Assessment of the Trophic Status of the Lagoon-bay of Tiagba in Côte d’Ivoire

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Abstract: The phenomenon of eutrophication was investigated on a period of two years (August 2007 -July 2009) in the lagoon-bay of Tiagba. Throughout this investigation, the bay showed a basic character, a very low salinity (1.82 ± 0.5) mg/L and a weak conductivity (3.34 ± 0.68) mS/cm. The hydrosystem and the growth of anthropogenic activities on its hillsides particularly favored the high rate of phosphorus (0.36 ± 0.22) mg/L and nitrogen (0.46 ± 0.12) mg/L. Consequently, a high chlorophyll-a (43.34 ± 19.33) μg/L, a low transparency (0.66 ± 0.07) m and a high suspended matters rate (28.87 ± 7.56) mg/L were observed. The trophic status determination, based on three conventional classifications showed that the lagoon bay of Tiagba was in hypereutrophication state. From The monthly observation of hydrochemistry it can be noted a constant hydro eutrophic characteristics of the bay.

Key words: eutrophication, lagoon-bay of Tiagba, phytoplankton, nutrients, water quality, Côte d’Ivoire

INTRODUCTION

Eutrophication is considered one of the major threats to the health of marine ecosystems and one of the relevant research topic today (Hermann JL, 2010; Nyenje, PM, 2010; Marieke M, 2010; Abigail, Mc-G, 2009; Jonne, K, 2009; Smith, V.H., 2009; Istvánovics, V., 2009; Javier, L and M. Arnaldo, 2009; Kim, N.I. and P.M. Thomas, 2009; Giordani, G, J.M. Zaldivar and P. Viaroli, 2009; Edna, G., W. Martin and S.S. Paulo, 2008; Javier, L., M. Arnaldo, M-G. Lázaro, 2008; Painting, S.J.; 2007; Kouassi, A.M., 2005; Mama, D., G. Ado and B. Yao, 2003; Lothe, A., 2000). This phenomenon is due to excessive nutrients in a lake or other body of water, usually caused by runoff of nutrients (animal waste, fertilizers, sewage, etc.) from the land, which causes a dense growth of plant life. The decomposition of the plants depletes the supply of oxygen, leading to the death of animal life (Mama, D., G. Ado and B. Yao, 2003; Lothe, A., 2000; Stoianov, I, S. Chapra and C. Maksimovic, 2000). In other words, it has disastrous consequences on the entire ecosystem such as loss of biodiversity, health risks for both man and beast, hindrance of the anthropogenic activities, etc. the struggle against this phenomenon is generally based on the trophic status of the system considered. Many conventional classifications of the trophic status have been developed. Though diverse, some of them establish clearly the trophic state of surface waters, providing at the same time ways to fight the threat.

The Ebrié system has been under study for many years and it appears favorable to the phenomenon of eutrophication; the lagoon-bay of Tiagba in particular. The previous research was led twenty years earlier on the whole system by Carmouze and Caumette (Carmouze, J.P and J.P. Caumette, 1985) and it revealed that the lagoon-bay is part of the strip with the highest bio-carbonate nutrients. So this bay is vulnerable to the phenomenon of eutrophication. Knowing its socio-economic value for Côte d’Ivoire, it is important to constantly check the pollution rate in order to guaranty its tourist attraction as well as its biodiversity.
MATERIAL AND METHODS

Localization and Morphologic Characteristics of Research Sphere:

