Assessment of physico-chemicalparameters 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 inflowsfrom the Agneby and Bandamanrivers, as well as chemical effluent dischargesfrom agri-food plants and humanactivities. The objective of thisworkis to study water quality in the western part of the Ebrié Lagoon. Water sampleswerecollected in sectors IV and V of the Ebrié lagoonfromeleven stations duringfebruary 2014 to january 2015.Temperature, pH, dissolvedoxygen and salinityweremeasured*in situ* by a multi-parameter. Transparencywasmeasured by a Secchi disc. Water samples for suspendedsolidscollected are determinedusing the methoddescribed by Aminot and Chaussepied. The resultindicatethat, meanannualtemperaturevariedbetween 28.84 ± 0.88°C and 28.91 ± 0.50°C in sectors IV and V respectively. In sector IV, the water isacidicduring the rainyseason,and alkalineduring the dry season in sector V. Meanannualdissolvedoxygen values obtainedduringthiscampaignwere 5.75 ± 1.28 mg/L and 6.19 ± 1.47 mg/L in sectors IV and V respectively. Aquatic life appears to be more normal in sector V than in sector IV. Meansalinity values showed the influence of the Vridi Canal on thesetwosectors. Meantransparency values werelow.averagesuspendedsolids values were high, especially in sector IV with 16.22 mg/L. The waters of sector IV are more turbidthanthose of sector V. There is a risk of disruptingphotosynthesis and production of toxicwasteharmful to fish and humans in ourstudy area.

Keywords : *Water quality, seasonal trends,water pollution*.

1. INTRODUCTION

In Côte d'Ivoire, the Ebrié lagoonreceives agricultural, domestic and industrialwastecontaining contaminants, mainlythrough drainage and the discharge of untreated effluent [1,2]. The Ebrié lagoonalsoreceives pollution fromfreshwater and marine waters through exchanges [3].As a result, all threeforms of pollution organic, microbial and chemical are present in the lagoon. Thesedifferent types of pollution lead to disturbances in the lagoon system, notably a reduction in aquaticorganisms and dissolvedoxygen, and the appearance of invasive aquatic plants [4].The adverse effects of lagoon pollution have been observedmainly on aquatic life [5,6].In 2013, sectors IV and V of the Ebrié lagoonrecorded major fishkills. These massive fishkills, which are nowrecurrent in thesetwosectors, are detrimental to the riverside population, whichisheavilydependent on fishresources.These pollutions also have negative impacts on humanhealth and the degradation of water quality [7]. In addition, climate change, whichisinducingextremephenomenasuch 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-chemicalparametersprovides information on water quality. Water qualityisassessed by physico-chemicalparameterssuch as temperature, pH, dissolvedoxygen, salinity, transparency and suspendedsolids. Temperatureplays an important role in the solubility of certain salts and gasesrequired for the equilibrium of aquatic life. pHisinfluenced by the physico-chemicalequilibriumbetween water, dissolvedcarbondioxide and the buffered solutions carbonates and bicarbonates [8]. Low pH values (acidic waters) increase the risk of pollutantsbeingpresent in more toxicionicform. On the other hand, high pH values (basic waters) increaseammonia concentrations, which are toxic to fish. Dissolvedoxygenlevels are favored by contact of the water body with the atmosphere, aeration (rapid water movement), oxygen-producingphotosynthesis and temperature. Salinityis a parameterthatprovides an indication of a water'sdegree of mineralization. It highlights the ionic concentration and abundance of dissolvedsalts (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 photosyntheticorganisms (phytoplankton, macroalgae, etc.) growing in the water column. Suspendedsolids can be a hazard to the aquaticenvironment and to humans. In addition, suspendedsolids are a means of accumulatingtoxicwaste in living organisms, becoming a poison that causes fishmortality[11]. In fact, they are deposited on phytoplanktonconsumed by fish.

2. MATERIAL AND METHODS

2.1Study area(Include the location map of study area i.e. country, state etc.)

The study area coverssectors IV and V. Sectors IV and V of the Ebrié lagoonrepresent the western part of the lagoon, encompassing the departments of Dabou and Jacqueville (Figure I). The twosectorsrepresent an area of 305 km^2 and a water volume of 1.24 km^3.

2.2. Water sampling

Water sampleswerecollectedmonthly in sectors IV and V fromFebruary 2014 to January 2015. Five stations wereselected in sector IV including Songon, N'Djem, Papoga, Taboth and Layo. Six stations Bapo, Koko, Ahua, Abraco, Mopoyem and Gboubo in sector V werealsoselected (Figure 1).

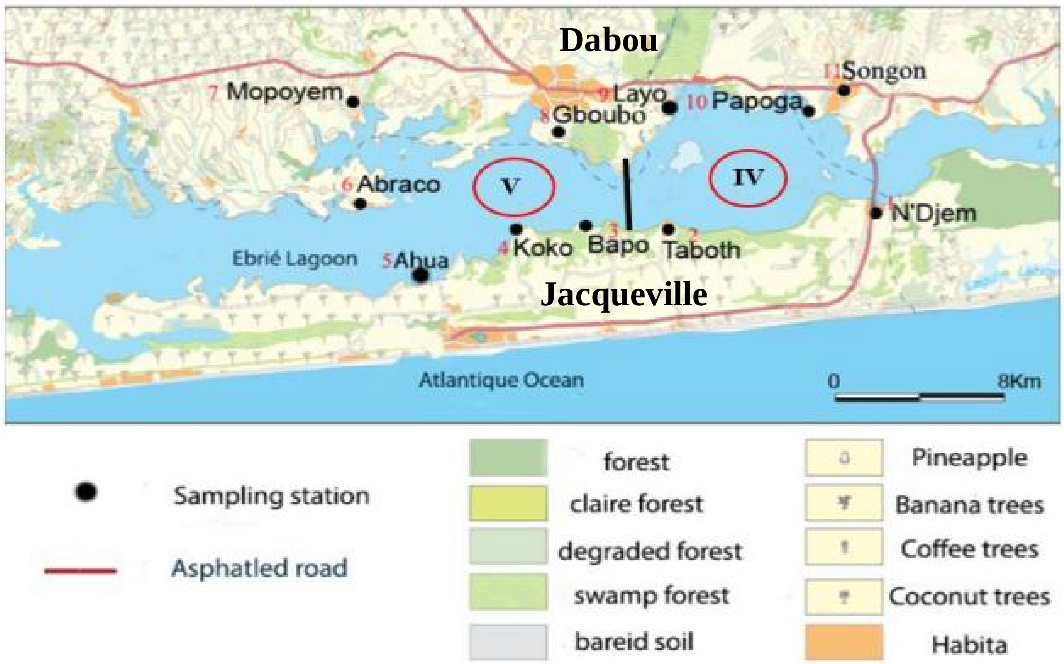

Figure 1 : ***Location of sampling sites (round) in sectors IV and V of Ebrié Lagoon, Côte d'Ivoire Sampling stations (1 N'djem, 2 Taboth, 3 Bapo, 4 Koko, 5 Ahua, 6 Abraco, 7 Mopoyem, 8 Gboubo, 9 Layo, 10 Papoga, 11 Songon)***

