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Study of Spatio - Temporal Variations of Physico - Chemical and Biotical Parameters Characterising the Quality of Ebrie Lagoon Water *(Ivory Coast)*

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Abstract

Pollution in the Ebrié lagoon in the urban area of Abidjan has increased in recent years. Antrophic activities in its watershed threaten the quality of its waters. The objective of this study is to make an inventory of the pollution level of the waters of the Ebrié lagoon in order to offer basic elements for urgent solutions. Monthly water samples were taken from the Koumassi, Vridi, Plateau, Cocody and Bingerville sites. Several parameters, namely temperature, pH, conductivity, nitrites, nitrates, phosphates, phosphates, and chlorophylls, were determined. The results show high water mineralization followed by low nutrient contents due to their assimilation for the development of phytoplantonic biomass. The average temperatures do not exceed 28°C, with pH values between 7-8. The chlorophyll-a levels, indicative of the eutrophication phenomenon, were compared with those of the evaluation grid of the Organisation for Economic Cooperation and Development (OECD), which shows that the waters of the Koumassi, Vridi and Bingerville sites are eutrophic, and those of the Plateau and Cocody sites are mesotrophic.

Keywords: Ebrié lagoon, trophic state, physico-chemical parameter, chlorophyll-a

INTRODUCTION

Pollutants have a negative impact on the environment and human health (Saxena et al., 2016). In recent years, water quality has deteriorated significantly due to uncontrolled industrial discharges, the intensive use of chemical fertilizers in agriculture and the disorderly use of water resources. This situation is all the more worrying in developing countries, particularly in sub-Saharan Africa. Since most households and industries do not have adequate waste and wastewater treatment systems, they release their waste into the environment. These organic pollutants such as phenols can be harmful or even fatal, some ions, and nutrient salts such as nitrogen and phosphorus when they exceed recommended highly concentrated, they cause intense eutrophication especially in areas with low renewal rates (Yao et al., 2009). The urban zone of the Ebrié lagoon is the receiving basin of various wastes of anthropogenic origin generated by the city of Abidjan (Pottier et al., 2008). It is used as a dumping ground for household waste, industrial waste, wastewater, septic tank landfills, and as if that were not enough, it is turned into topsoil. Three categories of pollution can be distinguished, namely chemical pollution, organic pollution and microbial pollution. In addition to these, pollution related to the seasonal appearance of floating plants from the lagoons Aghien and Potou must be added. The origins have been known for many years, and even if natural factors contribute to the situation, it is the lack of sanitation and waste treatment systems that make it a major ecological problem. The aim of this study is to monitor the temporal and spatial variation of abiotic and biotic parameters of Ebrié lagoon waters at Abidjan for deducing its pollution level and sustainable management.

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2. MATERIALS AND METHODS

2.1. Presentation of the site

The Ebrié Lagoon, located in the Abidjan region, has an area of 566 km^2 and extends for 125 km along the coast of Ivory Coast, between longitude 3° 40' and 4° 50' and latitude 5° 50' north (Figure 1). Its volume is about 25.109 m^3, it has many bays and channels of low depths (between 4 and 6 m) sometimes leading to pits of 20 m depth. This body of water is in permanent contact with the Atlantic Ocean via the Vridi Canal, 2.7 km long and 0.3 km wide, with an average depth of 20 m.Three (3) lagoon seasons are distinguished, namely the low-water season, from January to April, during which the marine influence through the Vridi Canal is maximum. Followed by the precipitation season from May to August when the lagoon is then influenced by precipitation on the forest zone bordering the ecosystem. Finally a season of floods from September to December during which the lagoon is more supplied with fresh water by three rivers; the Comoé, Mé, and Agneby.

