of Chlorophyll *a* in order to evaluate the trophic state of these bays. Physicochemical parameters studies have shown a significant variation of temperature, conductivity and salinity. The determination of chlorophyll *a* concentration yielded values that vary between 0.26 µg.l^{-1} and 25.16 µg.l^{-1}. The highest levels of chlorophyll *a* are observed about Koumassi stations: Koumassi 1 (15.84 µg l^{-1}), Koumassi 2 (17.89 µg.l^{-1}) and Koumassi 3 (25.16 µg.l^{-1}), located in Koumassi Bay. Thus, bays could be reunited into three trophic classes: Cocody, Marcory and Anna bays are apparently ultra-oligotrophic; those of Yopougon, Azito, Bietry and M'badon are mesotrophic, and the others (Banco and Koumassi) are eutrophic.

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INTRODUCTION

With an area of 566 km^2, Ebrie Lagoon stretches for 125 km along the Ivorian coast of the Gulf of Guinea, between 3°40 'and 4°50' west longitude and 5°20 'north latitude. Salinity of the environment is maximum in the dry season, from January to April; it is minimal during the flood of comoe river, which is Ebrie lagoon main affluent (August to November). This salinity varies according to the proximity or distance of the artificial channel of Vridi, in Abidjan, which constitutes the only permanent communication between the lagoon and ocean. It can reach 25 to 30% on march in the area closest to vridi canal and be close to zero in the eastern part on september when flood of affluents. Water temperature (28 to 29 ° C on average) is always higher of 2 to 3 °C than those of air. Ebrie lagoon system has experienced an increased deterioration of the quality of its water in recent decades (Yao *et al.,* 2009) associated with excessive wastewater spill into the natural environment without any preliminary treatment (Arfi *et al.,* 1981; Haskoning, 1999). These deposits of biodegradable compounds cause intense eutrophication phenomena, especially in areas with low turnover rates (Pagès *et al.,* 1980; Zabi, 1982) such as bays.

Numerous recent studies have been carried out to determine the physicochemical characteristics of Ebrie lagoon system (Kouassi *et al.,* 2005; Inza and Yao, 2015) and particularly bays (Yao *et al.,* 2009). Nevertheless, these studies don't include data on chlorophyll *a*, present and predominant in all microalgae (Kim and Travers, 1995). At the present state of knowledge, the work of Pagès *et al.,* (1979), Dufour (1984), Iltis (1984) and Seu-anoï *et al*. (2013) take into account chlorophyll *a* in determining the trophic status of Ebrie lagoon system. However, studies driven by the first authors quoted, covered the entire Ebrie lagoon system including some bays. The results of their works also date back more than three decades. There is therefore a need to update the data. As far as concerned Seu-anoï *et al.,* (2013), they worked in fields other than bays. Therefore, very little data are available about chlorophyll *a* quantification in Ebrie lagoon bays, which is threaten by industrial spills and domestic wastewater; hence the interest of this work. The objective of this study is to evaluate the trophic state of certain bays of Ebrie lagoon system, based on chlorophyll *a* contained in phytoplankton.

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MATERIAL AND METHODS

Location of sampling stations

The study was carried out in the urban area of Ebrie lagoon on August and October 2016. The water samples were taken from eleven (11) stations (Table 1) spread over nine (9) bays which are Azito Bay, Yopougon Bay, Banco Bay, Bietry Bay, Cocody Bay, Marcory Bay, M'badon Bay, Ana Bay and Koumassi Bay.