2.2. Determination of physico-chemicalproperties of water

A YSI 6920 multi-parameterwasused to measuretemperature, pH, salinity and dissolvedoxygen. This deviceconsists of a probe withelectrodes to beimmersed in the water and an electronic box (calibratedvoltmeter) displaying the values according to the parameter. Transparencywasmeasuredusing a Secchi disk, whichconsists of a weighted string graduated in centimeters (cm) and a disk. Finally, suspendedsolidsweredeterminedusing 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, dissolvedoxygen and pH weremeasured in situ using a YSI 6920 V2 multi-meter. Measurementsweretaken in the first 0.5 m of water depth. The meteriscalibratedbefore use, and the probe isimmerseddirectly in the water. Measurements are displayedautomatically.

Transparencyismeasuredusing the Secchi method. The Secchi diskisimmersed in water by means of a ropeuntilitdisappearscompletely. The disc isthenslowlyraised. As soon as itreappears, the distance separating the diskfrom the water surface isnoted, corresponding to the transparency (AFNOR 1997)[12].

Suspendedsolids (SS) are determinedusing the methoddescribed by Aminot and Chaussepied (1983)[13]and AFNOR standard NF T90-105 (1997) [12]. In the laboratory, 250 ml of the water to beanalyzedisfilteredthrough a membrane filter to retain all particleslargerthan 5 µm. The membrane isdried and weighedbefore and after filtration.

The difference in mass isused to determine the total dry mass of suspendedsolids. The filters are washedwithdistilled water and placed in an oven at 450-500°C for one hour. Eachfilteriscooled in a desiccator and weighed to obtain a mass m1. Twohundred and fifty (250) ml of eachsampleismeasured, homogenized by vigorousshaking and filtered. The filters are thenrinsedtwicewith 5 to 10 ml of distilled water, thenoven-dried at 70°C for twohours. Finally, the filterisweighed to the nearest 0.01 mg, giving us a mass m2. The quantity of dry matterisdeterminedaccording to the formula :

$$[MES] = \frac{m2 - m1}{V} \quad (4)$$

Where:

m1: filter mass before filtration (mg)

m2: filter mass after filtration and drying (mg)

V: volume of filtered water (ml).

2.3. Statisticalanalysis

All statisticaltreatments:means, standard deviations, comparisons, correlations, ANOVA and graphicalrepresentationswerecarried out using STATISTICA (version 7.1) and Microsoft Excel 2013.

3. RESULTS AND DISCUSSION

3.1 Results

The physico-chemicalparametersselected for thisstudy are temperature (°C), hydrogenpotential or pH, dissolvedoxygen (mg/L), salinity, transparency (m), and suspendedsolids (mg/L). The annual and seasonalmean values measured at the 11 stations in sectors IV and V are shown in Table1 (A and B) and Table 2 (A and B) respectively. The seasonal variation profiles for each station in the twosectors are shown in Figures 2 (a to f). The dry seasoncovers the periodfromDecember to March, the rainyseasonfrom April to July and the flood seasonfrom August to November.

Table 1 (A and B): Averageannual values for physico-chemicalparameters.Temperature (T) Dissolvedoxygen (O_2), Salinity (Sal), Transparency (Trans), Suspendedsolids (SS).

A	Sector IV
	Annual
T(°C)	28,84 ± 0,88
pH	7,13 ± 0,25
O_2(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_2(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) : Annualseasonal variation in physico-chemicalparameters
A= Sector IV and B = Sector V.Values withsuperscriptletters a, b and c show a differencebetweenseasons.

	Sector IV		A
	Seasons		
	Dry	Rainy	Flood
T(°C)	29,80 ± 0,23^{c}	28,76 ± 0,50^{b}	27,97 ± 0,54^{a}
pH	7,34 ± 0,08^{b}	6,90 ± 0,12^{a}	7,15 ± 0,27^{ab}
O_2(mg/L)	6,61± 1,34	5,41 ± 0,95	5,24 ± 1,30
Sal	4,97 ± 2,04^{b}	3,64 ± 1,77^{ab}	1,53 ± 1,14^{a}
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
T(°C)	29,48 ± 0,21[c]	28,89 ± 0,20 [b]	28,36 ± 0,06 [a]
pH	7,25 ± 0,12	7,25 ± 0,34	6,95 ± 0,33
O_2 (mg/L)	4,90 ± 0,59[a]	7,31 ± 1,21[b]	6,35 ± 1,41[ab]
Sal	2,82 ± 0,42 [a]	3,85 ± 0,81[b]	2,41 ± 0,32 [a]
Trans (m)	1,30 ± 0,16	1,28 ± 0,13	1,79 ± 0,60
SS (mg/L)	8,84 ± 2,17	9,73 ± 5,08	8,03 ± 7,17