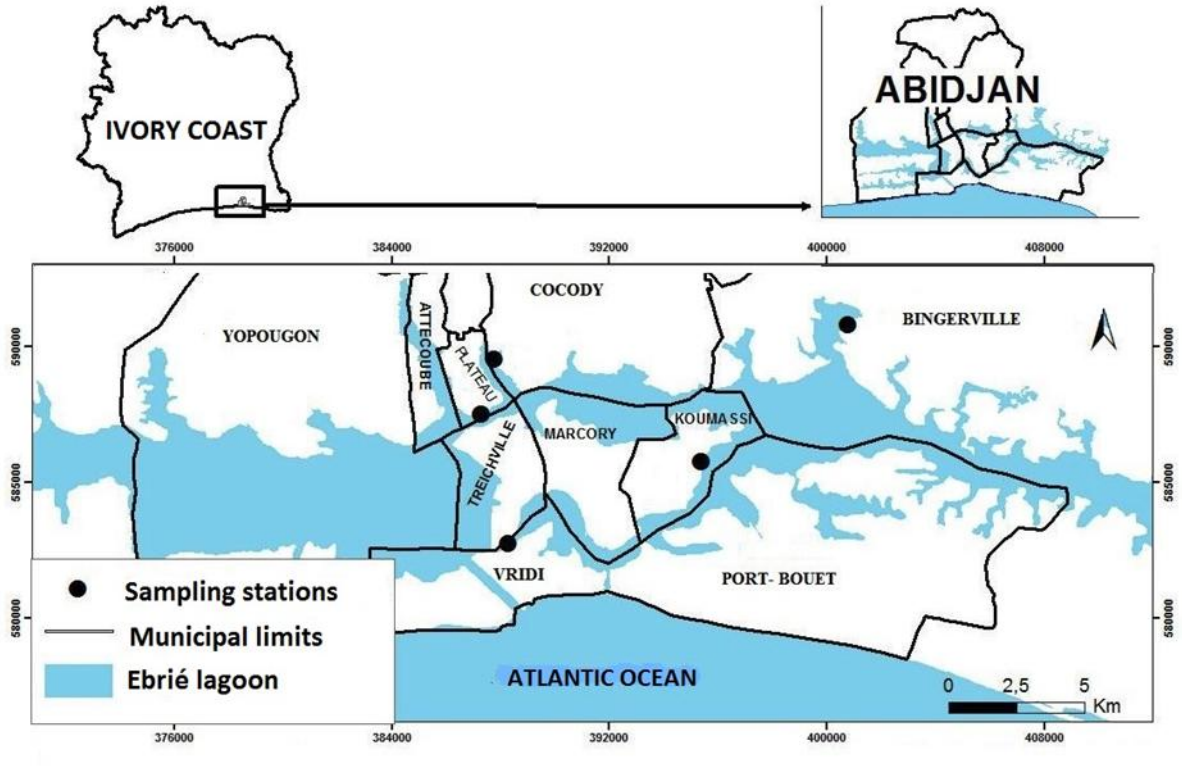

Figure 1: Location of the study area and sampling sites

2.2. Sampling Strategy

Water samples were taken at a monthly frequency from January to December 2016 at 5cm from the surface and 1m deep using a 2.5 litre VAN DORN-type water bottle. The samples are then placed in polyethene bottles in a 4°C cooler and processed in the laboratory within 24 hours.

2.3. Analysis

2.3.1 Biotic Parameters

250 ml of water was measured using a graduated test piece. This quantity is filtered on a Whatman GF/C (1.2 µm porosity) fibreglass filter that is previously covered with a thin layer of calcium carbonate ($CaCO_3$). After filtration, we centrifuged the samples with 10 ml of 90% acetone for 1 minute. The tube is placed in the dark and cool for 5 to 10 hours to allow the extraction of chlorophyll-a. The mixture is centrifuged at 4000 rpm for 5 minutes. The supernatant is poured into a 10 cm cell and analysed by the spectrophotometry method (WFJ-752 spectrophotometer) described by (Lorenzen, 1967).

2.3.2. Physical-chemical parameters

In-situ, the temperature and the pH were measured by a HachLange pHC 101 model HQ 40d multi-parameter probe, precision ± 0.3 ° C, and the electrical conductivity by a HANNA HI 99301 type conductivity meter with ± 2% accuracy. The concentration of phosphates is determined by the method of Murphy and Riley (1962). The method of Wood et al. (1967) modified by Le Poupon (1994) is used to determine the nitrate concentration (NO_3^-). The nitrites were determined by the method of Zambelli (Rodier, 1997).

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3. RESULTS AND DISCUSSIONS

3.1. Temperature

The average temperature of the sites is between 26.37 ± 1.47 °C and 27.71 ± 1.88 °C above ground level, while the depths range from 26.12 ± 1.32 °C to 27.75 ± 1.75 °C. The amplitudes of spatial and vertical variations are small (0.5 to 1 °C). The waters of the sites of Bingerville, Cocody and Koumassi are the warmest. On the Plateau, the lowest temperatures are recorded. On all sites, however, the surface temperatures are higher in Bingerville and the background water is warmer. The seasonal study shows that the highest temperature values are obtained during high and low water. Depth water is less hot than surface water on all sites. The highest surface temperature was recorded during the Bingerville dry season while the lowest surface temperature was recorded in the Plateau during the rainy season. During the precipitation season, average surface temperatures range from 24.75 ± 0.5 °C to 26.5 ± 1.29 °C compared to 24.75 ± 0.5 °C and 26.0 °C. It is noted that the waters are less hot during the precipitation season.