Table 1. Geographical coordinates and codes of the different sampling stations

Stations	Station codes	GPS coordinates	
Azito bay	Az	05°17.821N	04°04.740W
Yopougon bay	Yo	05°18.316N	04°03.917W
Banco bay	Ba	05°19.691N	04°01.969W
Bietry bay	Bi	05°16.752N	04°00.098W
Cocody bay	Co	05°19.677N	04°00.833W
Marcory bay	Ma	05°19.677N	04°00.833W
M'Badon bay	Mb	05°19.955N	03°55.737W
Anna bay	An	05°19.166N	05°54.007W
Koumassi 1 bay	Ks1	05°17.882N	03°56.090W
Koumassi 2 bay	Ks2	05°16,863N	03°55.719W
Koumassi 3 Bay	Ks3	05°16.457N	03°55.801W

Sampling

Chlorophyll *a* samples were taken at 0.5 m and 1m from the surface using a 2L Niskin bottle. They are collected with 0.5-liter polyethylene bottles covered with aluminum foils and labeled. A total of 44 samples were collected during these two seasons between half past 7 a.m. and half past 1 p.m. Transport of sampling bottles was carried out by a cooler containing frozen dry ice at Central Environmental Laboratory of the Ivorian Antipollution Center. In parallel with the sampling of chlorophyll *a*, pH, temperature, salinity, transparency and conductivity of lagoon water were measured in situ with a YSI 6920 digital display multi-parameter. Transparency was determined using a Secchi disk.

Laboratory analysis

Chlorophyll *a* analyses were conducted at Central Environmental Laboratory of the Ivorian Antipollution Center. These analyses were focused on water samples filtered on Whatman fiberglass type GF/C filters (Millerioux, 1975), with a diameter of 47 mm. Volume of filtered water is about 200 ml (Kim and Travers, 1995). Algae containing Chlorophyll *a* are kept on these filters. Filters are placed in aluminum foil and stored in a freezer at -20°C for 2 weeks (Holm-Hansen and Rieman, 1978). The extraction of chlorophyll *a* was made with 90% acetone (Millerioux, 1975). Absorbance measurements were performed on crude extract (non-acidified) using a spectrophotometer of HACH DR 6000 type. The wavelengths retained were: 750 nm, 663 nm, 645 nm, 630 nm, 430 nm and 410 nm (Scor Unesco, 1966, Rodier *et al.,* 2009). The amount of chlorophyll *a* was determined according to Scor UNESCO method (1966) by the following formulas:

$$C = [11.64 (A_0663 - A_0750) - 2.16 (A_0645 - A_0750) + 0.10 (A_0630 - A0750)] v / l. V$$

$$ID = (A_0430 - A_0750) / (A_0410 - A_0750)$$

$$P = 59.0 + 137.6 \ln ID$$

$$Chl\ a = C. P / 100$$

$$Pa = C - Chl\ a$$

With; C (µg.l-1): the crude concentration of chlorophyll a;

ID: the degradation index of chlorophyll;

P: percentage of chlorophyll a in the sample;

Chla (µg.l-1): chlorophyll concentration was adjusted by means of a trichromatic equation;

Pa (µg.l-1): concentration in pheopigments index. A0750, A_0663, A_0645, A_0630, A_0430, A_0410, the respective absorbances of the extract at wavelengths 750 nm, 663 nm, 645 nm, 630 nm, 430 nm and 410 nm.
v: the volume (in ml) of acetone used.
V: the volume (in l) of filtered sample.
l: the optical path of the measuring vessel (in cm).

Data processing

Various tables were produced using Excel 2010 software.
As far as concerned STATISTICA 7.1 software, it allowed to perform the ANOVA test to compare the variability of chlorophyll *a* rate from the different bays.

RESULTS AND DISCUSSION

Physicochemical parameters

Average, minimum and maximum values of transparency, temperature, pH, electrical conductivity and water salinity are given in Table 2.