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_2**	**Sal**	**Trans**	**SS**
	Dry	29,73 ± 0,46	7,29 ± 0,60	5,75 ± 0,21	7,51 ± 0,22^{a}	0,77 ± 0,09	16,60 ± 2,38^{a}
N'djem	**Rainy**	29,23 ± 0,40	6,97 ± 0,68	4,77 ± 0,48	5,44 ± 0,66^{a}	0,95 ± 0,04	11,16 ± 2,08^{b}
	Flood	28,38 ± 0,35	7,44 ± 0,29	3,45 ± 0,41	2,73 ± 0,42^{b}	0,77 ± 0,04	14,06 ± 2,14^{b}
	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
Taboth	**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
	Dry	29,86 ± 0,42	7,39 ± 0,56	6,23 ± 0,46	6,88 ± 0,10^{a}	1,02 ± 0,19	17,61 ± 2,75^{a}
Songon	**Rainy**	29,23 ± 0,38	6,76 ± 0,51	5,30 ± 0,38	5,57 ± 0,84^{a}	0,95 ± 0,17	13,23 ± 1,63^{b}
	Flood	28,26 ± 0,25	7,35 ± 0,17	4,53 ± 0,22	1,85 ± 0,22^{b}	0,65 ± 0,04	12,51 ± 2,63^{b}
	Dry	30,03 ± 0,45	7,47 ± 0,43	8,98 ± 2,31	3,66 ± 0,67	0,87 ± 0,15^{a}	15,36 ± 2,30^{a}
Papoga	**Rainy**	28,53 ± 0,26	6,91 ± 0,81	7,09 ± 1,36	2,67 ± 0,35	0,90 ± 0,20^{b}	14,16 ± 3,12^{a}
	Flood	27,24 ± 0,25	7,03 ± 0,31	6,65 ± 0,93	0,42 ± 0,22	0,55 ± 0,10^{c}	29,56 ± 5,77^{b}
	Dry	29,97 ± 0,44	7,30 ± 0,6	6,32 ± 0,25	3,42 ± 0,67^{a}	0,77 ± 0,05	16,16 ± 2,17^{a}
Layo	**Rainy**	28,03 ± 0,29	6,82 ± 0,73	4,91 ± 0,11	1,58 ± 0,28^{b}	0,65 ± 0,13	19,89 ± 2,91^{b}
	Flood	27,54 ± 0,42	6,74 ± 0,42	5,29 ± 0,01	0,24 ± 0,15^{b}	0,77 ± 0,04	20,75 ± 2,49^{b}

suspendedsolids (SS: mg/L), a= Sector IV and b = Sector V. Values withsuperscriptletters a, b and c show a differencebetweenseasons.

	Season	Temp	pH	O_2	Sal	Transp	SS
	Dry	29,69 ± 0,33	7,43 ± 0,64	5,86 ± 2,07	2,80 ± 0,80^{a}	1,31 ± 0,16^{a}	6,79 ± 0,97^{a}
Bapo	**Rainy**	28,87 ± 0,94	7,55 ± 0,83	8,59 ± 1,85	4,30 ± 0,30^{b}	1,45 ± 0,30^{b}	6,95 ± 0,62^{a}
	Flood	28,35 ± 0,60	7,09 ± 0,38	4,66 ± 1,97	2,50 ± 0,50^{c}	2,07 ± 0,29^{c}	22,35 ± 5,31^{b}
	Dry	29,40 ± 0,62	7,29 ± 0,39	4,35 ± 1,38	2,78 ± 0,75^{a}	1,57 ± 0,17^{a}	11,56 ± 4,02^{a}
Koko	**Rainy**	29,05 ± 0,91	7,46 ± 0,70	8,54 ± 1,98	4,41 ± 0,11^{b}	1,30 ± 0,16^{b}	4,12 ± 0,71^{b}
	Flood	28,35 ± 0,41	7,13 ± 0,25	8,88 ± 2,68	2,70 ± 0,19^{c}	2,54 ± 0,06^{c}	3,72 ± 1,05^{b}
	Dry	29,24 ± 0,36	7,34 ± 0,37	4,61 ± 0,45^{a}	2,76 ± 0,76	1,37 ± 0,05	7,25 ± 0,50^{a}
Ahua	**Rainy**	28,95 ± 0,47	7,52 ± 0,71	7,20 ± 0,02^{b}	2,27 ± 0,10^{b}	1,35 ± 0,13	8,75 ± 2,34^{b}
	Flood	28,31 ± 0,31	7,23 ± 0,18	6,24 ± 0,23^{b}	2,59 ± 0,27^{c}	1,23 ± 0,08	5,72 ± 1,60^{c}
	Dry	29,80 ± 0,12	7,15 ± 0,77	5,06 ± 1,31	2,75 ± 0,83^{a}	1,17 ± 0,53^{a}	6,83 ± 2,28
Abraco	**Rainy**	28,87 ± 0,21	6,73 ± 0,41	7,00 ± 0,66	4,31 ± 0,10^{b}	1,20 ± 0,48^{b}	7,74 ± 2,05
	Flood	28,48 ± 0,01	6,38 ± 0,64	6,53 ± 1,63	2,50 ± 0,26^{c}	2,32 ± 0,05^{c}	4,75 ± 1,51
	Dry	29,32 ± 0,10	7,08 ± 0,87	4,34 ± 1,41	2,27 ± 0,80^{a}	1,12 ± 0,28	9,53 ± 3,18^{a}
Mopoyem	**Rainy**	29,11 ± 0,10	6,94 ± 0,59	5,28 ± 0,67	3,67 ± 0,35^{b}	1,07 ± 0,09	18,63 ± 3,22^{b}
	Flood	28,30 ± 0,56	6,73 ± 0,28	5,50 ± 1,26	1,79 ± 0,10^{c}	1,08 ± 0,20	7,85 ± 4,25^{a}
	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^{a}
Gboubo	**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^{a}
	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^{b}

3.1.1Temperature

Overall, temperatures are slightlyhigher in sector V than in sector IV (Figure 2a). The meantemperature values in the surface waters of the Ebrié lagoonfromFebruary 2014 to January 2015 are 28.84 ± 0.88°C and 28.91 ± 0.50°C in sectors IV and V respectively (Table 1 (A and B)).

The highestmeantemperature (30.03 ± 0.45°C) wasrecordedduring the dry season at Papoga in sector IV (Table 3a) and the lowestmean (27.24 ± 0.25) wasmeasuredduring the flood seasonalso in sector IV and in the samelocality. Statisticalanalysis (ANOVA) showed a significantdifference ($p <0.05$) between the threeseasons (Table 1 (A and B)) in bothsectors.

3.1.2.pH

Surface waters sampled in sectors IV and V alternatebetween basic and acidic. Hydrogenpotential (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 ± 0.25 and 7.15 ± 0.27 in sectors IV and V respectively, indicatethatthese waters are generallyalkaline (Table 1). The alkalineenvironmentismostpronouncedduring the rainyseason at Bapo (7.55 ± 0.83) in sector V (Table 3B). The Abraco station (sector V) recorded the mostacidiccharacter (pH= 6.38) of thiscampaign (Table 3B). Furthermore, the ANOVA test for pH shows a significantdifference ($p < 0.05$) only in sector IV between the dry and rainyseasons.