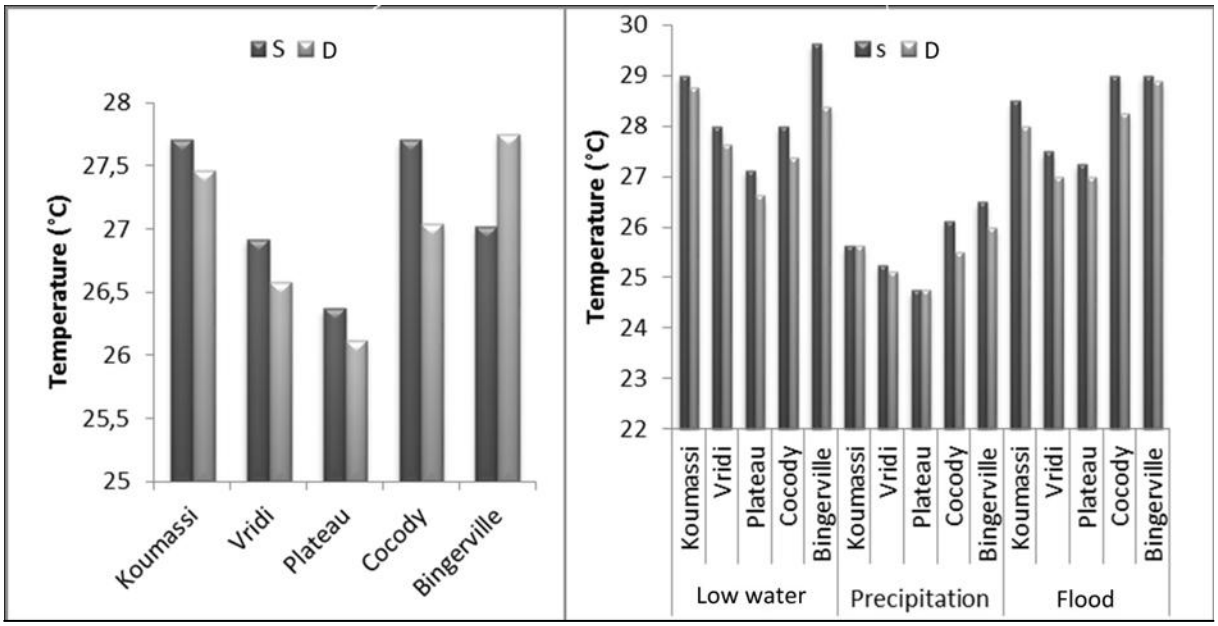

Figure 2 : Spatial and seasonal variation in the temperature of the waters of the Ebrié Lagoon

Temperature is an important factor in the aquatic environment (Derwich et al. 2010). It conditions the life of aquatic animal and plant organisms such as algae (Boukari et al. 2018). The temperature of the water is strongly influenced by the environmental conditions linked to the geographical location of the locality, the geology of the terrain crossed, the hydrology of the ecosystem and especially the prevailing climate (Rodier et al. 1984).

Surface water temperatures are slightly higher than those of deep water at all sites except Bingerville. The waters of the Vridi and Plateau sites are relatively colder than those of Cocody, Koumassi and Bingerville. Indeed, the waters of the Vridi and Plateau sites are rapidly renewed due to their connections with the Atlantic Ocean, so there is no thermal stratification during the study period (Ekou et al. 2011). This observation coincides with that made by Pagès et al. (1979) and Dufour (1982), which explain that spatial variations in water temperature originate in boundary environments. The average depth of the lagoon being 4 m, the mixing of the waters due to winds, fishing activities, navigation on the lagoon and tidal actions on the one hand, seasonal rocking of floods and low flows, but also runoff and direct precipitation on the water body, create a high degree of hydrodynamism that favours the mixing of surface waters with those of the underlying layers, thus creating a homogenization of temperature over the entire lagoon water column (Traore, et al., 2012). In addition, solar rays have the ability to pass through this small thickness of water to heat it homogeneously.

3.2. pH

The pH is essential to determine the level of acidity or basicity of the water. The range of pH averages for the five sites studied ranged from 7.05 ± 0.38 for the Koumassi site to 7.25 ± 0.48 for the surface Vridi site. In-depth, the values are higher, the minimum average was observed at Koumassi (7.08 ± 0.44) while the maximum was recorded at Vridi (7.42 ± 0.61). These waters are all alkaline during the study period. In the seasonal study, the lowest mean pH was observed during the Bingerville surface water precipitation season. The highest depth pH value was observed at Vridi during the flood season. It is also clear that the surface waters of the five sites studied are slightly acidic during the low season.

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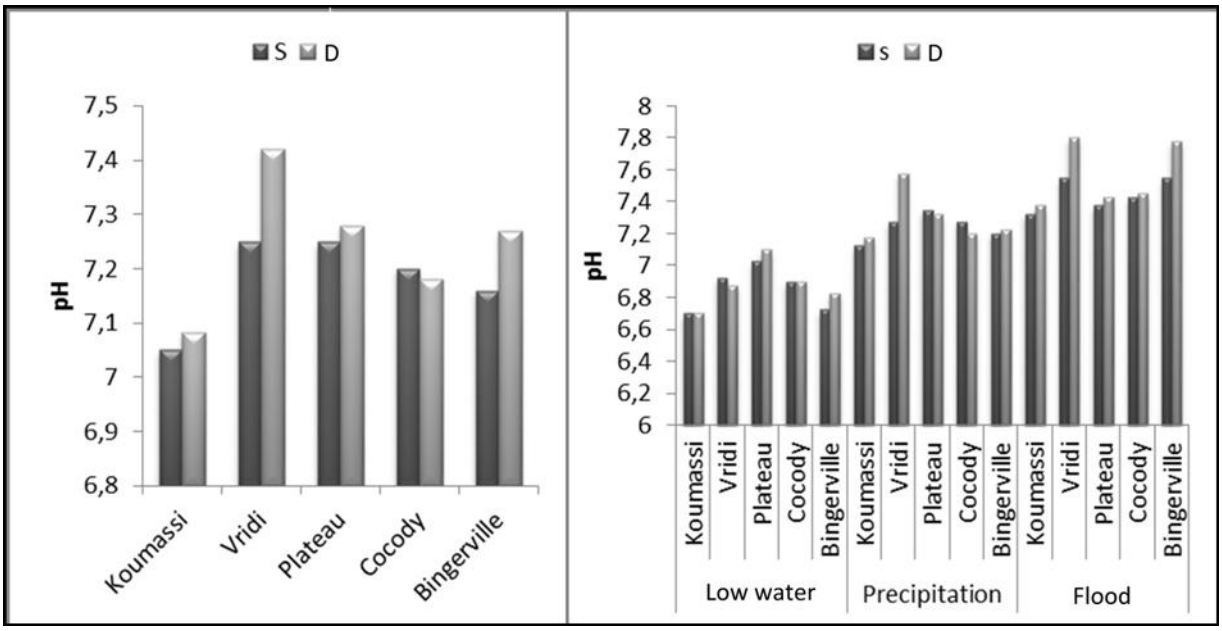