Table 2. Average values of physicochemical parameters

Parameters	Transp (m)	T (°c)	pH	Cond ($\mu S.cm^{-1}$)	Sal (‰o)
Average	0,83	27,35	6,93	15237,27	10,60
Mini	0,5	24,33	6,60	2465	1,24
Max	1,25	28,41	7,41	32378,5	20,61

Transp: transparency; T: temperature, pH: hydrogen potential; Cond: conductivity; Sal: salinity

Yopougon and Anna stations have the lowest transparency value (0.5 m). The highest value of transparency is observed at Azito and Banco stations (1.25 m). pH tells us about the alkalinity, neutrality or acidity of the water. It varies significantly from a station to another. Koumassi 2 and Koumassi 3 stations have the highest pH value (7.41). The lowest value (6.60) was observed at Yopougon Station (Figure 1). The lowest temperature of water was recorded about Banco station (24.33 ° C). M'badon station has the highest value (28.41 ° C). Salinity has the highest value (20.61% o) about Azito station, while Anna station has the lowest value (1.24% o) (Figure 2). Water temperature range from 24.33 °C to 28.41 ° C. Results (25 °C to 28 °C) were obtained by Kouakou *et al.,* (2008) about Grand-Lahou lagoon. Kouassi *et al.,* (2005) obtained temperatures between 26 °C and 27 °C during periods of flood and rainfall. According to these authors, low temperatures are due to the rise to surface, of deep cold waters about the coast (coastal upwelling). About waters studied, pH has values between 6.60 and 7.41. Kambire *et al*. (2014) obtained pH values between 6.96 and 7.8 about Aby lagoon.

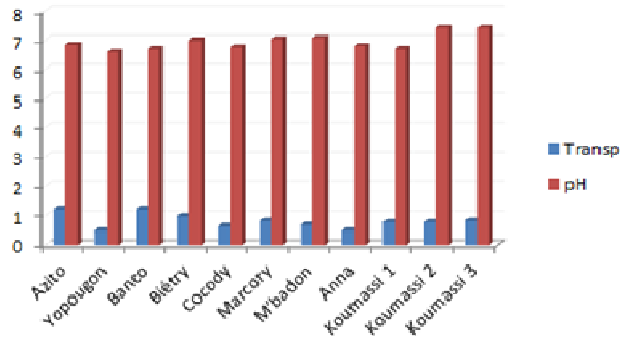

Figure 1. Variation of transparency and pH about stations

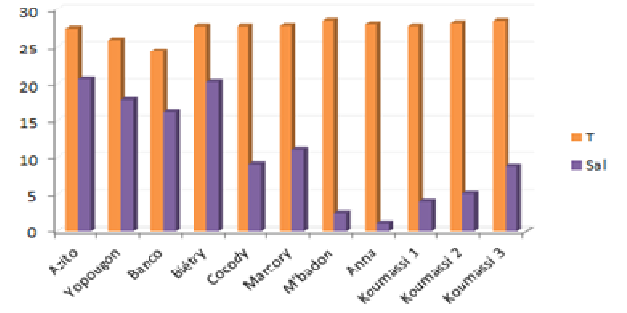

Figure 2. Variation of temperature and salinity about stations

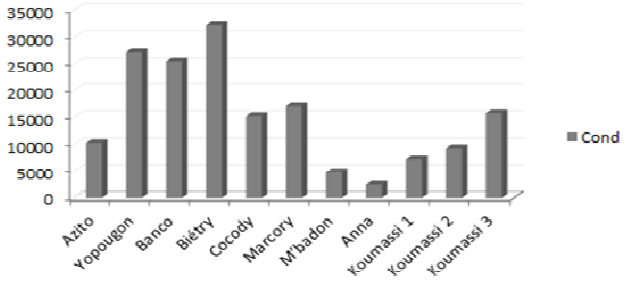

Figure 3. Variation of conductivity about stations

Values of 7.1 and 8.3 were recorded by Inza *et al.,* (2009) about Ebrie lagoon. The low values recorded are due, on the one hand, to high proportion of river or meteorological water, and on the other hand, to the processes of degradation and mineralization of organic particles (Yao *et al.,* 2009). Conductivity oscillates between 2465µS.cm^{-1} and 32278µS.cm^{-1}. These results are greater than those of Kambire *et al.,* (2014) between 705.2 and 2440.7 µS.cm^{-1} about Aby lagoon. This situation could be due to the entry of marine water into Ebrie lagoon via Vridi canal. Salinity is an indicator of origin of water. It has average values (1.24% o to 20.61% o). The results of this study are comparable to those of Seu-anoï et al. (2013) (0-27.5%) about Ebrie lagoon. High values of salinity were recorded on August about Yopougon (35.4% o), Azito (33.17% o), Biétry (32.86% o) and Banco (29, 77% o) bays. This could be explained by their proximity to Vridi canal. Indeed, the extension of Vridi canal has favored massive entry of marine water into lagoon under the effect of wind and high tide.

