

# Assessment of physico-chemical parameters in the western zone of Ebrié Lagoon (Côte d'Ivoire)

## Abstract

Waters of the western zone of the Ebrié lagoon are influenced by marine waters and inflows from the Agneby and Bandaman rivers, as well as chemical effluent discharges from agri-food plants and human activities. The objective of this work is to study water quality in the western part of the Ebrié Lagoon. Water samples were collected in sectors IV and V of the Ebrié lagoon from eleven stations during February 2014 to January 2015. Temperature, pH, dissolved oxygen and salinity were measured *in situ* by a multi-parameter. Transparency was measured by a Secchi disc. Water samples for suspended solids collected are determined using the method described by Aminot and Chaussepied. The result indicates that, mean annual temperature varied between  $28.84 \pm 0.88^\circ\text{C}$  and  $28.91 \pm 0.50^\circ\text{C}$  in sectors IV and V respectively. In sector IV, the water is acidic during the rainy season, and alkaline during the dry season in sector V. Mean annual dissolved oxygen values obtained during this campaign were  $5.75 \pm 1.28$  mg/L and  $6.19 \pm 1.47$  mg/L in sectors IV and V respectively. Aquatic life appears to be more normal in sector V than in sector IV. Mean salinity values showed the influence of the Vridi Canal on these two sectors. Mean transparency values were low. Average suspended solids values were high, especially in sector IV with 16.22 mg/L. The waters of sector IV are more turbid than those of sector V. There is a risk of disrupting photosynthesis and production of toxic waste harmful to fish and humans in our study area.

**Keywords :** *Quality, water, sectors IV and V, Ebrié lagoon.*

## 1. INTRODUCTION

In Côte d'Ivoire, the Ebrié lagoon receives agricultural, domestic and industrial waste containing contaminants, mainly through drainage and the discharge of untreated effluent [1,2]. The Ebrié lagoon also receives pollution from freshwater and marine waters through exchanges [3]. As a result, all three forms of pollution organic, microbial and chemical are present in the lagoon. These different types of pollution lead to disturbances in the lagoon system, notably a reduction in aquatic organisms and dissolved oxygen, and the appearance of invasive aquatic plants [4]. The adverse effects of lagoon pollution have been observed mainly on aquatic life [5,6]. In 2013, sectors IV and V of the Ebrié lagoon recorded major fish kills. These massive fish kills, which are now recurrent in these two sectors, are detrimental to the riverside population, which is heavily dependent on fish resources. These pollutions also have negative impacts on human health and the degradation of water quality [7]. In addition, climate change, which is inducing extreme phenomena such as long dry seasons, and population growth are leading to a scarcity of drinking water. Increasingly, public authorities are considering the use of surface waters such as the Ebrié lagoon as a source of fresh water. Knowledge of physico-chemical parameters provides information on water quality. Water quality is assessed by physico-chemical parameters such as temperature, pH, dissolved oxygen, salinity, transparency and suspended solids. Temperature plays an important role in the solubility of certain salts and gases required for the equilibrium of aquatic life. pH is influenced by the physico-chemical equilibrium between water, dissolved carbon dioxide and the buffered solutions carbonates and bicarbonates [8]. Low pH values (acidic waters) increase the risk of pollutants being present in more

toxic ionic form. On the other hand, high pH values (basic waters) increase ammonia concentrations, which are toxic to fish. Dissolved oxygen levels are favored by contact of the water body with the atmosphere, aeration (rapid water movement), oxygen-producing photosynthesis and temperature. Salinity is a parameter that provides an indication of a water's degree of mineralization. It highlights the ionic concentration and abundance of dissolved salts (sodium chloride) in water. It depends on the temperature, content and type of ions present in the water [8, 9, 10]. Water transparency enables us to assess the extent of the presence and production of photosynthetic organisms (phytoplankton, macroalgae, etc.) growing in the water column. Suspended solids can be a hazard to the aquatic environment and to humans. In addition, suspended solids are a means of accumulating toxic waste in living organisms, becoming a poison that causes fish mortality [11]. In fact, they are deposited on phytoplankton consumed by fish.

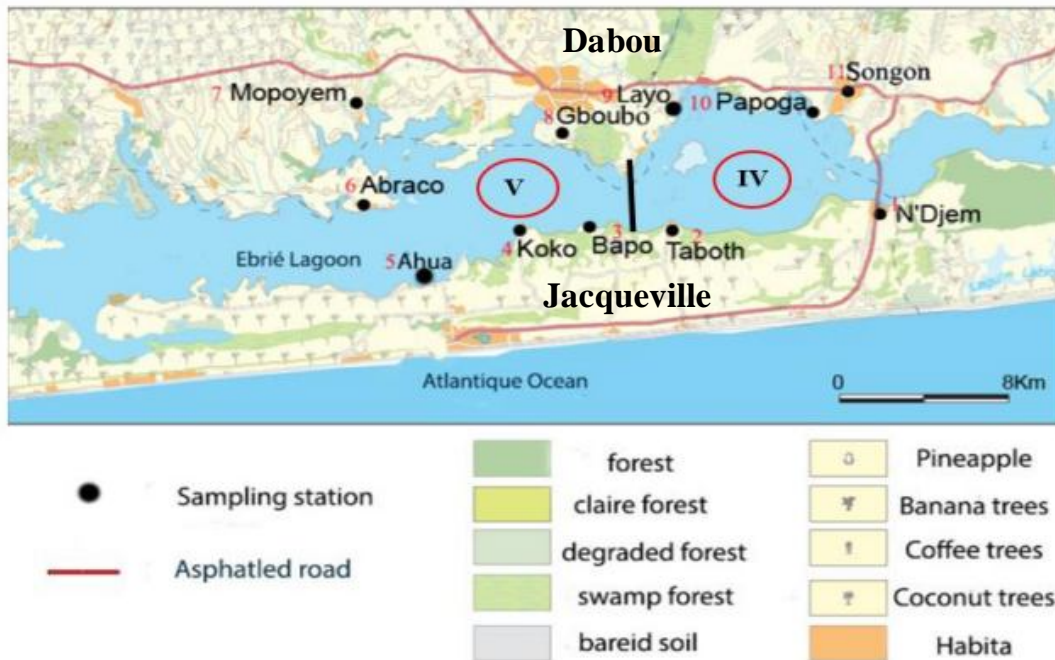
## **2. MATERIAL AND METHODS**

### **2.1 Study area**

The study area covers sectors IV and V. Sectors IV and V of the Ebrié lagoon represent the western part of the lagoon, encompassing the departments of Dabou and Jacqueville (Figure 1). The two sectors represent an area of 305 km<sup>2</sup> and a water volume of 1.24 km<sup>3</sup>.