Figure 3: Spatial and seasonal variation in the pH of the waters of the Ebrié Lagoon

pH is a limiting factor in aquatic ecosystems. This is one of the parameters that influence the behaviour and distribution of chemical elements in hydrosystems (Ayah et al. 2015).

Annual average pH values show that the lagoon waters are basic over much of our study period. These values are close to those obtained by (Yao et al. 2009; Ekou et al. 2011).

3.3. Conductivity

Electrical conductivity makes it possible to assess at the overall mineralization of the water. On average, we note that the conductivity values remain the same on the surface as on the bottom of each of the studied sites. The maximum mean conductivity value was observed at Vridi with a value of 8.57 ± 1.22 mS/cm, followed by that of the plateau (6.81 ± 3.2 mS/cm), while the minimum value obtained at the Bingerville site was 3.32 ± 0.14 mS/cm. At the seasonal level, mean electrical conductivity values for surface water ranged from 1.16 ± 0.52 mS/cm at Bingerville during precipitation season to 8.86 ± 1.69 mS/cm at Vridi, during low water season, while those for depth water ranged from 2.53 ± 0.33 mS/cm to 8.72 ± 1.63 mS/cm.

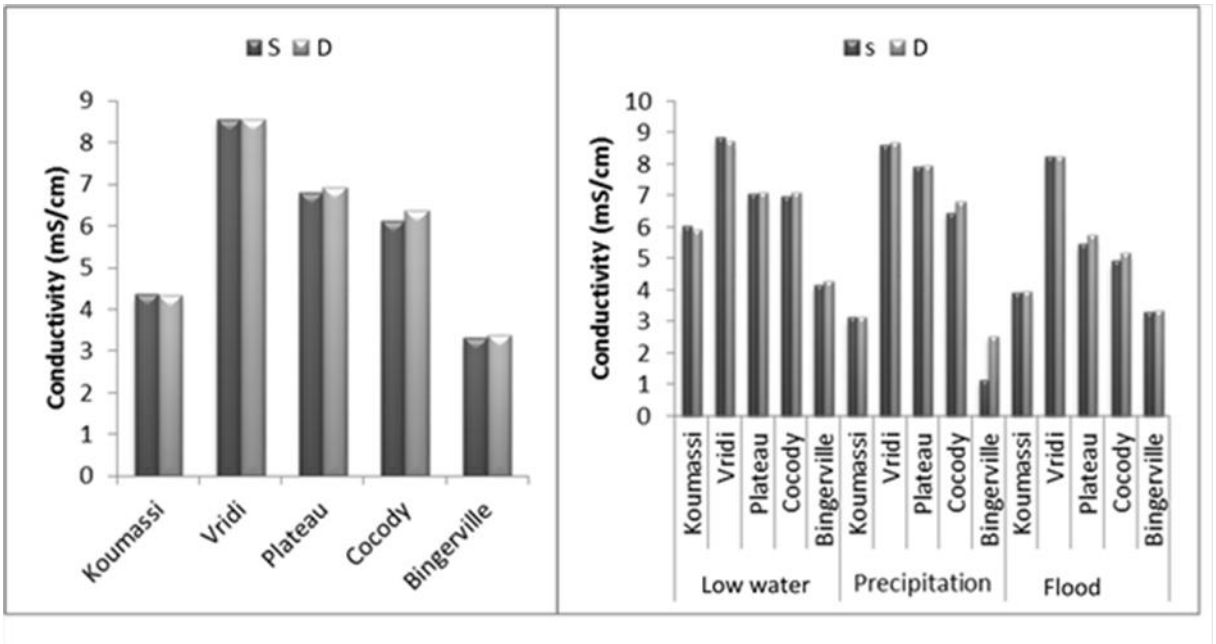

Figure 4 : Spatial and seasonal variation in the conductivity of the waters of the Ebrié Lagoon