Content of chlorophyll *a*

The average, minimum and maximum concentrations of chlorophyll *a* analyzed at 0.5 and 1m during the sampling periods about the different stations are given in Table 3.

Table 3: Average, minimum and maximum values of chlorophyll *a* at 0.5 m and 1m deep

Parameters	Chl*a* $_{(0,5\ m)}$ (µg.l^{-1})	Chl*a* $_{(1m)}$ (µg.l^{-1})
Average	7,84	3,30
Mini	0,26	0,41
Max	25,16	11,23

The highest value of chlorophyll *a* at 0.5 m was observed about Koumassi 3 station (25.16 µg l^{-1}) and the lowest one about Marcory station (0.26 µg l^{-1}). Chlorophyll *a* at 1 m deep has the highest value (11.23 µg l^{-1}) about Koumassi 3 station, while Marcory station has the lowest value (0.41 µg.l^{-1}) (Figure 4).

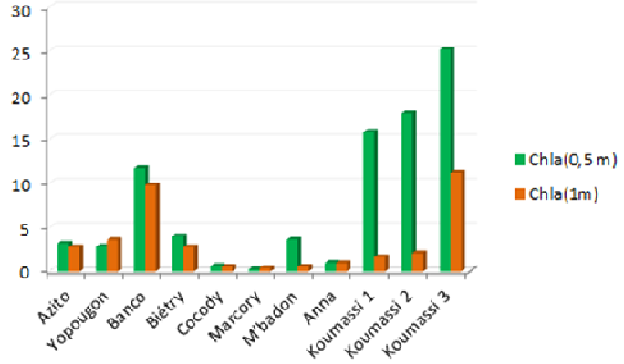

Figure 4. Graph of average values of chlorophyll *a* about stations

Chlorophyll *a* values vary between 0.26µg.l^{-1} and 25.16µg.l^{-1}. Eltis (1984) recorded values between 0.9 and 28.4 µg.l^{-1} about Ebrie lagoon. Seu-anoï *et al.,* (2013) gave values between 0 and 22 µg.l^{-1} about Ebrie lagoon. During the upwelling of Goree Bay (Senegal), Toure (1983) found chlorophyll *a* values between 0.5 µg.l^{-1} and 15 µg.l^{-1} about surface area of upwelling. Levels between 6 and 20 µg.l^{-1} were recorded by Kim and Travers (1995) about the pond of Berre in the Mediterranean.

Table 4: Trophic status classification according to the OECD study (1982)

Level of trophy	Total P	Average Chl	Maximum Chl	Average Secchi	Minimum Secchi
Ultra-oligotrophic	< 4,0	< 1,0	< 2,5	> 12,0	> 6,0
Oligotrophic	< 10,0	< 2,5	< 8,0	> 6,0	> 3,0
Mesotropic	10 - 35	2,5 - 8	8 - 25	6 - 3	3 – 1,5
Eutrophic	35 - 100	8- 25	25 - 75	3 – 1,5	1,5 – 0,7
Hypereutrophic	> 100	> 25	> 75	< 1,5	< 0,7

Legend: Total P = annual average of total phosphorus concentration (µ /l). Average Chl = average annual concentration of chlorophyll a in surface water (µg/l). Maximum Chl = maximum annual concentration of chlorophyll a in surface water (µg/l). Average Secchi = average annual depth of transparency of Secchi disk (m). Minimum Secchi = minimum annual depth of transparency of Secchi disk (m).

