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Geomorphological Changes at the Estuary of Comoe River (Grand-Bassam, South Eastern Côte d'Ivoire) Due to Suspended Solids Transport

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Authors' contributions

This work was carried out in collaboration between all authors. Author AKL designed the study; the authors LT, DLOZ and KKL corrected the primary draft of the paper. All authors read and approved the final manuscript.

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ABSTRACT

The estuary of Comoe River in Grand-Bassam is facing to a hydrosedimentary dynamics spectacular than the others estuaries of Côte d'Ivoire. The sediments deposits produce a sandbank which breaks the natural contact between Comoe River and Atlantic Ocean. This increases the concentration of solid matters in suspension, the confinement and the invasion of the estuarian environment by aquatic vegetables. This study aims to know the spatio-temporal dynamics of physicochemical parameters, from the suspended solid loads of Comoe River estuary.
The water samplings have been made over two seasonal cycles between 2005 and 2007

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to quantify suspended solid transport. The solid discharges in suspension in the estuary are estimated about 72000 tons of sediments per year. The estuary waters are moderately mineralised and present some pH values near the neutrality. Mineralization is influenced by seasons. The estuary is turbid and slightly oxygenated over every season. The dissolved oxygen averages are 0.5 and 1.6 mg.L^{-1} respectively during the rainy and the dry seasons Comoe River estuary has relatively low salinities (with an average of 1 mg.L^{-1}).

Keywords: Hydrology; suspended matters; estuary; Comoe River; Côte d'Ivoire.

1. INTRODUCTION

The estuarial environments present complex particulate dynamics [1]. The deposits of particles transported by rivers and marine waters modify the morpho-structure of the estuarial landscapes. In addition, the pollutants from various origins, are conveyed by the suspended particles, to affect the quality of estuarial waters and the aquatic life.

In Côte d'Ivoire, the mouths of the large rivers (Comoe, Bandama, Sassandra and Cavally) are confronted to more and more accentuated dynamism which generally causes the displacements of the points of junction river-ocean. In Grand-Lahou, [2,3] report that the mouth of the river Bandama gradually undergoes a migration towards the West.

On the level of the mouth of Comoe River at Grand-Bassam, zone of meeting between the Atlantic Ocean, the Ebrie lagoon and the Comoe River, the hydrosedimentary dynamics is even more spectacular so that the successive deposits of sediments give rise to a sandbank which breaks the natural contact between the river and the ocean [4]. Consequently, the quick filling up of the mouth of Comoe river led to the significant modification of the physicochemical parameters and the fast development of the aquatic plants on the lagoon [5,6] .Dredging operations were carried out to open this mouth which closed again a few years later [7,8,9]. Some operations of opening therefore took respectively place in 1987, 1990 and 2005 after the fillings up observed in 1975, 1989 and 2003. Today, the mouth of Comoe river remains closed and leads to the confinment of the estuarial environment. [2]indicated that the closing of the mouth of Comoe would has considerable consequences at the same time sedimentological (silting), chemical (confinment, dessalure), ecological and economic (fishing, tourism) as well.

The former studies about the hydrosedimentary problems mainly described the hydrological fluctuations of the river and the dynamism of the littoral drift. The spatio-temporal dynamics of the physicochemical parameters, particularly suspended sediment loads of the mouth of Comoe was not studied yet. The comprehension of the dynamics of any alluvial environment lies primarily in the interactions between the water run-off and the carrying of the sediments [10]. This study aims to know the spatio-temporal dynamics of the physicochemical parameters and the annual total assessment of suspended sediment loads in the estuary of Comoe River. This work is integrated in the study of hydrology and sedimentation into the mouth of Comoe River. The finality of this study is the simulation of the hydrosedimentary phenomena in the Comoe estuary.

2. STUDY AREA AND METHODS

2.1 Study Area

The mouth of the Comoe River is located in Grand-Bassam (South-east of Côte d'Ivoire) at the Eastern end of the Ebrie lagoon between the Western longitudes 3º42 and 3º44 and the latitudes 5º12 and 5º14 Northern (Fig. 1).

The basin-side of the Comoe River is a stickler for four different countries (Côte d'Ivoire, Ghana, Burkina Faso and Mali) and covers a surface of 78 000 km^2. Vegetation of the basin of Comoe passes gradually from grassy savannah in the extreme North to the ombrophilous forest in the South [11]. This vegetation underwent significant modifications because of the intensification of agricultural activities and the strong demographic pressure. The principal geological formations of Comoe's estuary are those of the quaternary one. They are essentially made up by muds and sands [7,12]. The climate of the basin is characterized by the tropical mode in the North, the attenuated equatorial mode in the Center and the equatorial transition mode in the South [13,14]. Rainfall and hydrological records respectively collected by the Society of Development, Exploitation and Meteorology (SODEXAM) and the Direction of Human Hydraulics (DHH) permit to appreciate the various seasons in the area of Comoe estuary. There are two rainy seasons (the long season occurs between April and July and the small one between October and November) and two dry seasons (the long season is spread out December till March and the smallest from August to September).