Conductivity is the ability of a water to conduct electric current. This ability depends on several factors such as the nature of the ions present and their total concentrations. It gives an idea of salinity, allows a good appreciation of the matter in solution in natural water and allows to detect variations in the chemical composition of the water. The conductivity of natural water is between 50 and 1500 µS/cm. All measured conductivity values in our study, indicate very high mineralization since they are all on

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average above 1500 µS/cm. The averages obtained in surface and bottom waters are the same on all the stations of our study. This result is similar to that obtained by Chouti et al. (2017) in the study of the coastal lagoon from Togbin to Grand-Popo (South-West Benin). Like temperature, the spatial variation in conductivity also originates in frontier environments. Indeed, lagoons by their definitions are water reservoirs in coastal depressions that act as buffers between continental and ocean waters. This particular situation exposes them to the influence of both fresh inland waters and salty ocean waters, which gives the lagoons their brackish character. However, depending on seasons, type of lagoon, bathymetry, geomorphology, ocean and continental water supplies, ocean predominance may prevail over continental dominance or vice versa (Durand et al., 1994). This vertical homogeneity is thus the result of sufficient mixing of ocean and continental waters on the one hand, and sufficient mixing of surface waters with deep waters on the other. The sites of Vridi and Plateau near the Vridi channel, show the maximum averages. This is due to the predominance of marine saltwater (Yao et al. 2009). The averages recorded at Koumassi, Cocody and Bingerville stations are also high due to lack of water renewal, confined to bays (Aknaf et al. 2017). Comparison of measured conductivity values at the water level of the study with those measured at Aghien Lagoon (Konan et al. 2017) and Senegal River (Dick et al. 2017) ranging from 48 .2 to 98,6 µs/cm and 47.4 to 67.1 µs/cm. These waters are found to be of good quality compared to those of the Ebrié lagoon, which receives industrial and domestic discharges without prior treatment.

3.4. Nitrates and nitrites

Surface water nitrate averages ranged from 1140.89 ± 828.18 µg/L at Koumassi to 3033.89 ± 1247.27 µg/L at Vridi. While those in the deep ranged from 1377.74 ± 902.71 µg/L to 3222.39 ± 1652.31 µg/L. The Vridi and Plateau sites have the highest nitrate levels compared to the lowest in Koumassi. In all the sites studied, the nitrate content of the depth water is higher than that of the surface water. Seasonal survey results show that seasonal mean surface waters ranged from 503.04 ± 269.12 µg/L to 3837.79 ± 2022.75 µg/L for surface waters and from 769.30 ± 314.93 µg/L to 3718,61 ± 2161.25 µg/L for those in the deep layer. On average, levels are low in the low season and high in the flood season.

Mean surface nitrite concentrations ranged from 444.87 ± 146.76 µg/L at Vridi to 570.46 ± 195.12 µg/L at Koumassi, while in the deep layer they ranged from 449.01 ± 133.47 µg/L to 553,9 ± 187.16 µg/L at Vridi and Bingerville, respectively. Seasonal averages for nitrites ranged from 165.91 ± 102.92 µg/L to 454.43 ± 137.04 µg/L and 152.59 ± 120.67 µg/L to 509.36 ± 188.42 µg/L, respectively, in surface and depth waters. The highest value is recorded in Bingerville during the precipitation season, while the lowest at Vridi in the low water season. These results show that the water nitrite levels are higher in the flood season.