3.1.3 Dissolvedoxygen

Meandissolvedoxygen values are 6.61 ± 1.34 mg/L and 4.90 ± 0.59 mg/L in the dry season, 5.41 ± 0.95 mg/L and 7.31 ± 1.21 mg/L in the rainyseason, and 5.24 ± 1.3 mg/L and 6.35 ± 1.41 mg/L in the flood season for sectors IV and V respectively (Table 2 (A and B)). Annual values are 5.75 ± 1.28 mg/L and 6.19 ± 1.47 mg/L in sectors IV and V respectively (Table 1 (A and B)). Overall, dissolvedoxygen values in sector V werehigherthanthoseobtained in sector IV. Statisticalanalysis (ANOVA) revealed a significantdifference ($p < 0.05$) only for sector V between dry and rainyseasons.

3.1.4 Salinity

Salinity varies from 1.53 ± 1.1 in the flood season to 4.97 ± 2.04 in the dry season in sector IV and from 2.41 ± 0.3 in the flood season to 3.85 ± 0.81 in the rainyseason in sector V (Table2 (A and B)). Mean values are 3.38 ± 2.14 and 3.03 ± 1.53 in sectors IV and V respectively. Overall, the salinity values measured in sector IV are higherthanthosefound in sector V. The highest values werefound at N'djem (7.51 ± 0.22) and Songon (6.88 ± 0.10) during the dry season in sector IV (Table 3A). Statisticalanalysis (ANOVA) shows a significantdifference ($p <0.05$) betweenseasons for bothsectors.

3.1.5 Transparency

Transparencyislow in sectors IV and V. Meantransparency values observed over the threeseasonswerelower in sector IV than in sector V (Figure 2e). Annual values were 0.86 ± 0.18 m and 1.46 ± 0.42 m in sectors IV and V respectively (Table 1 (A and B)). The highest values wereobserved at Koko (2.54 ± 0.06 m) and Abraco (2.32 ± 0.05 m) during the flood season in sector V (Table 3B). The lowest value wasrecorded at Papoga (0.55 ± 0.10 m) during the flood season in sector

IV (Table 3A). Statisticalanalysis (ANOVA) showedthattherewas no significantdifference ($p > 0.05$) between the threeseasons in the twosectors.

3.1.6 Suspendedsolids

Averagesuspendedsolids values over the threeseasons are higher in sector IV than in sector V (Figure 2f). Annual values are 16.22 ± 4.51 mg/L in sector IV and 8.87 ± 4.96 mg/L in sector V (Table 1 (A and B)). The highest value wasobservedduring the flood season (29.56 ± 5.77 mg/L) at Papoga in sector IV. The lowest values wererecorded in sector V, againduring the flood season, at Koko (3.72 ± 1.05 mg/L) and Gboubo (3.82 ± 1.17 mg/L) (Table 3B). In bothsectors, the ANOVA test showed no significantdifference ($p > 0.05$) betweenseasons.

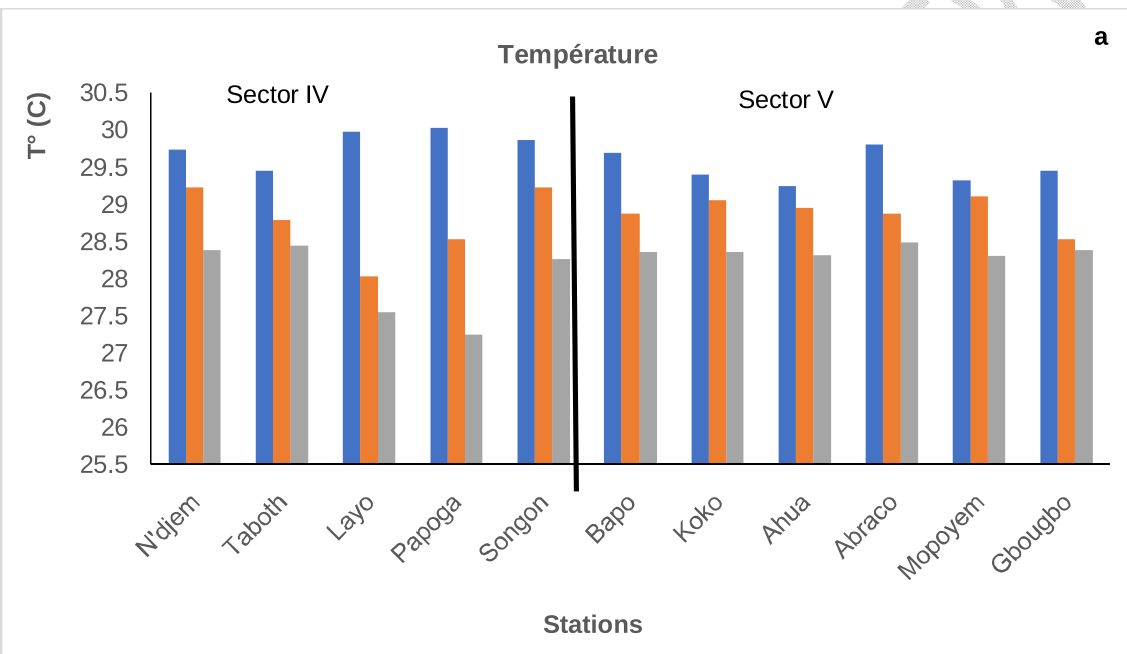

Figure 2a: ***Seasonal variations in water temperature at stations in sectors IV and V of Ebrié Lagoon.Blue = Dry Season Orange = RainySeason Gray= Flood Season***