Tiagba is a lake village and commune in the Ébrié Lagoon of Côte d’Ivoire, known for its traditional houses built on stilts. It is also a prime tourist attraction in Côte d’Ivoire because of its individuality. The lagoon-bay of Tiagba is located in the far-west of the Ébrié system (4°40’ and 4°45’ longitude west and 5°20’ latitude north). It is a large (11.50 km²), shallow (mean depth, 2.9 m) lagoon, with water volume estimated at 3.35 $10^6$ m³ and a maximum and minimum length respectively of 4.11 and 3.69 km. The catchment basin is about 135 km². The bay of Tiagba communicates with the waters of the central Channel and the lagoon-bay of Cosrou. This system presents two channels: “Passe de Cosrou” on its South-East and “Passe de Chenal central” on its South. It is about 4.70 m deep with a maximum length of 0.39 km; which correspond to a section of 1.833 m². That channel is not deep (1.30 m about) with 0.20 km length; or an average section of 260 m². The lagoon-bay of Tiagba is like all the Ébrié system. The general form of the basin, the depth and the partitioning of the shores affect the ecologic evolution of the whole system. The ratio Area/Volume is high and enhances exchange between water and air and between water and sediment. So the whole water is affected by surface turbulence; which reduces vertical gradients and accelerates exchange between water and sediment, thereby increasing the turbulence. The lagoon-bay of Tiagba is far from Vridi Channel (80km) that constitutes the single entrance of sea-water in the Ébrié system, so it undergoes little sea influence. The tides are very low with currents rarely exceeding 0.1 to 0.2 m s⁻¹ (Dufour, Ph., J-J. Albaret, J.R. Durand et D. Guiral, 1994). So its renewal rate is linked to rainfall (meteorite runoff and fluvial contributions). On that coastline of Côte d’Ivoire, the climate is characterized by a long and a short rainy-season (respectively may-July and October), and a long and short dry season (respectively in December-April and august). The direct contributions of meteorite runoff waters are important in rainy-seasons. Water stream contributions essentially provide on the one hand from the river Bandama, characterized by an annual flood (from September to October) and pours into the lagoon of Grand-Lahou (A tiny part reaches the bay of Tiagba through the Channel of Assagny), and on the other hand from the river Ira, located in the coastline area and characterized by annual floods (the first and most important in June and the second in October). It pours in the bay of Cosrou through which, it reaches the lagoon-bay of Tiagba during the annual floods. The bad renewal is partly due to the small area of the coastline of the river Ira and the low contribution in water of the river Bandama. The localization and some characteristics of that lagoon-bay are illustrated by Fig.1. The anthropogenic activities of its coastlines are dominated by agriculture. This bay receives domestic and agricultural wastes because of the lack of sanitation systems on the drainage basin.

Fig. 1: Geographic localization of the lagoon-bay of Tiagba in the Ébrié system
Sampling:
The campaigns were led on a two years period (August 2007 and July 2009). During that period, monthly research assignments were performed; a total of 24. Five stations were considered for the sampling as indicated in Fig. 2. They were chosen taking into account the soils occupation and their fluvial relationship contributions on the bay.

The water samples were taken with 1 or 2 liters Niskin container. The collection, the analysis and the conservation of the samples depended to the analysis to be performed in lab. In fact, for chlorophyll a, after pre-filtering with silk linen of 60 μm diameter, the sample was filtered again on a micro-glace filter of 0.47 μm diameter. Then, the micro-glace filter is kept at 4 °C away from light. D.O in the samples was fixed with manganese sulphate (MnSO₄) and a reactive solution containing iodide potassium (KI) or sodium (NaI) combined whether with potassium hydroxide (KOH) or sodium hydroxide (NaOH). The bottles containing the samples were then kept in water at ambient temperature. To determine SM, TP and TNK, samples were directly taken in 1 liter polyethylene flasks and stored at 0°C in an ice chest.

Physicochemical Parameters:
The physicochemical parameters such as temperature, pH, conductivity and salinity were determined in situ by using a portable multi parameter WTW pH-cond 340 i while transparency was determined by using a Secchi disk. Dissolved Oxygen (D.O) was performed according to AFNOR NF EN 25813 ISO 5813 (AFNOR NF T 90-141 1993). Suspended Matters (SM) was assessed according to AFNOR NF T 90-105. (AFNOR NF T 90 105. 1978). Total Nitrogen (TN) was performed according to the method of Kedjahl suggested by the AFNOR T 90-110. (AFNOR NF T 90-110. 1981), while the chlorophyll a was assessed by AFNOR T 90-117 (AFNOR T 90-117. 1999). For these two last parameters, a spectrophotometer UV-V Jasco 530 i was used.

Fig. 2: Sampling stations

Statistical Methods:
Standard deviation (SD), mean, and variation coefficient (VC) were performed by using STATISTICA software (version 5.5).