### **2.2. Sampling campaign**

Water samples were collected monthly in sectors IV and V from February 2014 to January 2015. Five stations were selected in sector IV including Songon, N'Djem, Papoga, Taboth and Layo. Six stations Bapo, Koko, Ahua, Abraco, Mopoyem and Gboubou in sector V were also selected (Figure 1).



**Figure 1 : Location of sampling sites (round) in sectors IV and V of Ebrié Lagoon, Côte d'Ivoire**  
**Sampling stations (1 N'djem, 2 Taboth, 3 Bapo, 4 Koko, 5 Ahua, 6 Abraco, 7 Mopoyem, 8 Gboubo, 9 Layo, 10 Papoga, 11 Songon)**

## 2.2. Measuring equipment for physico-chemical parameters

A YSI 6920 multi-parameter was used to measure temperature, pH, salinity and dissolved oxygen. This device consists of a probe with electrodes to be immersed in the water and an electronic box (calibrated voltmeter) displaying the values according to the parameter.

Transparency was measured using a Secchi disk, which consists of a weighted string graduated in centimeters (cm) and a disk. Finally, suspended solids were determined using glass micro-filters (diameter 47 mm) in an oven (450-500°C) and an oven for drying the filters, a desiccator and a NIKON-type balance with 0.01 g precision.

On board the boat, temperature, salinity, dissolved oxygen and pH were measured in situ using a YSI 6920 V2 multi-meter. Measurements were taken in the first 0.5 m of water depth. The meter is calibrated before use, and the probe is immersed directly in the water. Measurements are displayed automatically.

Transparency is measured using the Secchi method. The Secchi disk is immersed in water by means of a rope until it disappears completely. The disk is then slowly raised. As soon as it reappears, the distance separating the disk from the water surface is noted, corresponding to the transparency (AFNOR 1997)[12].

Suspended solids (SS) are determined using the method described by Aminot and Chaussepied (1983)[13] and AFNOR standard NF T90-105 (1997) [12]. In the laboratory, 250 ml of the water to

be analyzed is filtered through a membrane filter to retain all particles larger than 5 µm. The membrane is dried and weighed before and after filtration.

The difference in mass is used to determine the total dry mass of suspended solids. The filters are washed with distilled water and placed in an oven at 450-500°C for one hour. Each filter is cooled in a desiccator and weighed to obtain a mass  $m_1$ . Two hundred and fifty (250) ml of each sample is measured, homogenized by vigorous shaking and filtered. The filters are then rinsed twice with 5 to 10 ml of distilled water, then oven-dried at 70°C for two hours. Finally, the filter is weighed to the nearest 0.01 mg, giving us a mass  $m_2$ . The quantity of dry matter is determined according to the formula :

$$[MES] = \frac{m_2 - m_1}{V} \quad (4)$$

Where:

$m_1$ : filter mass before filtration (mg)

$m_2$ : filter mass after filtration and drying (mg)

V: volume of filtered water (ml).

All statistical treatments: means, standard deviations, comparisons, correlations, ANOVA and graphical representations were carried out using STATISTICA (version 7.1) and Microsoft Excel 2013.

### 3. RESULTS AND DISCUSSION

#### 3.1 Results

The physico-chemical parameters selected for this study are temperature (°C), hydrogen potential or pH, dissolved oxygen (mg/L), salinity, transparency (m), and suspended solids (mg/L). The annual and seasonal mean values measured at the 11 stations in sectors IV and V are shown in Table 1 (A and B) and Table 2 (A and B) respectively. The seasonal variation profiles for each station in the two sectors are shown in Figures 2 (a to f). The dry season covers the period from December to March, the rainy season from April to July and the flood season from August to November.

**Table 1 (A and B): Average annual values for physico-chemical parameters. Temperature (T), Dissolved oxygen (O<sub>2</sub>), Salinity (Sal), Transparency (Trans), Suspended solids (SS).**

A	Sector IV
	Annual

T(°C)	28,84 ± 0,88
pH	7,13 ± 0,25
O <sub>2</sub> (mg/L)	5,75 ± 1,28
Salinity	3,38 ± 2,14
Trans (m)	0,86 ± 0,18
mg/L)	16,22 ± 4,51

B	Sector V
	Annual
T(°C)	28,91 ± 0,50
pH	7,15 ± 0,27
O <sub>2</sub> (mg/L)	6,19 ± 1,47
Sal	3,03 ± 1,55
Trans (m)	1,46 ± 0,42
mg/L)	8,87 ± 4,96

Table 2 (A and B) : Annual seasonal variation in physico-chemical parameters  
A= Sector IV and B = Sector V. Values with superscript letters a, b and c show a difference between seasons.