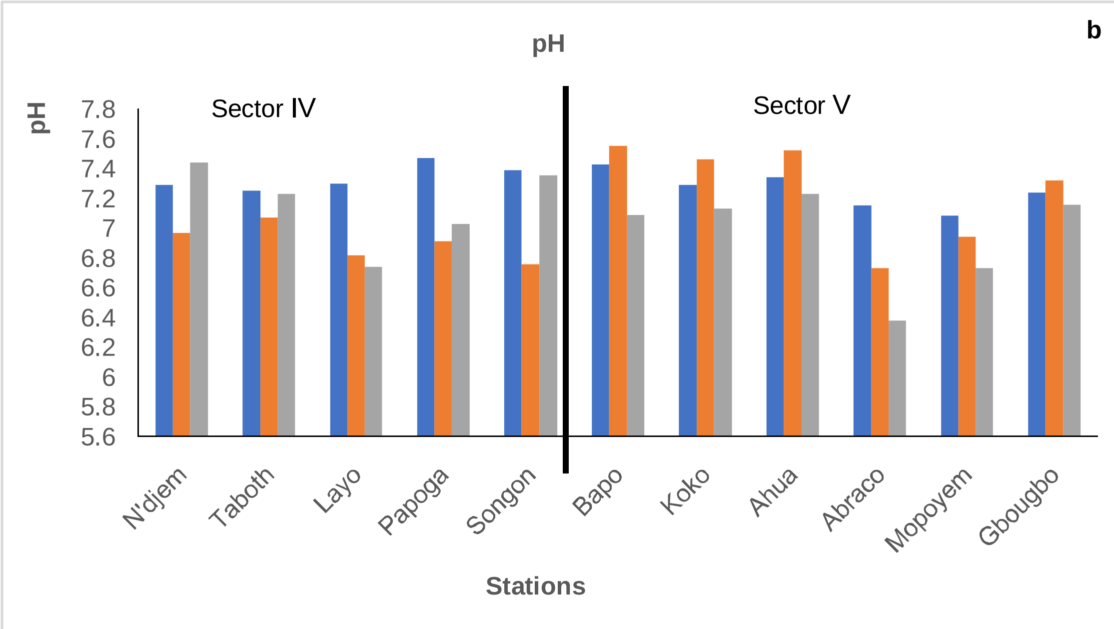

Figure 2c ***Seasonal variations in water temperature at stations in sectors IV and V***
Blue = Dry Season   Orange = RainySeason   Gray= Flood Season

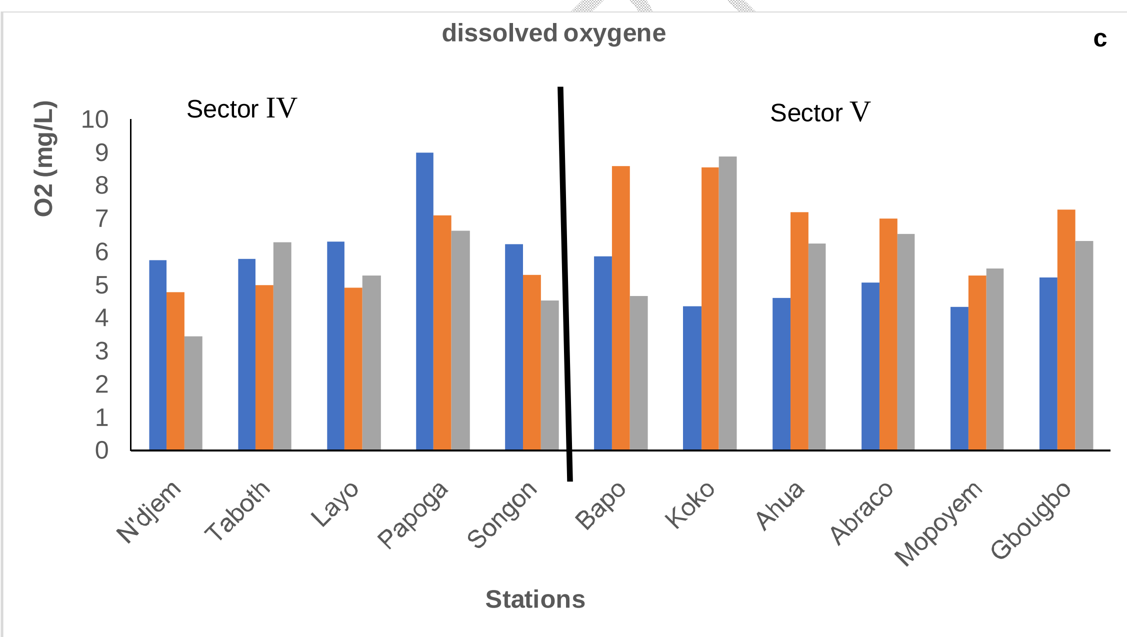

Figure 2c: ***Seasonal variations in dissolvedoxygen in water at stations in sectors IV and V of Ebrié Lagoon*.Blue = Dry Season   Orange = RainySeason   Gray= Flood Season**

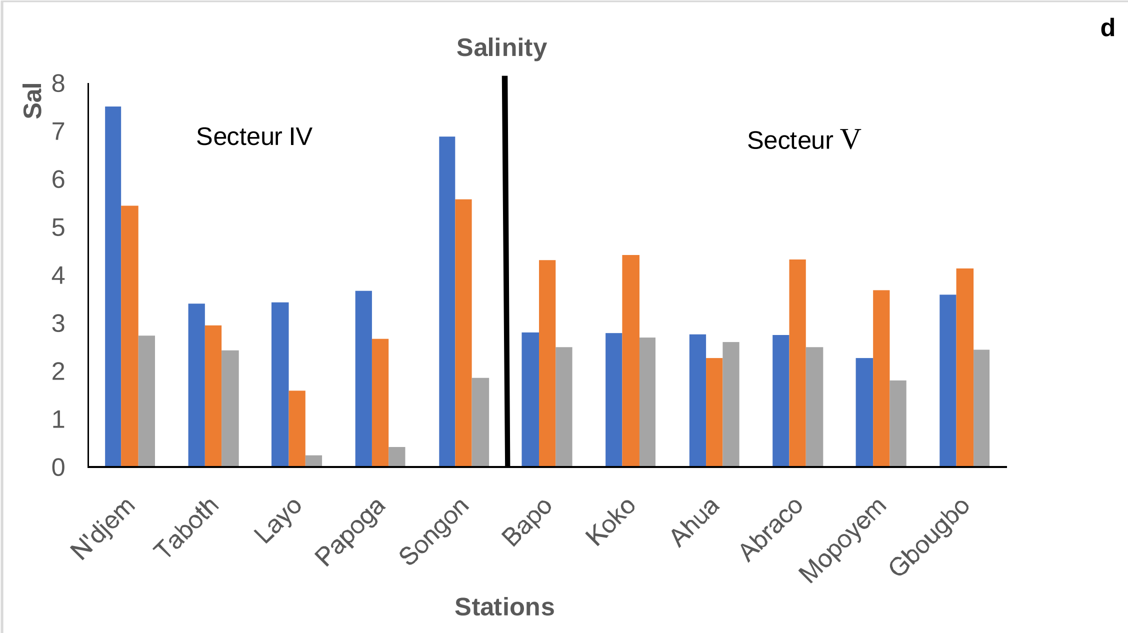

Figure 2d: ***Seasonal variations in water salinity at stations in sectors IV and V of the Ebrié lagoon.*** **Blue = Dry Season   Orange = RainySeason   Gray= Flood Season**