RESULTS AND DISCUSSION

Results:
Physicochemical factors mean ± SD are represented in the tables 1 and 2. From these data, it can be noted that the average on the period of salinity is 1.82 ± 0.50 mg/L and the one of conductivity is 3.34 ± 0.68 mS/cm. these results show enough the remoteness of the bay from Vridi Channel that constitute as mentioned previously, the unique water entrance in Ebrié system. In these conditions, the bay is under little sea-influence with low tides. The sea-influence reaches the maximum in dry season (January-April) and in early rainy-season (May). This provokes a light increase in salinity and conductivity from January to May; except in March when water flow from early rains provoke a light increase in conductivity. In April and May respectively, conductivity and salinity reach the maximum (4.5 mS/cm) and (2.8 mg/L). On the hand, when there are floods in rainy season, rain-waters, floods from river Ira and Bandama (unsalted and little mineralized waters) provoke a desalination and a decrease in conductivity in June and December. This is more observable in July where both physicochemical parameters show minimal values as shown by Fig. 3A (2.2 mS/cm for conductivity and 1mg/L for salinity).
Table 1: Physicochemical parameters analyzed in situ from August 2007 to July 2009 in the lagoon-bay of Tiagba (mean ± SD).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salinity mg/L</td>
<td>1.82±0.50</td>
</tr>
<tr>
<td>Conductivity mS /cm</td>
<td>3.34±0.68</td>
</tr>
<tr>
<td>Temperature°C</td>
<td>29.59±1.49</td>
</tr>
<tr>
<td>pH</td>
<td>8.19±0.44</td>
</tr>
<tr>
<td>Redox potential (U) mV</td>
<td>32.8±7.88</td>
</tr>
<tr>
<td>Transparency m</td>
<td>0.66±0.07</td>
</tr>
</tbody>
</table>

Table 2: Physicochemical parameters analyzed in lab from August 2007 to July 2009 in the lagoon-bay of Tiagba (mean ± SD).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM mg/L</td>
<td>24.87±7.56</td>
</tr>
<tr>
<td>DO mg/L</td>
<td>6.30±0.56</td>
</tr>
<tr>
<td>TNK mg/L</td>
<td>0.46±0.12</td>
</tr>
<tr>
<td>TP mg/L</td>
<td>0.36±0.22</td>
</tr>
<tr>
<td>Chlorophyll a μG/L</td>
<td>43.34±19.33</td>
</tr>
</tbody>
</table>

M, suspended matters; DO, dissolved oxygen; TNK, total nitrogen according to Kedjahl; TP, total phosphorus.

Regarding the temperature during the whole period of study, its mean value is about 29.6 ±1.49 °C. The maximal value is observed during floods in October (31°C). The lowest temperatures are obtained during the rainy season i.e. in August (27.3 °C) due to cloud cover and marine upwelling, present along the entire coastline of the Gulf of Guinea (fig. 3B).

Referring to the chlorophyll a, it can be noted a high content (43.34 mg/L at least during the whole period of study) and a strong variation from one period to another (VC = 44.6%). The maximum values are reached in early flood season (September, 83.7 μg/L) and minimum ones in dry season (February, 18.6 μg/L). It is important to note that the rainfall inputs generate two opposing effects on the proliferation of phytoplankton. Indeed, the intake of nutrients via runoff from March to June Stimulate the proliferation of phytoplankton but the intake of humic acid through the flood of the river Bandama and Ira inhibit it from September December (Fig. 3B).

Moreover, dealing with U and pH, the means values during the period of study are 8.19 ± 0.44 for pH and -32.8 ± 7.88 mV for U. So the bay can be said to have basic and reduction characteristics taking into account the low variation coefficient (5.33 % for pH and 24.08 % for conductivity).

During floods, contributions of river Bandama and Ira (acidic and oxidizing waters) provoke a decrease in pH and U with changing amplitudes. In this period precisely in November, the reducing capacity shows minimal values (-26.6 mV). In early dry season (January-February), the decomposition of macrophytes drained in the bay by floods of the river Ira and Bandama, release acid components such as gallic, ellagic and tannic acids. This provokes decrease in pH particularly in February (7.5). That is the same for U which falls at -36.4 mV in January and -30 mV in February (Fig. 3C).