	Sector IV		A
	Seasons		
	Dry	Rainy	Flood
T(°C)	29,80 ± 0,23 <sup>c</sup>	28,76 ± 0,50 <sup>b</sup>	27,97 ± 0,54 <sup>a</sup>
pH	7,34 ± 0,08 <sup>b</sup>	6,90 ± 0,12 <sup>a</sup>	7,15 ± 0,27 <sup>ab</sup>
O <sub>2</sub> (mg/L)	6,61 ± 1,34	5,41 ± 0,95	5,24 ± 1,30
Sal	4,97 ± 2,04 <sup>b</sup>	3,64 ± 1,77 <sup>ab</sup>	1,53 ± 1,14 <sup>a</sup>
Trans (m)	0,93 ± 0,19	0,92 ± 0,18	0,74 ± 0,15
SS (mg/L)	15,97 ± 1,31	14,40 ± 3,26	18,31 ± 7,02

	Sector V		B
	Seasons		
	Dry	Rainy	Flood

<b>T(°C)</b>	$29,48 \pm 0,21^c$	$28,89 \pm 0,20^b$	$28,36 \pm 0,06^a$
<b>pH</b>	$7,25 \pm 0,12$	$7,25 \pm 0,34$	$6,95 \pm 0,33$
<b>O<sub>2</sub> (mg/L)</b>	$4,90 \pm 0,59^a$	$7,31 \pm 1,21^b$	$6,35 \pm 1,41^{ab}$
<b>Sal</b>	$2,82 \pm 0,42^a$	$3,85 \pm 0,81^b$	$2,41 \pm 0,32^a$
<b>Trans (m)</b>	$1,30 \pm 0,16$	$1,28 \pm 0,13$	$1,79 \pm 0,60$
<b>SS (mg/L)</b>	$8,84 \pm 2,17$	$9,73 \pm 5,08$	$8,03 \pm 7,17$

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Table 3 : Seasonal variation in temperature (Temp : °C), pH, dissolvedoxygen (O2: mg/L), salinity (Sal), transparency (Trans: m) and

		Sector V				B	
		Sector IV				A	
	Season	Temp	pH	O <sub>2</sub>	Sal	Trans	SS
N'djem	Dry	29,73 ± 0,46	7,29 ± 0,60	5,75 ± 0,21	7,51 ± 0,22 <sup>a</sup>	0,77 ± 0,09	16,60 ± 2,38 <sup>a</sup>
	Rainy	29,23 ± 0,40	6,97 ± 0,68	4,77 ± 0,48	5,44 ± 0,66 <sup>a</sup>	0,95 ± 0,04	11,16 ± 2,08 <sup>b</sup>
	Flood	28,38 ± 0,35	7,44 ± 0,29	3,45 ± 0,41	2,73 ± 0,42 <sup>b</sup>	0,77 ± 0,04	14,06 ± 2,14 <sup>b</sup>
Taboth	Dry	29,45 ± 0,03	7,25 ± 0,51	5,79 ± 0,49	3,40 ± 0,15	1,22 ± 0,12	14,12 ± 2,74
	Rainy	28,78 ± 0,42	7,07 ± 0,59	5,00 ± 0,36	2,95 ± 0,62	1,17 ± 0,05	13,56 ± 2,59
	Flood	28,44 ± 0,45	7,23 ± 0,36	6,28 ± 0,24	2,42 ± 0,20	0,97 ± 0,06	14,70 ± 3,22
Songon	Dry	29,86 ± 0,42	7,39 ± 0,56	6,23 ± 0,46	6,88 ± 0,10 <sup>a</sup>	1,02 ± 0,19	17,61 ± 2,75 <sup>a</sup>
	Rainy	29,23 ± 0,38	6,76 ± 0,51	5,30 ± 0,38	5,57 ± 0,84 <sup>a</sup>	0,95 ± 0,17	13,23 ± 1,63 <sup>b</sup>
	Flood	28,26 ± 0,25	7,35 ± 0,17	4,53 ± 0,22	1,85 ± 0,22 <sup>b</sup>	0,65 ± 0,04	12,51 ± 2,63 <sup>b</sup>
Papoga	Dry	30,03 ± 0,45	7,47 ± 0,43	8,98 ± 2,31	3,66 ± 0,67	0,87 ± 0,15 <sup>a</sup>	15,36 ± 2,30 <sup>a</sup>
	Rainy	28,53 ± 0,26	6,91 ± 0,81	7,09 ± 1,36	2,67 ± 0,35	0,90 ± 0,20 <sup>b</sup>	14,16 ± 3,12 <sup>a</sup>
	Flood	27,24 ± 0,25	7,03 ± 0,31	6,65 ± 0,93	0,42 ± 0,22	0,55 ± 0,10 <sup>c</sup>	29,56 ± 5,77 <sup>b</sup>
Layo	Dry	29,97 ± 0,44	7,30 ± 0,6	6,32 ± 0,25	3,42 ± 0,67 <sup>a</sup>	0,77 ± 0,05	16,16 ± 2,17 <sup>a</sup>
	Rainy	28,03 ± 0,29	6,82 ± 0,73	4,91 ± 0,11	1,58 ± 0,28 <sup>b</sup>	0,65 ± 0,13	19,89 ± 2,91 <sup>b</sup>
	Flood	27,54 ± 0,42	6,74 ± 0,42	5,29 ± 0,01	0,24 ± 0,15 <sup>b</sup>	0,77 ± 0,04	20,75 ± 2,49 <sup>b</sup>

suspended solids (SS: mg/L), a = Sector IV and b = Sector V. Values with superscript letters a, b and c show a difference between seasons.