The flows observed in the South of the basin of Comoe are strongly influenced by the tropical mode of transition of the North. This mode generally comprises only one period of high waters (August-September-October), followed by a fast drying up from November to December (Fig. 2).

The hydrological data of Fig. 2 are in relation with those measured at the hydrometric station of Yakasse-Comoe, located at about 30 km upstream from the mouth (see Fig. 1). The most significant flows at this station are recorded over September-October during the short rainy seasons. However, [15] reported that the two rainy seasons cause risings in June-July and September-October at under-basins.

2.2 Methods

The samples were carried out on two seasonal cycles between 2005 and 2007. They were carried out weekly during the typical months of the four hydrological seasons. Thus, samplings took place during February, June, August and October, corresponding respectively to the long dry season, the long rain season, the short dry season and the short rain season. To determine the average of suspended sediment loads, 1248 water samples were taken at the rate of 144 samples per season on 13 measuring sites spread over the whole estuary and the branch of Comoe river (see Fig. 1). The water samples were taken at various depths (0.5, 2, 5 and 10 m). Temperature, pH, conductivity, redox potential and salinity measurements were taken *in situ* by means of a multi-parameter (W.T.W. 82362 model). The dissolved oxygen and the turbidity were also measured respectively with a portable oxymeter (CRISON OXi 330 model) and a turbidimeter (HANNA mark, LP 2000 model). The positions of the measuring site were located by using a GPS GARMIN GPS 40 model.