From table 2, it can be noted that the average dissolved oxygen (DO) in the water column was 6.36 ± 0.56 mg/L. this shows a good oxygenation. DO is enough in both dry and rainy seasons with maximum values (7.3 mg/L). Yet, river Bandama and Ira (poor in dissolved oxygen because of organic and humic acid components) provoke a decrease of oxygen during flood. In this period, dissolved oxygen shows annual minimal values in November of 5.2 mg/L as shown by Fig. 3D.

While considering SM and transparency during the study, the average of SM is 24.9 ± 7.56 mg/L. The average of transparency is 0.66 ± 0.07 m. The transparency (VC = 10.66%) is less variable than SM (VC = 30.42%). So, the bay shows turbulent characteristics like any brackish environment. The maximum value of SM is obtained in rainy-season (July 41.4 mg/L) and the minimum is in early dry season (January 17.2 mg/L). Transparency shows maximum values in dry season (February 0.56 m) and in flood times (October 0.81 m). The evolution of SM and transparency is globally regulated by rainfall. Meteorite runoff waters by leaching the soil carry directly SM to surface as particles. The latter progressively integrate the sediment via the water column and stimulate the growth of phytoplankton. Increase in SM can be observed in the water column from March to July, except in June (rainiest month) when dilution effects provoke a decrease. A contradictory increase of transparency with the content of SM in March and May is observed, while a logic increase of transparency with the decrease in suspended matters in June and July is noted. This can be explained by the repartition of the suspended matters in the water column. In fact, because of the meteorite runoff water contribution from the early rains, the suspended matters are more concentrated from March to May. On the other hand, the dissolution effects of the waters from that bay linked to the meteorite runoff water contribution denuded from suspended matters from June to July provoke a contradictory evolution of these physicochemical parameters.

During floods, the waters from river Bandama and Ira inhibit the phytoplanktonic increase because they contain less suspended matters and humic acid. So, the suspended matters fall when transparency grows from September to December, particularly in October when the floods from the two rivers jam.

In the months of low rainfall (January-February), the release of SM from sediments and decomposition of macrophytes, induce a loss of transparency. In this period, the suspended matters are more present in the epilimnion than the hypolimnion as well as the interface water sediment (Fig. 3E).
While considering the TNK and TP the means taken during the study are 0.36 ± 0.12 mg/L and 0.46 ± 0.22 mg/L respectively for the TP and TNK. So, the content of these two nutrients is very high on the bay. Although the physicochemical conditions are favorable to their release from sediments, the evolution of these two nutrients is mainly due to the pluviometric contributions. Runoff waters transport nitrogen in dissolution form and phosphorus in particles essentially. In addition, because of the humic and karstic characteristics of the bay of Cosrou and the Canal of Assagny, particles brought by river Bandama and Ira are retained. This partly explains the great variability of TP (CV = 62.41%) compared to the TNK (CV = 25.91%).

During floods (September-December) waters from river Bandama and Ira, poor in particles because of the humic and karstic characteristics of the Canal of Assagny and the bay of Cosrou, carry essentially dissolved phosphorus and nitrogen. That provokes the evolution of these nutrients with the same amplitudes. The meteorite runoff waters from the early rains (March-April) contain more nitrogen than the long rainy-season so that in April there is a peak of 0.7 mg/L. The opposite is observed for phosphorus with maximum value (1.1 mg / L) was obtained in June, the month of highest rainfall on the annual plan, and that of the first and largest flood of the river Ira.

When there is little rain, the evolution of these nutrients could be explain by their release from sediments and the decomposition of macrophytes brought during floods (January), but also by their great consumption by phytoplankton (August) (Fig. 3F).