	Season	Temp	pH	O <sub>2</sub>	Sal	Transp	SS
<b>Bapo</b>	Dry	29,69 ± 0,33	7,43 ± 0,64	5,86 ± 2,07	2,80 ± 0,80 <sup>a</sup>	1,31 ± 0,16 <sup>a</sup>	6,79 ± 0,97 <sup>a</sup>
	Rainy	28,87 ± 0,94	7,55 ± 0,83	8,59 ± 1,85	4,30 ± 0,30 <sup>b</sup>	1,45 ± 0,30 <sup>b</sup>	6,95 ± 0,62 <sup>a</sup>
	Flood	28,35 ± 0,60	7,09 ± 0,38	4,66 ± 1,97	2,50 ± 0,50 <sup>c</sup>	2,07 ± 0,29 <sup>c</sup>	22,35 ± 5,31 <sup>b</sup>
<b>Koko</b>	Dry	29,40 ± 0,62	7,29 ± 0,39	4,35 ± 1,38	2,78 ± 0,75 <sup>a</sup>	1,57 ± 0,17 <sup>a</sup>	11,56 ± 4,02 <sup>a</sup>
	Rainy	29,05 ± 0,91	7,46 ± 0,70	8,54 ± 1,98	4,41 ± 0,11 <sup>b</sup>	1,30 ± 0,16 <sup>b</sup>	4,12 ± 0,71 <sup>b</sup>
	Flood	28,35 ± 0,41	7,13 ± 0,25	8,88 ± 2,68	2,70 ± 0,19 <sup>c</sup>	2,54 ± 0,06 <sup>c</sup>	3,72 ± 1,05 <sup>b</sup>
<b>Ahua</b>	Dry	29,24 ± 0,36	7,34 ± 0,37	4,61 ± 0,45 <sup>a</sup>	2,76 ± 0,76	1,37 ± 0,05	7,25 ± 0,50 <sup>a</sup>
	Rainy	28,95 ± 0,47	7,52 ± 0,71	7,20 ± 0,02 <sup>b</sup>	2,27 ± 0,10 <sup>b</sup>	1,35 ± 0,13	8,75 ± 2,34 <sup>b</sup>
	Flood	28,31 ± 0,31	7,23 ± 0,18	6,24 ± 0,23 <sup>b</sup>	2,59 ± 0,27 <sup>c</sup>	1,23 ± 0,08	5,72 ± 1,60 <sup>c</sup>
<b>Abraco</b>	Dry	29,80 ± 0,12	7,15 ± 0,77	5,06 ± 1,31	2,75 ± 0,83 <sup>a</sup>	1,17 ± 0,53 <sup>a</sup>	6,83 ± 2,28
	Rainy	28,87 ± 0,21	6,73 ± 0,41	7,00 ± 0,66	4,31 ± 0,10 <sup>b</sup>	1,20 ± 0,48 <sup>b</sup>	7,74 ± 2,05
	Flood	28,48 ± 0,01	6,38 ± 0,64	6,53 ± 1,63	2,50 ± 0,26 <sup>c</sup>	2,32 ± 0,05 <sup>c</sup>	4,75 ± 1,51
<b>Mopoyem</b>	Dry	29,32 ± 0,10	7,08 ± 0,87	4,34 ± 1,41	2,27 ± 0,80 <sup>a</sup>	1,12 ± 0,28	9,53 ± 3,18 <sup>a</sup>
	Rainy	29,11 ± 0,10	6,94 ± 0,59	5,28 ± 0,67	3,67 ± 0,35 <sup>b</sup>	1,07 ± 0,09	18,63 ± 3,22 <sup>b</sup>
	Flood	28,30 ± 0,56	6,73 ± 0,28	5,50 ± 1,26	1,79 ± 0,10 <sup>c</sup>	1,08 ± 0,20	7,85 ± 4,25 <sup>a</sup>
<b>Gboubo</b>	Dry	29,45 ± 0,41	7,24 ± 0,68	5,23 ± 1,41	3,58 ± 0,90	1,27 ± 0,26	11,09 ± 5,52 <sup>a</sup>
	Rainy	28,52 ± 0,21	7,32 ± 0,82	7,28 ± 1,16	4,14 ± 0,55	1,35 ± 0,10	12,21 ± 4,77 <sup>a</sup>
	Flood	28,38 ± 0,76	7,16 ± 0,33	6,34 ± 1,34	2,43 ± 0,30	1,52 ± 0,47	3,82 ± 1,17 <sup>b</sup>

### 3.1.1 Temperature

Overall, temperatures are slightly higher in sector V than in sector IV (Figure 2a). The mean temperature values in the surface waters of the Ebrié lagoon from February 2014 to January 2015 are  $28.84 \pm 0.88^\circ\text{C}$  and  $28.91 \pm 0.50^\circ\text{C}$  in sectors IV and V respectively (Table 1 (A and B)).

The highest mean temperature ( $30.03 \pm 0.45^\circ\text{C}$ ) was recorded during the dry season at Papoga in sector IV (Table 3a) and the lowest mean ( $27.24 \pm 0.25$ ) was measured during the flood season also in sector IV and in the same locality. Statistical analysis (ANOVA) showed a significant difference ( $p < 0.05$ ) between the three seasons (Table 1 (A and B)) in both sectors.

### 3.1.2 pH

Surface waters sampled in sectors IV and V alternate between basic and acidic. Hydrogen potential (pH) values range from 6.90 to 7.34 in sector IV and from 6.95 to 7.25 in sector V. However, the mean pH values  $7.13 \pm 0.25$  and  $7.15 \pm 0.27$  in sectors IV and V respectively, indicate that these waters are generally alkaline (Table 1). The alkaline environment is most pronounced during the rainy season at Bapo ( $7.55 \pm 0.83$ ) in sector V (Table 3B). The Abraco station (sector V) recorded the most acidic character (pH = 6.38) of this campaign (Table 3B). Furthermore, the ANOVA test for pH shows a significant difference ( $p < 0.05$ ) only in sector IV between the dry and rainy seasons.

### 3.1.3 Dissolved oxygen

Mean dissolved oxygen values are  $6.61 \pm 1.34$  mg/L and  $4.90 \pm 0.59$  mg/L in the dry season,  $5.41 \pm 0.95$  mg/L and  $7.31 \pm 1.21$  mg/L in the rainy season, and  $5.24 \pm 1.3$  mg/L and  $6.35 \pm 1.41$  mg/L in the flood season for sectors IV and V respectively (Table 2 (A and B)). Annual values are  $5.75 \pm 1.28$  mg/L and  $6.19 \pm 1.47$  mg/L in sectors IV and V respectively (Table 1 (A and B)). Overall, dissolved oxygen values in sector V were higher than those obtained in sector IV. Statistical analysis (ANOVA) revealed a significant difference ( $p < 0.05$ ) only for sector V between dry and rainy seasons.