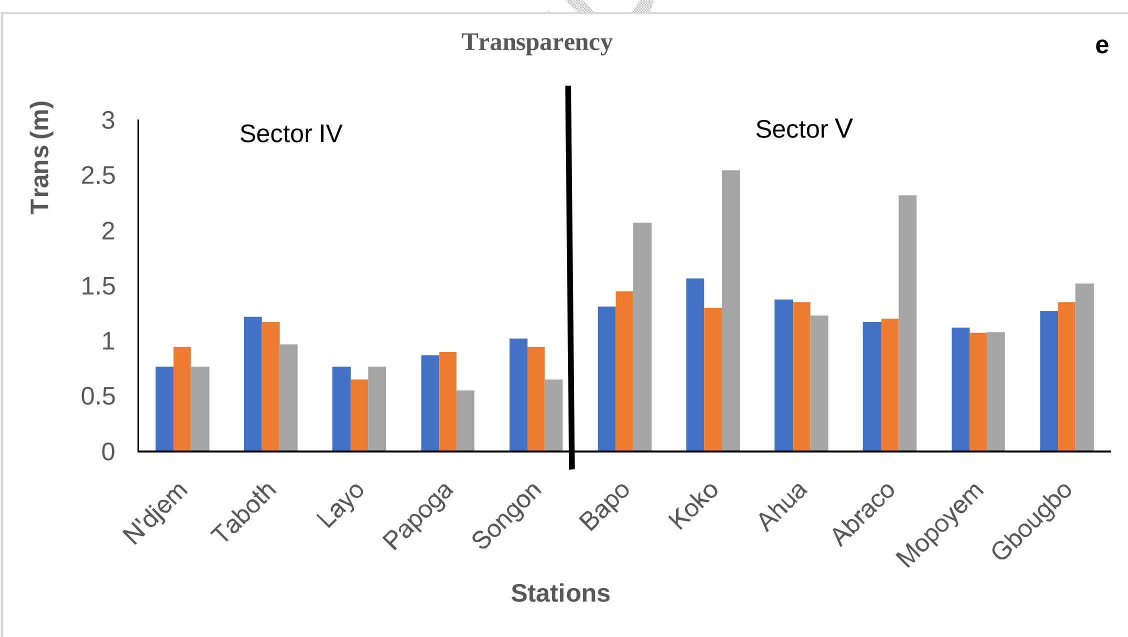

Figure 2e:***Seasonal variations in water transparency at stations in sectors IV and V of the Ebrié lagoon.*** **Blue = Dry Season   Orange = RainySeason   Gray= Flood Season**

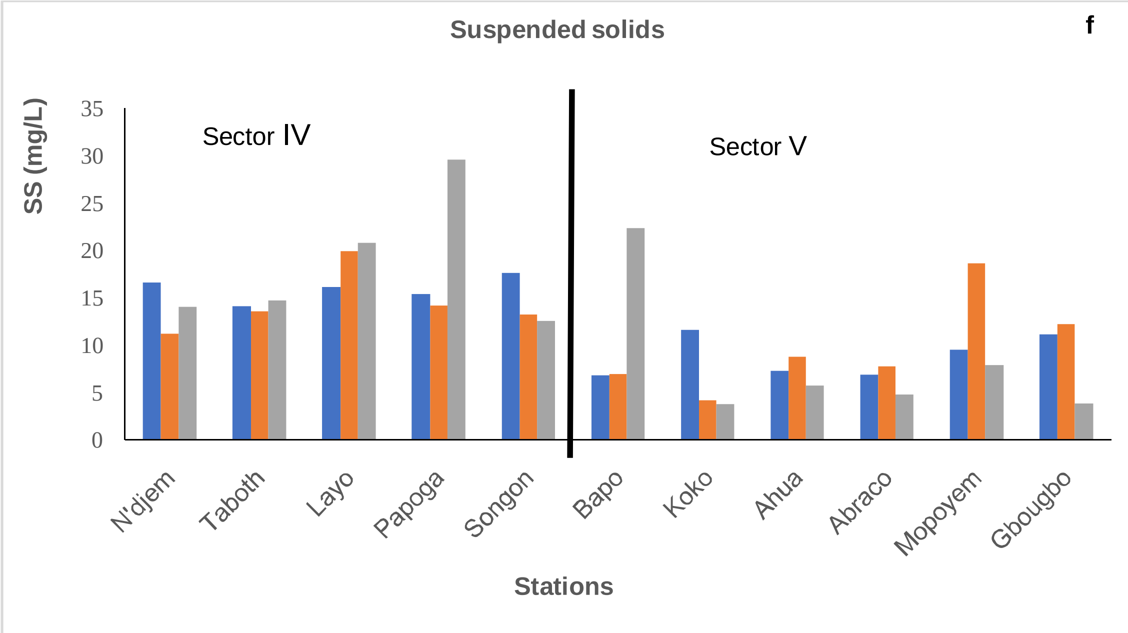

Figure 2f: ***Seasonal variations in suspendedsolids in water at stations in sectors IV and V of the Ebrié lagoon.*****Blue = Dry Season   Orange = RainySeason   Gray= Flood Season**