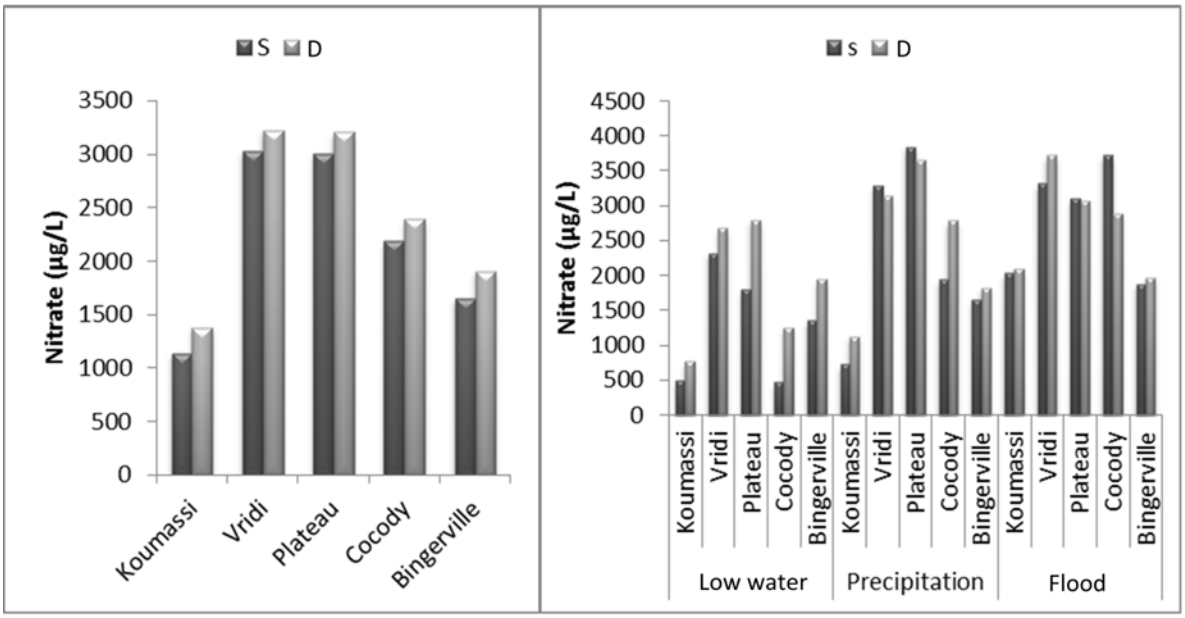

Figure 5: Spatial and seasonal variation of nitrates in the waters of the Ebrié Lagoon

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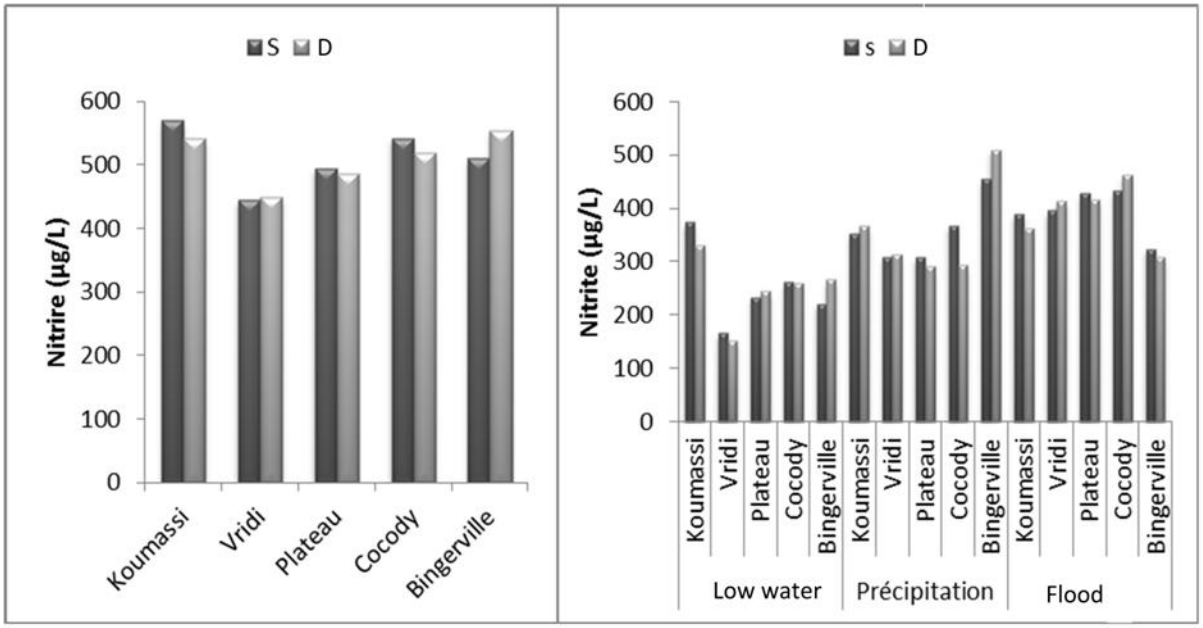

Figure 6: Spatial and seasonal variation of nitrite in the waters of the Ebrié Lagoon

Nitrogen pollution can be estimated by the determination of nitrate and nitrite levels. Nitrates come from the oxidation of ammoniums to nitrites and then to nitrates. Nitrous ion (NO_2^-) is unstable. It turns into nitrate, which is the end state of ammonium oxidation. Nitrate ions (NO_3^-), considered as a pollution indicator, represent the most soluble form of nitrogen. Its presence in surface waters is linked to the intensive use of fertilizers. However, in urban areas, high nitrate concentrations are mainly due to the presence of household and industrial waste, particularly in the agro-food industries. The economy of Côte d'Ivoire is based on agriculture, the agro-food industries are very established there, and the most important in the large metropolis of Abidjan, thus discharging their effluent sometimes not-so-treated in the Ebrié lagoon. The mean concentrations obtained are between 1140.89 and 3222.39 µg/L. These values are in the same order of magnitude as those found by Zandagba et al. (2016) in Nokoué lac. Nitrite has concentrations ranging from 444.87 to 570.46 µg/L. These high concentrations can affect the development of aquatic species, as water containing nitrites even at low doses may be considered suspect or even lethal to fish (Vissin et al. 2010).

3.5. Phosphates

Average surface water phosphate concentrations ranged from 3.79 ± 2.16 µg/L at Bingerville to 8.54 ± 1.5 µg/L at Vridi. In the deep layer, the same variations are noted. The Vridi site has the highest concentrations while the Bingerville site has the lowest concentrations. Seasonally, levels in surface waters range from 2.22 ± 0.43 µg/L to 9.25 ± 1.45 µg/L and from 2.39 ± 0.29 µg/L to 8.77 ± 1.19 µg/L in the deep layer.