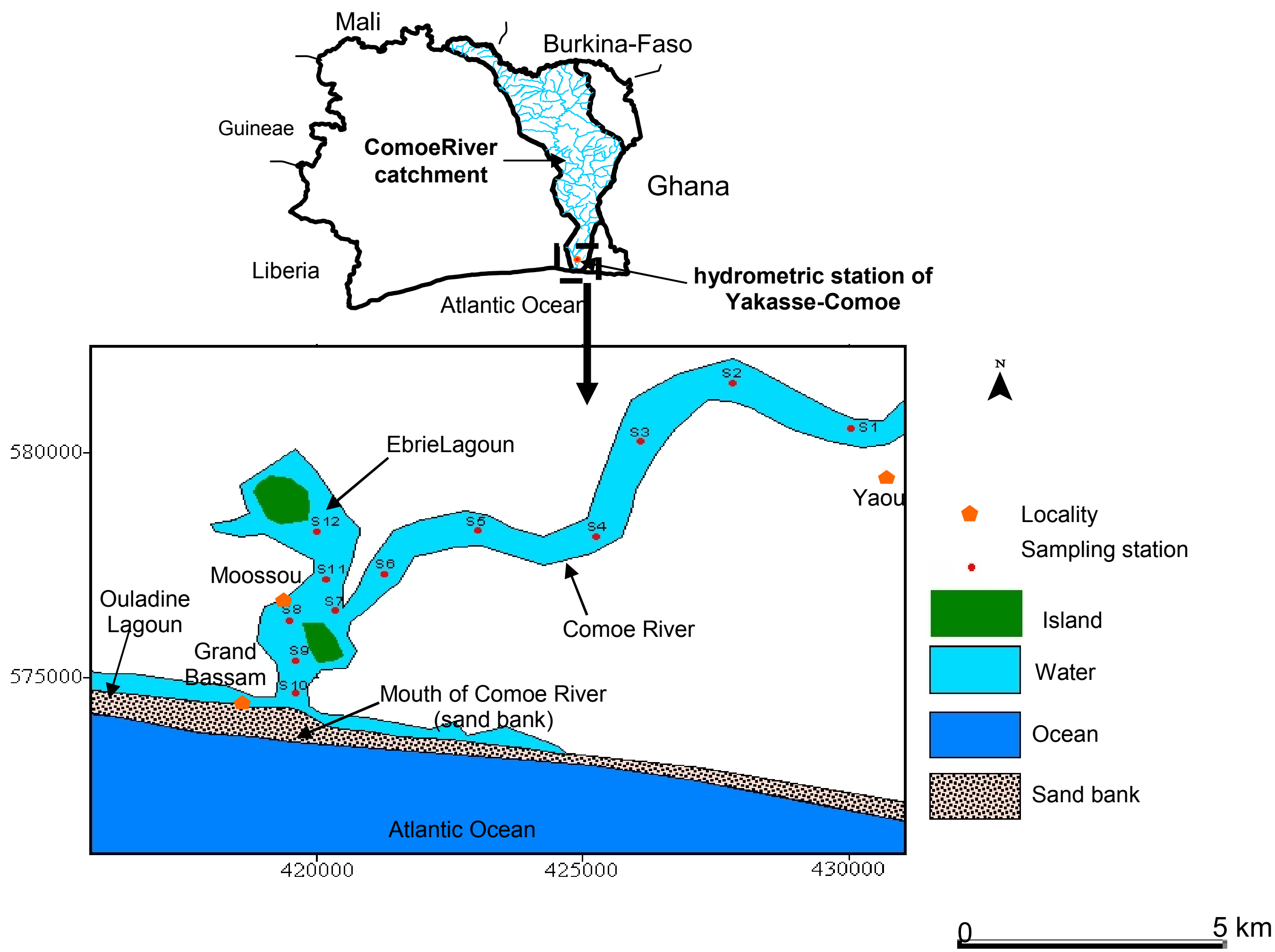

Fig. 1. Localization of the estuary of Comoe River in Grand-Bassam

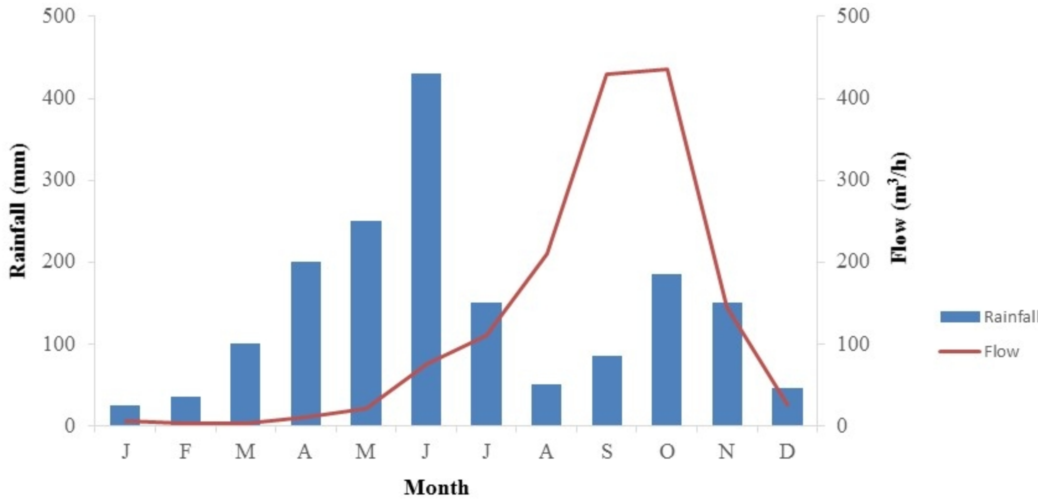

Fig. 2. Monthly average variations of rainfalls and flows at the estuary of Comoe River from 1982 to 2006
(Source: SODEXAM and DHH)

The water samples were filtered on a millipore slope of filtration using WHATMAN GF/F circular filters of 47 mm as diameter and 0.45 µm of porosity initially weighed. After drying at 105°C during two hours, the filters are carefully recovered and reweighed in order to determine the total suspended solids concentrations expressed in $mg.L^{-1}$ [16].

Results were appreciated according to a longitudinal gradient and a vertical gradient. From upstream towards the month, the dynamics of the various physicochemical parameters was observed at the level of the stations S_{YC}, St1, St2, St3, St4, St5, St6, St7, St8, St9 and St10.

The annual suspended solid load of the estuary was obtained from the average concentrations of seasonal samplings. The suspended sediment transport is calculated as follows [17,18]:

$$Q_{ss} = Q_L.C \quad (1)$$

With Q_{SS}, the solid flows in suspension ($kg.s^{-1}$); Q_L, liquid flow ($m^3.s^{-1}$) and C, average concentration of suspended matters ($g.L^{-1}$).

During an interval of time δT corresponding to the total duration of a season, seasonal solid flux (A_S in kg) are deduced by setting:

$$A_s = Q_{ss}.\delta t \quad (2)$$

The annual flux of solid matters in suspension transported by the river in the estuary is finally obtained by adding the four seasons solid contributions.

3. RESULTS

3.1 Physicochemical Characterization of Waters of the Estuary of the Comoe River

Table 1 presents the values of physicochemical parameters of the estuary of Comoe River according to the different hydrological seasons. The values presented in this table are related to the stations S6, S7, S8, S9, S10 and S11 (see Fig. 1), located in the estuarial part of the river.