3.2DISCUSSION

In thisstudy, meanannualtemperature variations variedfrom 28.84 ± 0.88°C and 28.91 ± 0.50°C in sectors IV and V respectively. These high lagoon water temperature values in ourstudy area are due to sunshine. These values are similar to thosefound in sectors IV and V of the Ebrié Lagoon by Atsé et al, (2009) and Konan (2010) [14,15]. Theseauthorsfoundtemperaturesrangingfrom 26.3 to 30.7°C in the western part of the Ebrié lagoon. Overall, thermal stabilitywasobserved in sectors IV and V of the Ebrié lagoon. This situation isobserved in lagoons in the tropical zone. This resultwasalsoobserved in studiescarried out in the Fresco and Grand-Lahou lagoons [16,17]. Theseslightlyelevatedtemperature values are likely to catalyzebiological, biochemical and chemicalreactions. They can alsopromote the metabolicactivity of aquaticorganisms and, finally, the development of thermophilicspecies, leading to an ecologicaldisturbancethatisharmful to living beings in thisenvironment[18]. The waters of the Ebrié lagoon in Sectors IV and V alternatebetweenacidic and basic characteristics. These are acidicduring the rainyseason in sector IV (Table 2A) and alkalineduring 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 duringthisperiod. On the other hand, the acidity of the water during the rainyseasoncouldbeexplained 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-foodfactories and humanactivities on banana plantations, on the other, of oil palm and rubbertrees in the Dabou and Jacqueville area[19,20]. Varlet'swork on surface water in the same areas gave pH values below 6 [21]. It isgenerallyacceptedthat pH values between 6.5 and 8.5 characterize waters whereaquatic life developsnormally[22]. Thus, pH values obtained in sectors IV and V are favorable to aquatic life. Dissolvedoxygenis essential for life in aquaticenvironments[23]. Aquatic life isthreatenedbelow 5mg/L (3mg/L for carp), according to Pearce and Schumann (2003) [24]. The meanannualdissolvedoxygen values obtainedduringthiscampaignwere 5.75 ± 1.28 mg/L and 6.19 ± 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 obtainedduringthisstudywas 3.45 mg/L. This value wasrecordedduring the flood season at N'djem (sector IV). This resultcouldbeexplained, on the one hand, by the proximity of this station to the Philippe Grégoire YACE bridge under construction at the time, when large machines usedviscousoils to run their engines and, on the other hand, by run-off water carrying large quantities of organicmatter and humicacidsfromanthropicactivities and industrial plantations (Sicoroilmill). The aerobicdecomposition of theseorganic fats depletes the aquaticenvironment of oxygen[9]. In thisstudy, the mean value (3.38 ± 2.14) found in sector IV ishigherthan the mean value (3.03 ± 1.55) obtained in sector V. This resultcouldbeexplained by the factthatsector IV iscloser to the Vridi canal and therefore more influenced by marine waters thansector V, whichisfurtherfrom the Vridi canal. The highestseasonalsalinity values wereobserved in the dry season in sector IV at N'djem (7.51) and Songon (6.88). This situation is due to a combination of twophenomena. The phenomenon of excessive evaporation due to the sun's rays duringthisperiod, and the direct action of marine waters on the two stations due to theirproximity to the Vridi canal [25]. The lowestseasonal values wereobservedduring the flood season at Layo (0.24) and Papoga (0.24), also in sector IV. Theselowlevels can beexplained by significant inputs fromrunoff and the Agneby River [26]. In thisstudy, transparencyisrelativelylow at all stations. Meantransparency values in sectors IV and V were (0.86 ± 0.18) m and (1.46 ± 0.42) m. These values are comparable withthose of Konan (2010), Bodji (2015) and Djadji (2015), whoshowedthat in the western part of the Ebrié lagoon, transparencyvariedbetween 0.4 and 4 m [15, 27, 28]. Theselowtransparency values are thought to be due to the combination of a strong phytoplankton population and strongbottomcurrentsthatbringsuspendedparticles to the surface [29].

In thiscampaign, the meanannual values recorded for suspendedsolids (SS) were (16.22 ± 4.51) mg/L and (8.87 ± 4.96) mg/L in sectors IV and V respectively. This meansthat the water in sector IV is more turbidthan in sector V. The high suspendedsolids values in ourstudy area couldbeattributed to extensive agricultural practices and urban and industrialactivities in the study area. High Suspendedsolids values can disruptphotosynthesis by preventing the diffusion of light rays into the water, leading to a reduction in dissolvedoxygen production and the transport of toxicwaste[30]. Bhutekar et al. [31] alsodocumented the similarresultswith respect to the water quality of Godavari river in India. The quality of water determines the healthy habitat for aquaticorganisms. The poor water quality causes adverse impact on the aquatic system [32].Based on water quality of the water body, a comprehensiverestoration can beplanned [33].

4. CONCLUSION

Western zone waters of the Ebrié lagoon, in particularsectors IV and V, have a slightly high thermal stability, whichcouldfavor the development of termophilicspecies, causing an ecologicaldisturbance for living beings. The waters of this zone are acidicduring the rainyseason in sector IV and alkalineduring 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 Bandamanrivers via the Azagny canal and the discharge of chemicaleffluents from agri-food plants and humanactivities. The aquaticenvironment at Ndjemispoor in dissolvedoxygen, in the vicinity of large machines introducedinto the water to build infrastructure. Public authoritiesneed to regulateusing of these machines in the aquaticenvironmentduring major works. Overall, aquatic life isalmost normal in bothsectors. However, the waters of sector IV are more turbidthanthose of sector V. Averagesalinity values show the influence of the Vridi Canal on thesetwosectors. The high levels of suspendedsolids in ourstudy area couldbeattributed to extensive agricultural practices and urban and industrialactivities in the study area. These can disruptphotosynthesis by preventing the diffusion of light rays in the water, leading to a reduction in the production of dissolvedoxygen and carryingtoxicwasteharmful to fish and humans.Furtherstudies are needed to determinewhether the waters of sectors IV and V of the Ebrié Lagoon maybe the cause of massive fishmortality.

REFERENCES

[1] Yao, K. M. Métongo., S. B., Trokourey, A., &Yobou, B. (2009) Assessment of sediment contamination by heavymetals in a tropical lagoonurban area (Ebrié lagoon, Côte d'Ivoire). International Journal of Biological and Chemical Sciencesvol 3, pp. 755- 770.

[2] Coulibaly, A. S., Monde, S., Wognin, A. V., & Aka, K. (2010). Dynamics of trace metalelements in sediments of the bays of Abidjan (Bay of Banco and harbor). European Journal of Scientific Research, vol. 46, pp. 204-215.

[3] Kouassi, A.M., Tidou, A.S. and Kamenan, A. (2005) Hydrochemical and microbiologicalcharacteristics of the waters of the Ebrié lagoon (Côte d'Ivoire). AfricanAgronomy, 17, 73-162. https://doi.org/10.4314/aga.v17i2.1663.

[4] Koffi, S.O., Coffy, A.A., Villeneuve, J.P., Sess, D.E. and N'Guessan, Y.T. (2009) Pollution of a Tropical Lagoon by the Determination of OrganochlorineCounts. Tropicultura, 27, 77-82.

[5] Grall, J., Clemarec, M. (1997). Usingbioctic indices to estimatemacrobenthiccommunitydisturbances in the Bay of Brest, Estuarine Coastal and shelf science, 44 supplement A 43 -53.

[6] Gnohoussou, P. (2002). Influence of organic pollution on invertebrates of Lake Nakoué, Advanced AgronomyDiplomaThesis. National School of Agronomy of Toulouse (ENSAT) France.

[7] Tuo, A.D., Soro, M.B., Trokourey, A., and Bokra, Y. (2012) Assessment of Waters Contamination by Nutrients and Heavy Metals in the Ebrie Lagoon (Abidjan, Ivory Coast). Research Journal of EnvironmentalToxicology, 6, 198-209.

[8] El Oumlouki, K. (2014). Study of the physicochemicalquality of water and soils in the Souss Massa region (Case of Issenperimeter), Morocco. J. Mater. Environ. Sci. Vol. 5 (S2) p. 2365-2374.