### 3.1.4 Salinity

Salinity varies from  $1.53 \pm 1.1$  in the flood season to  $4.97 \pm 2.04$  in the dry season in sector IV and from  $2.41 \pm 0.3$  in the flood season to  $3.85 \pm 0.81$  in the rainy season in sector V (Table 2 (A and B)). Mean values are  $3.38 \pm 2.14$  and  $3.03 \pm 1.53$  in sectors IV and V respectively. Overall, the salinity values measured in sector IV are higher than those found in sector V. The highest values were found at N'djem ( $7.51 \pm 0.22$ ) and Songon ( $6.88 \pm 0.10$ ) during the dry season in sector IV (Table 3A). Statistical analysis (ANOVA) shows a significant difference ( $p < 0.05$ ) between seasons for both sectors.

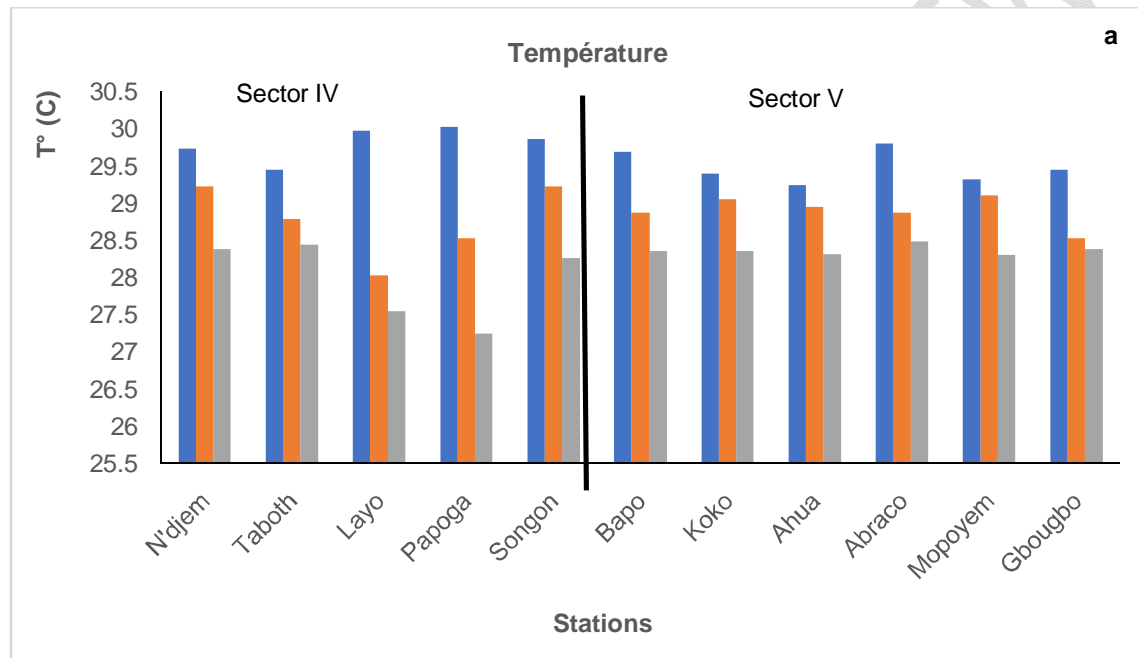
### 3.1.5 Transparency

Transparency is low in sectors IV and V. Mean transparency values observed over the three seasons were lower in sector IV than in sector V (Figure 2e). Annual values were  $0.86 \pm 0.18$  m and  $1.46 \pm 0.42$  m in sectors IV and V respectively (Table 1 (A and B)). The highest values were observed at Koko ( $2.54 \pm 0.06$  m) and Abraco ( $2.32 \pm 0.05$  m) during the flood season in sector V (Table 3B). The lowest value was recorded at Papoga ( $0.55 \pm 0.10$  m) during the flood season in sector

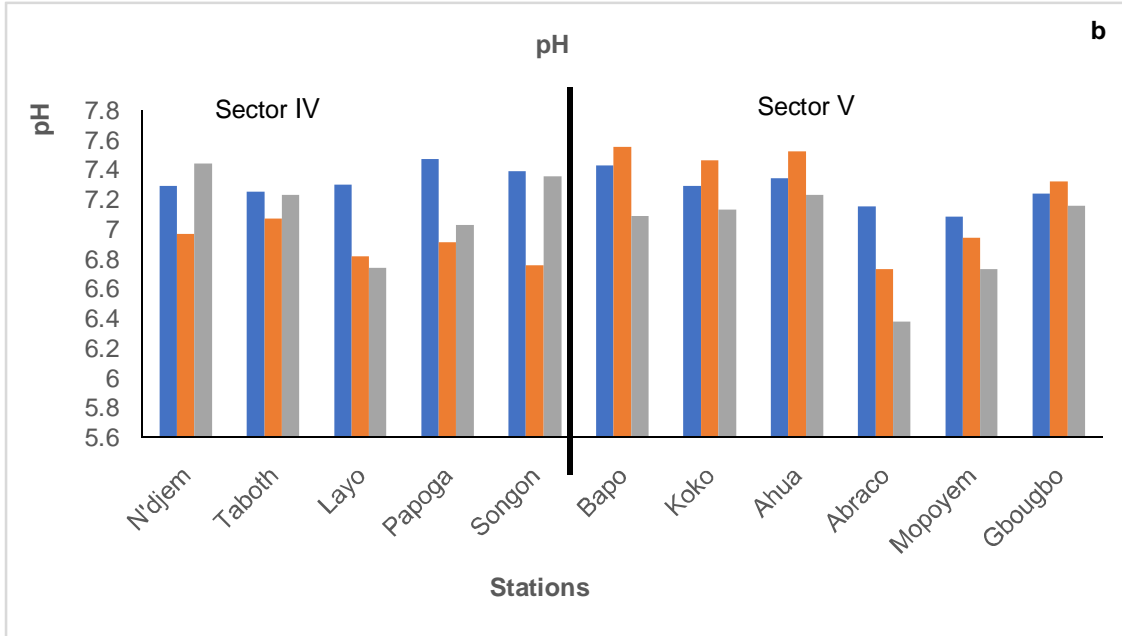
IV (Table 3A). Statistical analysis (ANOVA) showed that there was no significant difference ( $p > 0.05$ ) between the three seasons in the two sectors.