Evaluation of the trophic state of bays

The concentration range of chlorophyll *a* varies according to the trophic state of the field. The International Cooperative Freshwater Monitoring Program of OECD (1982) has set limit values for chlorophyll *a* concentrations (Table 4). Considering the limit values of trophic categories indicated above and taking into account chlorophyll *a* concentrations at 0.5 m, bays can be grouped into three trophic classes (Table 5):

Table 5. Classification of the trophic status of bays according to the level of chlorophyll *a*

Bays	Average Chl*a* ($\mu g.l^{-1}$)	Average Chl*a* limit ($\mu g.l^{-1}$)	Levels of trophy
Cocody	0,63		
Marcory	0,26		
Ana	0,98	< 1,0	Ultra-oligotrophic
Biétry	4,01		
Azito	3,20		
Yopougon	2,84		
M'badon	3,61	2,5 – 8	Mesotrophic
Banco	11,72		
Koumassi	19,63	8- 25	Eutrophic

- Bays with ulta-oligotrophic waters: Cocody, Marcory and Anna bays;
- Bays with mesotrophic waters: Yopougon, Azito, Bietry and M'badon bays.
- Bays with eutrophic waters: Banco and Koumassi bays.
- Several factors could explain the trophic state of Ebrie lagoon bays waters system.

The apparently ultra-oligotrophic state of Cocody and Marcory bays waters is due to a phenomenon of sedimentation of phytoplankton coupled with the excessive organic pollution of these bays. This situation furthers the consumption of oxygen in such a way that the hypolimnion of these bays has become anoxic with the production of hydrogen sulphide. These conditions may inhibit growing of phytoplankton in these bays. The low chlorophyll *a* level of Anna Bay waters is thought to be related to low photosynthetic production and dilution by inland waters (Dufour 1984). The mesotrophic state of Yopougon, Azito and Bietry bays water is due to the high salinities that would affect the growth of certain phytoplankton species of freshwater which could be sensitive. Indeed, Iltis (1984) and Seu-anoï *et al.,* (2013) showed the presence of freshwater phytoplankton algae Ebrié lagoon, in the urban area of Abidjan. The eutrophic status of Banco and Koumassi bays water is believed to be related to higher photosynthetic production and lower dilution by inland and marine waters. ANOVA test ($p < 0.05$) shows that there is no significant variation about chlorophyll *a* levels between different bays. However, Marcory bay has the lowest value of chlorophyll *a* ($0.26 \mu g.l^{-1}$) and the highest one is recorded about Koumassi bay ($19.63 \mu g.l^{-1}$).

Conclusion

This work focuses on the estimation of chlorophyll *a* levels in phytoplankton about some bays in Abidjan district (Ebrie lagoon, Ivory Coast). The physicochemical characterization of these bays water of this lagoon system shows that water temperature is above 24 °C. pH is between 6.60 and 7.41. As far as concerned salinity, it is high about Bietry and Azito bays. The quantification of chlorophyll *a* in phytoplankton allowed estimating its levels in bays. The average values of chlorophyll *a* of the whole bays oscillate between 0.26 $\mu g.l^{-1}$ and 25.16 $\mu g.l^{-1}$ over the sampling period considered. The highest levels of chlorophyll *a* are observed in Koumassi 1 ($15.84 \mu g.l^{-1}$), Koumassi 2 ($17.89 \mu g.l^{-1}$) and Koumassi 3 ($25.16 \mu g.l^{-1}$) stations, in Koumassi Bay. However, there is no significant variability of chlorophyll *a* levels between different bays. Chlorophyll *a* levels in phytoplankton were used to evaluate the trophic status of bays.

Thus, water of bays can be grouped into three trophic classes: bays with apparently ultra-oligotrophic waters which concern Cocody, Marcory and Anna bays, mesotrophic bays which are represented by Yopougon, Azito, Biétry and M'badon bays and bays with eutrophic waters that are Banco and Koumassi bays.

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