[9] Yao, K.M. (2004). Determination of certain pollution parameters in certain bays of the Abidjan lagoon (Côte d'Ivoire). DEA thesis. University of Cocody, Côte d'Ivoire, 78 p.

[10] Gnohoussou, P., (2002). Influence of organic pollution on invertebrates of Lake Nakoué. Diplomathesis in Advanced Agronomy. National School of Agronomy of Toulouse (ENSAT). France, 49p.

[11] Guiral D., and Chantraine, J. M. (1983). Hypothesis on the origin of the mortalitiesobserved in the Ebrié lagoonin 1979. Document. Scientific. OceanographicResearch Center, Abidjan 14 (2), 61-95.

[12] AFNOR., 1997. Water quality, collection of French standards. Editions AFNOR, Paris, 46 p.

[13] Aminot, A. Chaussepied, M. (1983). Manual of chemical analyses in the marine environment. CNEXO, Editions Jouve, Paris, p.320-395.

[14] Atsé, B.C., Konan, K.J., and Kouassi, N.J. (2009). Reproductive biology of the CichlidaeTylochromisjentinki (Steindachner, 1895) in the Ebrié lagoon (Côte d'Ivoire). Cybium, vol. 33 p.11-19.

[15] Konan, K.J. (2010). Study of population parameters, reproductive biology and feedingstrategies of the CichlidaeTylochromisjentinki (Steindachner, 1895) in the Ebrié Lagoon (Côte d'Ivoire). Doctoral Thesis. University of Cocody Abidjan, Côte d'Ivoire, 175 p.

[16] ISSOLA, Y. (2008). Physicochemicalcharacteristics of a tropical coastallagoon:Frescolagoon (Côte d'Ivoire). Afrique Science, vol. 04, n°3 p.368 – 393.

[17] Kouassi, A. M. (2005). Hydrochemistry and water quality of two tropical lagoons in Côte d'Ivoire (Ebrié), Grand Lahou. Doctoral thesis, University of Cocody Abidjan, 147 p.

[18] Bakary, I., Soro, M.B., Trokourey, A., Etchian, O.A., and Bokra, Y. (2009). Physicochemicalcharacterizations of surface waters and sediments of the Bay of Billionaires, Ebrié lagoon, Ivory Coast. Ivorian Science and TechnologyReview, vol. 13 p. 139 – 154.

[19] Atta, K. L., Gogbe, T., and Moussoh, A. A. (2014). The problem of foodsupply for a secondary city in the context of city-countryside relations in Adioukrou country: Dabou. Europeanscientific journal, 10 (17), 393-307.

[20] Kouassi, A.E., Ahoussi, K.E., Koffi, Y.B. (2014). Physicochemicalcharacterization of leachatefrom a West Africanlandfill: the case of the Akouedolandfill (Abidjan, Ivory Coast). Larhyss Journal, vol. 19, pp. 63-74.

[21] Marchand, M., and Martin, J-L. (1985). Determination of chemical pollution (hydrocarbons, organochlorines, metals) in the Abidjan lagoon (Ivory Coast) by studyingsediments. Océonogr. Trop. vol. 20, pp. 25-39.

[22] Brussels Institute for Environmental Management / Environmental Data Observatory 2005. Physicochemical and chemicalquality of surface water:generalframework. Main

measurablephysicochemical and chemicalparameters. [Online], [available at] http//:document.environnement .brussels /opac_css/elecfile/ Eau%202 [accessed 26 September 2017]

[23] Koffi, K. M., Coulibaly, S., Atsé B. C., and Kouamelan, E. P. (2014). Survey of Heavy Metals Concentration in Water and Sediments of the estuaryBietri Bay, Ebrie Lagoon, Côte d'Ivoire. International Journal of Resarch in Earth and environmental Science, vol. 1 n°3, p.1-9.

[24] Pearce, M. W., and Schumann, E. H. (2003). Dissolvedoxygencharacteristics of the gamtoosestuary, South Africa. African journal of marine Sciences, 25, 99-109.

[25] Yao, M. K., Yao, K. B., Trokourey, A., and Métongo, S. B., (2010). Assessment of the trophicstatus of the lagoon-bay of Tiagba in Côte d'Ivoire. Australian Journal of Basic and Applied Sciences, 8, 4038-4045.

[26] Kouassi, A. M., Tidou, A. S., and Kamenan, A. (2005). Hydrochemical and microbiologicalcharacteristics of the waters of the Ebrié lagoon (Côte d'Ivoire). AfricanAgronomy, p.117-136.

[27] Bodji, I. M. (2015). Biology and ecology of an AfricanfishPomadasysjubelini (Cuvier, 1830) (Pisces, Haemulidae) in threelagoon complexes (Grand-lahou, Ebrié and Aby) of Ivory Coast. Single thesis in Hydrobiology, Félix Houphouet Boigny University Abidjan, (Ivory Coast), 181 p.

[28] Djadji, E. L. G. (2015). Study of the biological traits and diet of twospecies of mugilidae, Liza Falcipinnis, Valenciennes, 1836 and MugilCephalus, Linnaeaus, 1758, in the Ebrié and Grand-Lahou lagoon complexes, Ivory Coast. Single thesis in Hydrobiology, Félix Houphouet Boigny University-Abidjan (Ivory Coast), 191 p.

[29] Ouattara, M. (2000). Reproduction strategies and reactions to environmental pressures in the AfricanfishMormyropsanguilloides and Marcuseniusussheri (Mormydidae) Schilbemandibularis and S. intermedius (Schilbeidae) (Bia and Agnébi basins, Ivory Coast). Doctoral thesis, Abobo-Adjamé University Abidjan (Ivory Coast), 258 p.

[30] Affian, K., Kadio, B., Djagoua, E. V., Digbehi, Z. B., Monde, S., Wognin, A.M., Krou, D., and Mobio, A. (2008). Flow of suspendedmatterfrom the Comoé River in the Ivoriancoastal zone. CAMES Review, Sciences and Medicine, 6, 88-93.

[31] Bhutekar, D. D., Aher, S. B., &Babare, M. G. (2018). Spatial and seasonal variation in physic-chemicalproperties of Godavari River water at Ambadregion, Maharashtra. *Journal of Environment and Biosciences*, *32*, 15-23.

[32] Bhutekar, D. D., & Aher, S. B. (2019). Biological monitoring of riverineecosystem and itscorrelationwith water quality. *Biosc Biotech ResComm*, *12*, 194-202.

[33] Bhutekar, D. D., Aher, S. B., &Babare, M. G. (2014). Conservation strategies for Kavandi Lake based on water quality. *Current World Environment*, *9*(2), 394.