In order to clearly determine the trophic status of the bay of Tiagba, three conventional classifications are used (O.C.D.E (Organisation de Coordination et Développement Economique), 1982; Walmsley, R.D and M. Butty, 1980; Thorton, J.A and W.K. Ndoku, 1982; Wood, G., 1975; Ministère du Développement Durable, de l'Environnement et des Parcs (MDDEP), 2006). From these classifications, it can be noted that the bay of Tiagba is at the ultimate stage of that ecologic threat i.e. a hypereutrophication state. This has to do with its hydrosystem which keeps nutrients in the waters. Hence, the anthropic impact cannot be denied (deforestation, growth of agro-industry and truck-farming, demographic growth etc). The monthly observation of hydrochemistry on that bay revealed constant hydro eutrophic characteristics.

Discussion:

This work, led on two years (August 2007-July 2009), confirmed the hydrochemical evolution on this bay essentially linked to rainfall and its low renewal rate and high capacity of retention. This implies its lacustrian characteristics. Tiagba lagoon bay is enough the remoteness from Vridi Channel (80 km), the unique water sea entrance in the Ebrié system. In these conditions, the bay is under little sea-influence with low tides. So, it is observed the weak concentrations of conductivity and salinity in this bay. These conditions are known to be favorable for the proliferation of macrophytes on the Ivorian mainland waters during seasons of flood.
(Guiral, D and E. N'da, 1994). Localized in tropical climate, this bay presents already temperatures superior to 20°C. These temperatures values are favorable to growth, reproduction of organisms (especially plankton development by its active role in photosynthesis) and microbial activities. In addition they provoke evaporation, dissolution of oxygen, chemical and biochemical reactions (Gunter G., 1967; Bowden, K.F., 1980; Day, JH., 1981), dissolution and dissociation of dissolved salts (Nixon, SW., 1990). Even though affected by the decomposition of macrophytes (Saito, K., 1989) and by the waters from river Bandama and Ira, pH is above 7 and U is below 0. The basic and reduction character of this bay are due essentially to the effects of the anoxic superficial sediments on the water column of the bay. During the study, values of these physicochemical parameters show a predominance of algal eutrophication on the one hand and on the other hand the release of phosphorus from sediments. As concerned DO, taking the classification of Beaupoil and Bornens (Beaupoil, C., P. Bornens, 1997) for reference, the bay of Tiagba contains enough oxygen due to its important surface exchange (11.5 km²). This supports good atmospheric oxygen dissolution. According to Konan et al., (2008), the surface of the water affects the DO because water is enriched mainly by contact with oxygen from the air. The low contribution in organic matters on the coastlines and its localization in a highly rainfall zone also favor a good oxygenation. Development of anthropogenic activities on the coastline and its hydrosystem favor the high presence of nitrogen and phosphorus. In fact, demographic growth, deforestation, growth of agro-industry and truck-farming contribute to soil erosion by rainfall. The runoff waters carry essentially phosphorus in particles and nitrogen in dissolved form in this lagoon-bay (Jordan, TF, J.W. Pierre and D.L. Correll, 1986; Jordan, TE, D.L. Correll, J. Mikas and D.E. Weller, 1991). These nutrients are kept in water column. This high presence of these nutrients favors the development of phytoplankton. That is confirmed by high content of chlorophyll a in this case study. Furthermore, that planktonic vegetation is dominated by seaweeds because of the pH conditions as well as nutrients content. The consequences of this situation are the low transparency and the relative SM high content of this bay. The bay shows turbulent characteristics like any brackish environment (Kouassi, A.M., 2005; Konan, K.S., 2008; Jordan, TF, 1986; Millet, B., 1984). The present-day trophic status of lagoon-bay of Tiagba is hyper-eutrophication, the pick of the development of eutrophication.

Conclusion:

Human’s pressures destroy Tiagba lagoon-bay. The hyper-eutrophication of the bay confirms its bad state. Then, ecological biodiversity and animal resources are endangered instead. This immediately affects human resources so that hydric diseases can be observed to the coastline inhabitants. The lack of modern healthcare facilities can also worsen that situation of sickness in the concerned areas. This bay plays a very important role in the development of Côte d’Ivoire. Consequently, it deserves a particular care from the authorities and this work can help reach such an objective.

REFERENCES


Ministère du Développement Durable, de l’Environnement et des Parcs (MDDEP), 2006. Réseau de surveillance volontaire des lacs ; Méthode, Québec.


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