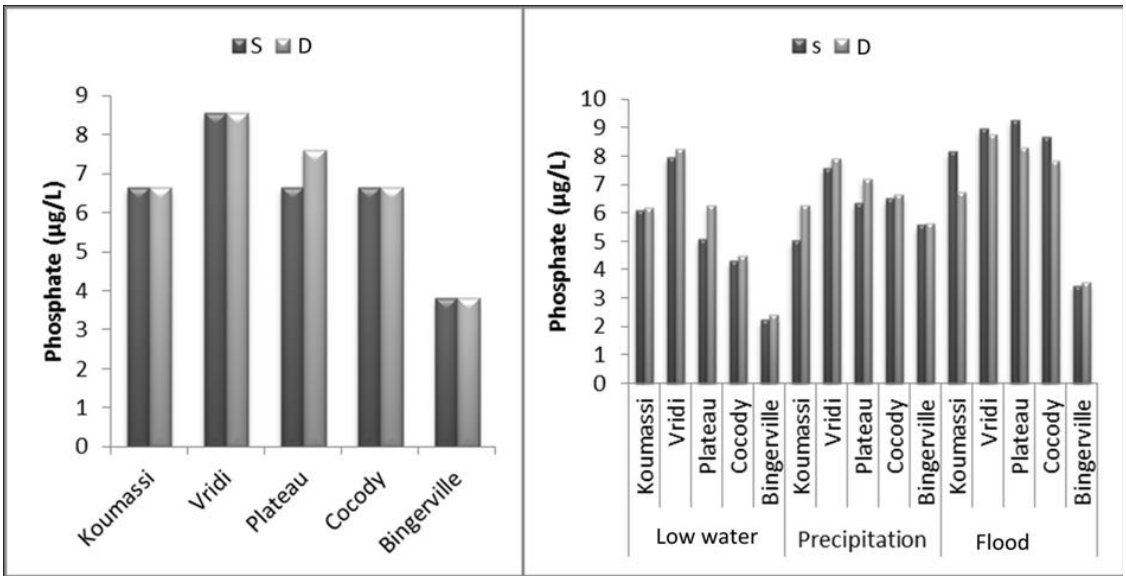

Figure 7 : Spatial and seasonal variation of phosphates in the waters of the Ebrié Lagoon

With nitrates, phosphates play a decisive role in the eutrophication of rivers. However, above a certain concentration, and when conditions are favourable, they can cause excessive growth of algae and aquatic plants. The low levels recorded would

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correspond to the removal of phosphorus by chemicals such as adsorption to metal hydroxides and precipitation to calcium, which may constitute significant levels of particulate phosphorus sedimentation (Ekou et al. 2011). However, according to Silvino and Barbosa (2015), phosphorus concentrations are low probably due to their assimilation through high algal productivity. The effects of phytoplankton and macrophytes, sediment characteristics, high pH and wind mixing are among other factors influencing phosphate availability in water (Mama, 2010; Noumon et al., 2015; Tapsoba et al., 2016). These results are similar to those of Konan et al. (2017) but remain weak compared to those of Ekou et al. (2011) and Yao et al. (2009).

3.6. Spatial and temporal dynamics of chlorophyll biomass

The mean surface water concentrations of chlorophyll-a vary from 3 ± 1.75 µg/L obtained at the Plateau to 9.66 ± 5.012 µg/L at Bingerville. Deepwater concentrations range from 3.85 ± 1.22 µg/L at Plateau to 16.09 ± 7.8 µg/L at Vridi. The seasonal study, on the other hand, gives average surface layer concentrations ranging from 2.49 ± 1.52 µg/L obtained at the Plateau during the flood season to 15.63 ± 3.54 µg/L recorded at Bingerville during the dry season. In the deep layers, averages ranged from 3.63 ± 2.9 µg/L to 26.93 ± 12.72 µg/L obtained at Vridi during the rainy season.