### 3.1.6 Suspended solids

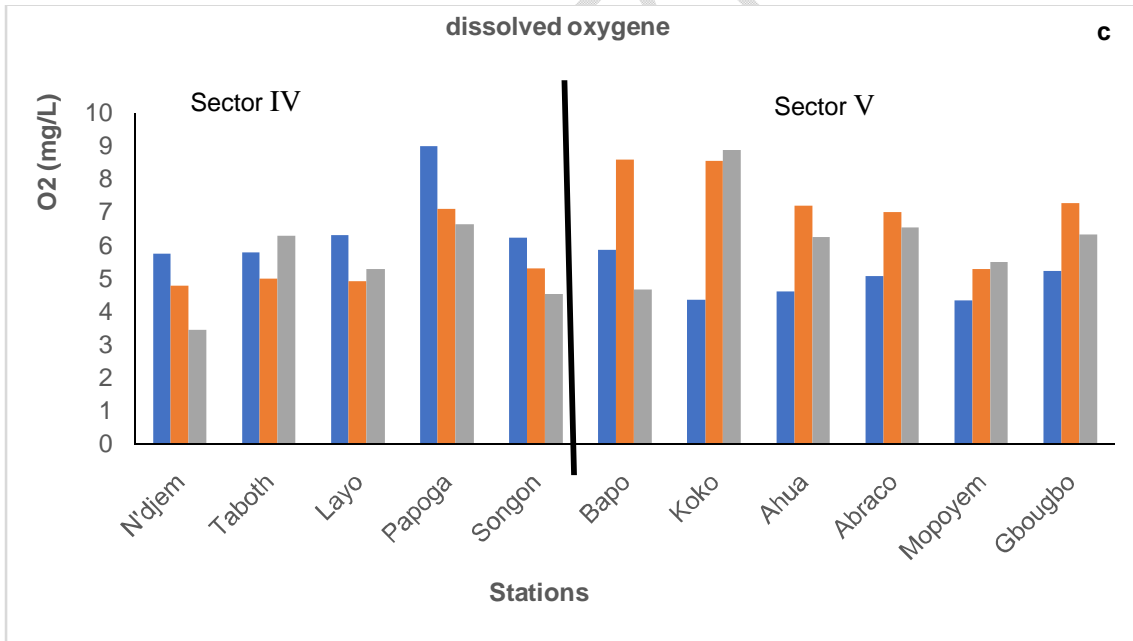
Average suspended solids values over the three seasons are higher in sector IV than in sector V (Figure 2f). Annual values are  $16.22 \pm 4.51$  mg/L in sector IV and  $8.87 \pm 4.96$  mg/L in sector V (Table 1 (A and B)). The highest value was observed during the flood season ( $29.56 \pm 5.77$  mg/L) at Papoga in sector IV. The lowest values were recorded in sector V, again during the flood season, at Koko ( $3.72 \pm 1.05$  mg/L) and Gboubou ( $3.82 \pm 1.17$  mg/L) (Table 3B). In both sectors, the ANOVA test showed no significant difference ( $p > 0.05$ ) between seasons.



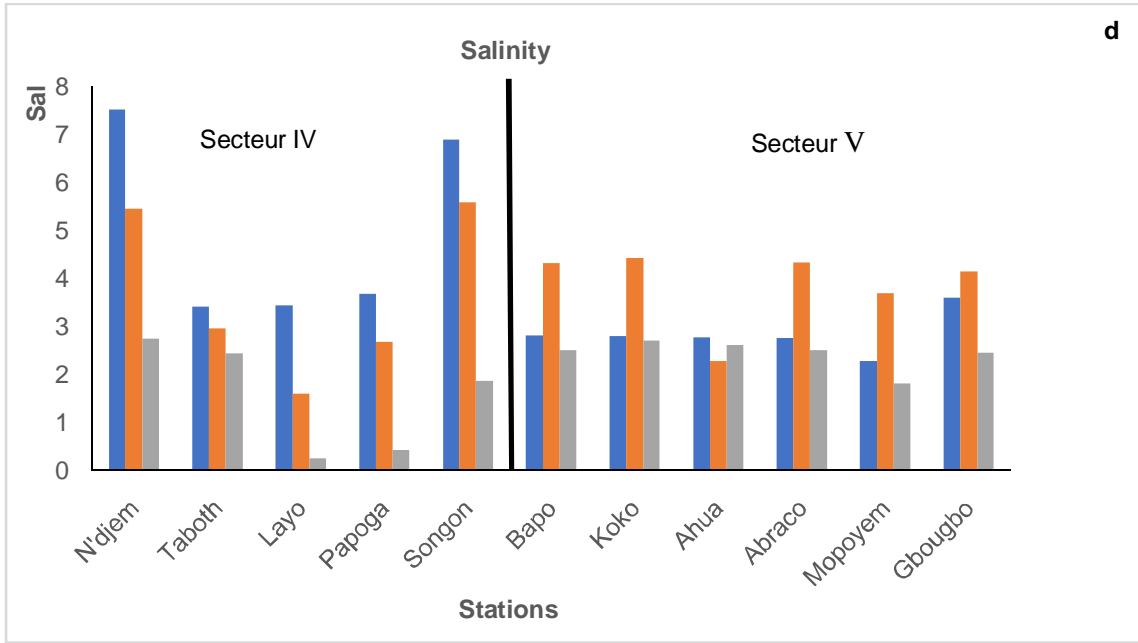
**Figure 2a: Seasonal variations in water temperature at stations in sectors IV and V of Ebrié Lagoon. Blue = Dry Season Orange = Rainy Season Gray= Flood Season**



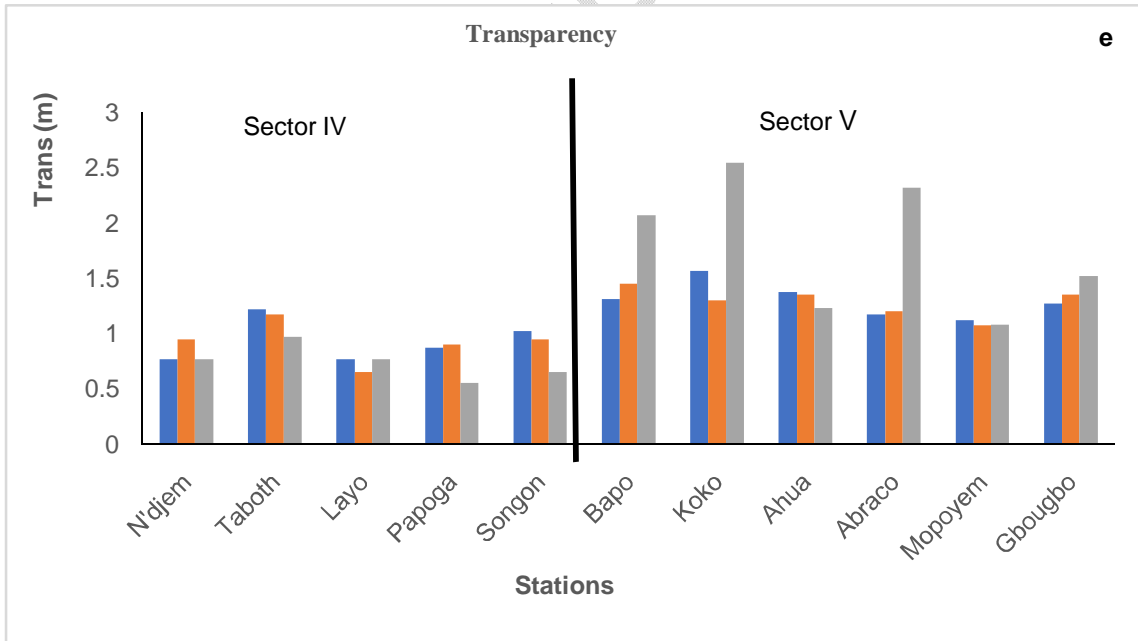
**Figure 2c** Seasonal variations in water temperature at stations in sectors IV and V  
 Blue = Dry Season Orange = RainySeason Gray= Flood Season



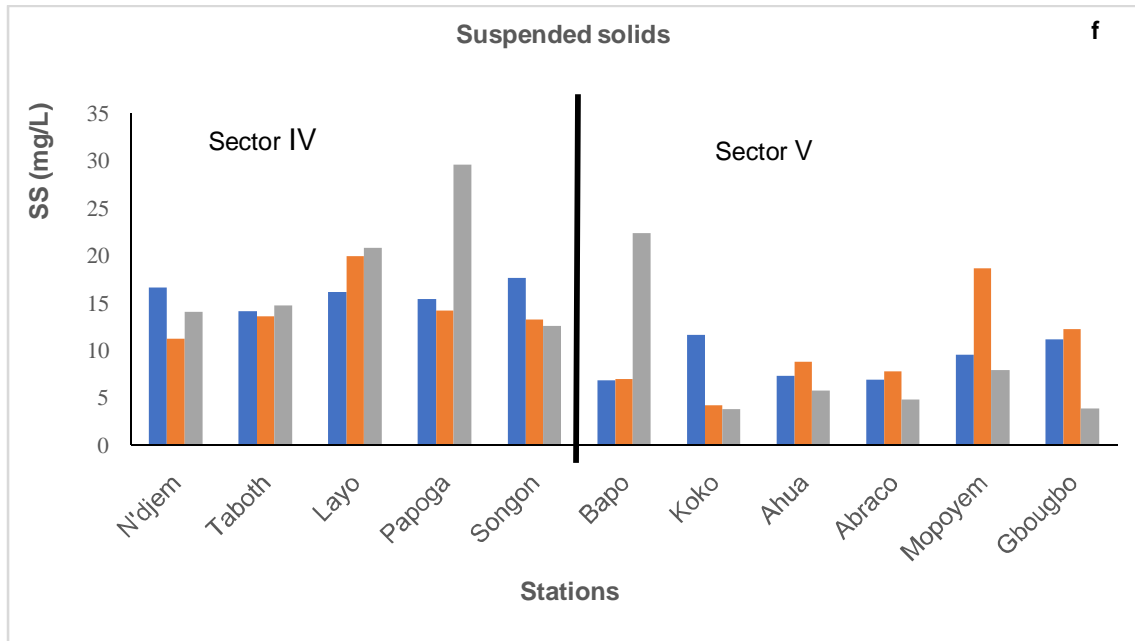
**Figure 2c:** Seasonal variations in dissolvedoxygen in water at stations in sectors IV and V of Ebrié Lagoon. Blue = Dry Season Orange = RainySeason Gray= Flood Season



**Figure 2d: Seasonal variations in water salinity at stations in sectors IV and V of the Ebrié lagoon. Blue = Dry Season Orange = RainySeason Gray= Flood Season**



**Figure 2e: Seasonal variations in water transparency at stations in sectors IV and V of the Ebrié lagoon. Blue = Dry Season Orange = RainySeason Gray= Flood Season**



**Figure 2f: Seasonal variations in suspended solids in water at stations in sectors IV and V of the Ebrié lagoon. Blue = Dry Season Orange = Rainy Season Gray= Flood Season**