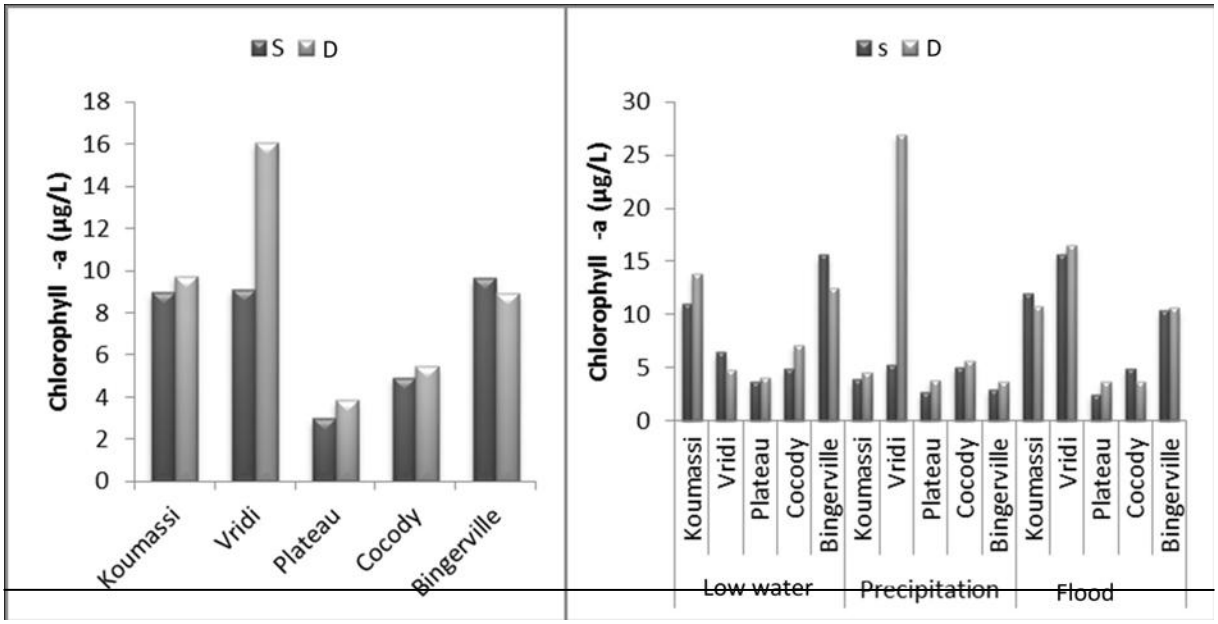

Figure 8 : Spatial and seasonal variation of chlorophyll-a in the waters of the Ebrié Lagoon

Chlorophyll-a is considered as an excellent indicator of the trophic state of a body of water. The lowest annual average concentration of chlorophyll-a is recorded at the plateau site despite the high levels of nutrients observed. This may be due to the current, as short transit times do not allow phytoplankton to exploit nutrient resources (Dodds, 2006). In addition to domestic discharges, Koumassi and Vridi sites in industrial areas receive nitrogen and phosphorus-rich industrial effluents, which are the main factors in algal growth (Johnson et al. 2006). The Bingerville site is located in the Abidjanese suburb, far from the waste, but has agricultural and livestock activities in its catchment area. The quality of the water at this site would be strongly influenced by these activities and would result in a source of pollution of the water from rainfall. The assessment of the trophic level is an important parameter for monitoring the evolution of water quality (Carlson 1977, Lillesand et al. 1983). We assessed the trophic level of the waters analysed from the OECD classification grid (1982) based on the chlorophyll-a concentration. It is apparent that the waters of the Plateau and Cocody sites with annual mean concentrations between 8 and 25 µg/L are mesotrophic and those of Koumassi, Vridi, and Bingerville are eutrophic, with mean concentrations between 2.5 and 8 µg/L. The waters of the Plateau and Cocody sites are classified as mesotrophic, which is a transition state, between oligotrophic and eutrophic. The Plateau site is located in the business centre and is equipped with adequate infrastructure for the collection and treatment of wastewater. The environment, therefore, does not record any real pollutant-generating activities and is, therefore, less subject to discharges. In 2015, the site was undergoing remediation and site development, the work that leads to the improvement of water conditions, hence the results of our work.. A similar study was conducted by Ekou et al. (2011) from May to January on the Vridi and Plateau sites. The mean concentrations of chlorophyll-a and phosphorus during the study allowed them to classify Vridi waters as mesotrophic and those of the Eutrophic Plateau with reference to the table of the trophic status classification system set by OECD (1982). With the same considerations, Sané et al. (2013) reveal that Guiers Lake in Senegal is in eutrophic state from 2002 and 2004 before moving to hypertrophic state in 2005. Elsewhere, in the democratic and popular Laos republic of Southeast Asia, Martinet et al. (2016) assessed the trophic status of reservoir lake Nam Theun 2.

4. CONCLUSION

The pollution of the Ebrié lagoon remains a crucial problem for the Ivory Coast. The results of this study showed that there was no thermal stratification of water bodies. The surface water temperature is relatively similar to the depth temperature. The

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waters of Koumassi, Cocody and Bingerville are warmer while those of the Plateau is less. Lagoon waters have a high rate of mineralization. Low nutrient levels are recorded. Chlorophyll-a levels are high and reveal the phytoplantonic load in water bodies through nutrient uptake, justifying their low recorded levels. These results enabled us to estimate the trophic state of the waters of the Ebrié Lagoon from the OECD Water Quality Assessment Grid. This study shows that the waters of the Koumassi, Vridi and Bingerville sites are eutrophic, and those of the Plateau and Cocody sites are mesotrophic. These results show the worrying state of degradation of the waters of the Ebrié lagoon subjected to huge discharges from Abidjan. This situation poses a threat to the resources which are being closed and to the health of the populations which consume them. We recommend the strengthening of the environmental policy, by equipping the specialized structures with more means for the effectiveness of the mission assigned to them. We, therefore, hope to raise awareness or refocus on other sites, populations living in precarious dwellings on the banks of the Ebrié lagoon in Abidjan. We do not encourage the clean-up and development of Cocody Bay and would like it to take into account the entire Ebrié lagoon in Abidjan.

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