### 3.2 DISCUSSION

In this study, mean annual temperature variations varied from  $28.84 \pm 0.88^\circ\text{C}$  and  $28.91 \pm 0.50^\circ\text{C}$  in sectors IV and V respectively. These high lagoon water temperature values in our study area are due to sunshine. These values are similar to those found in sectors IV and V of the Ebrié Lagoon by Atsé et al, (2009) and Konan (2010) [14,15]. These authors found temperatures ranging from  $26.3$  to  $30.7^\circ\text{C}$  in the western part of the Ebrié lagoon. Overall, thermal stability was observed in sectors IV and V of the Ebrié lagoon. This situation is observed in lagoons in the tropical zone. This result was also observed in studies carried out in the Fresco and Grand-Lahou lagoons [16,17]. These slightly elevated temperature values are likely to catalyze biological, biochemical and chemical reactions. They can also promote the metabolic activity of aquatic organisms and, finally, the development of thermophilic species, leading to an ecological disturbance that is harmful to living beings in this environment [18]. The waters of the Ebrié lagoon in Sectors IV and V alternate between acidic and basic characteristics. These are acidic during the rainy season in sector IV (Table 2A) and alkaline during the dry season in sector V (Table 2B). The basic character of the waters is due to the influence of marine waters on all the stations during this period. On the other hand, the acidity of the water during the rainy season could be explained by inputs from the Agneby and Bandama rivers via the Azagny canal, on the one hand, and by the discharge of chemical effluents from agri-food factories and human activities on banana plantations, on the other, of oil palm and rubber trees in the Dabou and Jacquville area [19,20]. Varlet's work on surface water in the same areas gave pH values below 6 [21]. It is generally accepted that pH values between 6.5 and 8.5 characterize waters where aquatic life develops normally [22]. Thus, pH values obtained in sectors IV and V are favorable to aquatic life. Dissolved oxygen is essential for life in aquatic environments [23]. Aquatic life is threatened below 5 mg/L (3 mg/L for carp), according to Pearce

and Schumann (2003) [24]. The mean annual dissolved oxygen values obtained during this campaign were  $5.75 \pm 1.28$  mg/L and  $6.19 \pm 1.47$  mg/L in sectors IV and V respectively. Aquatic life appears to be more normal in sector V than in sector IV. Furthermore, the lowest value obtained during this study was 3.45 mg/L. This value was recorded during the flood season at N'djem (sector IV). This result could be explained, on the one hand, by the proximity of this station to the Philippe Grégoire YACE bridge under construction at the time, when large machines used viscous soils to run their engines and, on the other hand, by run-off water carrying large quantities of organic matter and humic acids from anthropic activities and industrial plantations (Sicoro mill). The aerobic decomposition of these organic fats depletes the aquatic environment of oxygen [9]. In this study, the mean value ( $3.38 \pm 2.14$ ) found in sector IV is higher than the mean value ( $3.03 \pm 1.55$ ) obtained in sector V. This result could be explained by the fact that sector IV is closer to the Vridi canal and therefore more influenced by marine waters than sector V, which is further from the Vridi canal. The highest seasonal salinity values were observed in the dry season in sector IV at N'djem (7.51) and Songon (6.88). This situation is due to a combination of two phenomena. The phenomenon of excessive evaporation due to the sun's rays during this period, and the direct action of marine waters on the two stations due to their proximity to the Vridi canal [25]. The lowest seasonal values were observed during the flood season at Layo (0.24) and Papoga (0.24), also in sector IV. These low levels can be explained by significant inputs from runoff and the Agneby River [26]. In this study, transparency is relatively low at all stations. Mean transparency values in sectors IV and V were ( $0.86 \pm 0.18$ ) m and ( $1.46 \pm 0.42$ ) m. These values are comparable with those of Konan (2010), Bodji (2015) and Djadji (2015), who showed that in the western part of the Ebrié lagoon, transparency varied between 0.4 and 4 m [15, 27, 28]. These low transparency values are thought to be due to the combination of a strong phytoplankton population and strong bottom currents that bring suspended particles to the surface [29].

In this campaign, the mean annual values recorded for suspended solids (SS) were ( $16.22 \pm 4.51$ ) mg/L and ( $8.87 \pm 4.96$ ) mg/L in sectors IV and V respectively. This means that the water in sector IV is more turbid than in sector V. The high suspended solids values in our study area could be attributed to extensive agricultural practices and urban and industrial activities in the study area. High suspended solids values can disrupt photosynthesis by preventing the diffusion of light rays into the water, leading to a reduction in dissolved oxygen production and the transport of toxic waste [30].

#### **4. CONCLUSION**

Western zone waters of the Ebrié lagoon, in particular sectors IV and V, have a slightly high thermal stability, which could favor the development of thermophilic species, causing an ecological disturbance for living beings. The waters of this zone are acidic during the rainy season in sector IV and alkaline during the dry season in sector V. The waters of Sectors IV and V are influenced by marine waters and the contribution of the Agneby and Bandaman rivers via the Azagny canal and the discharge of chemical effluents from agri-food plants and human activities. The aquatic environment at Ndjemispor in dissolved oxygen, in the vicinity of large machines introduced into the water to build infrastructure. Public authorities need to regulate using of these machines in the aquatic environment during major

works. Overall, aquatic life is almost normal in both sectors. However, the waters of sector IV are more turbid than those of sector V. Average salinity values show the influence of the Vridi Canal on these two sectors. The high levels of suspended solids in our study area could be attributed to extensive agricultural practices and urban and industrial activities in the study area. These can disrupt photosynthesis by preventing the diffusion of light rays in the water, leading to a reduction in the production of dissolved oxygen and carrying toxic waste harmful to fish and humans. Further studies are needed to determine whether the waters of sectors IV and V of the Ebrié Lagoon may be the cause of massive fish mortality.

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