Comoe River undergoes seasonal fluctuations relatively well marked. Suspended sediment loads and the turbidity show the highest values during the rainy seasons. The conductivity and the dissolved oxygen register the highest values in dry seasons. Globally, the waters of the estuary are fairly mineralized and pH values are close to neutrality. The environment is slightly oxygenated over every season and presents relatively lowsalinities.

3.2 Vertical Seasonal Evolution of Physicochemical Parameters

Seasonal variations of physicochemical parameters of the estuary of Comoe River were followed according to a vertical profile (Figs. 3a, b, c, d, e, f, g and h). For each season, the average value of each parameter was calculated respectively at 0.5; 2; 5 and 10 m depth.

On the whole, temperature, redox potential and dissolved oxygen concentration decrease from the surface towards the bottom over all the seasons (see Figs. 3a, b and c). pH values increase from 0.5 to 4 m and decrease to 10 m of depth (Fig. 3d). The amplitude between surface waters and ground waters is, on average, about 1.7°C for the temperature, 6.9 mV for the redox potential, 0.8 $mg.L^{-1}$ for the dissolved oxygen and 0.6 for the pH.

Temperature profiles show the establishment of a thermocline around 4 m in the water column. Variations of the temperature and pH values present overall two tendencies during every season. During the rainy seasons and the short dry season, the temperature slightly increases from the surface to 4 m of depth and then, undergoes a fast reduction towards the bottom. On the other hand, during the long dry season, the temperature undergoes a fast reduction from the surface to 4 m of depth and a slow one thereafter until the bottom. Thus it is established a thermocline at 4 m of depth. The dissolved oxygen concentration and the redox potential gradually undergo a quasi similar reduction with the depth.

Contrary to the evolution of the temperature, the redox potential, the dissolved oxygen and the pH the vertical distribution of salinity, conductivity, turbidity and suspended matters present a positive vertical gradient (Figs. 3e, f, g and h). Generally, the values of these four parameters present an evolution with two tendencies. From the surface to 4 m of depth, they increase slowly. From 4 m, one observes a sharp increase of these parameters until the bottom. This stratification is more perceptible with the conductivity where amplitudes between surface values and those from the bottom are around an average of 900 µS.cm-1 during dry seasons. Amplitudes between surface waters and those from the bottom are about 2.3‰ for salinity, 715 µS.cm-1 for conductivity, 11.5 NTU for turbidity and 17 mg.L-1 for suspended matters.

Table 1. Variations of seasonal average values of physicochemical parameters in the estuary of Comoe River (72 samples/season)

Parameters		Long dry season	Long rainy season	Short dry season	Short rainy season
Temperature (ºC)	Minimum	28.35	26.46	26.60	26.68
	Maximum	30.48	27.95	28.89	28.68
	Average	29.44	27.54	27.91	28.02
	Standard deviation	0.96	0.72	0.96	0.91
pH	Minimum	6.79	6.58	6.41	6.64
	Maximum	7.60	7.50	6.75	7.11
	Average	7.33	7.24	6.23	6.95
	Standard deviation	0.37	0.44	0.15	0.21
Conductivity ($\mu S.cm^{-1}$)	Minimum	258	105	210	124
	Maximum	1254	675	1110	521
	Average	628	343.50	522	348.25
	Standard deviation	434	264.06	401.14	165.94
Dissolved oxygen ($mg.L^{-1}$)	Minimum	1.09	1.09	1.03	0.32
	Maximum	2.16	1.55	2.04	1.13
	Average	1.69	0.19	1.56	0.84
	Standard deviation	0.45	0.19	0.38	0.36
Turbidity (NTU)	Minimum	22.74	30.55	15.12	25.12
	Maximum	30.00	49.28	27.11	33.22
	Average	25.23	36.74	18.63	27.48
	Standard deviation	3.33	8.51	5.72	3.84
Salinity (‰)	Minimum	0.64	0.01	0.10	0.02
	Maximum	2.83	1.06	2.40	1.18
	Average	1.33	0.39	0.93	0.48
	Standard deviation	0.88	0.40	0.88	0.44
Redox potential (mV)	Minimum	18.38	17.48	14.39	13.00
	Maximum	26.73	28.14	16.00	20.00
	Average	24.40	24.56	14.99	16.50
	Standard deviation	4.02	4.80	0.72	3.11
Suspended solid ($mg.L^{-1}$)	Minimum	11.64	32.36	11.43	32.36
	Maximum	20.02	54.11	23.45	58.37
	Average	21.66	39.16	14.74	40.25
	Standard deviation	3.97	10.07	5.83	12.17

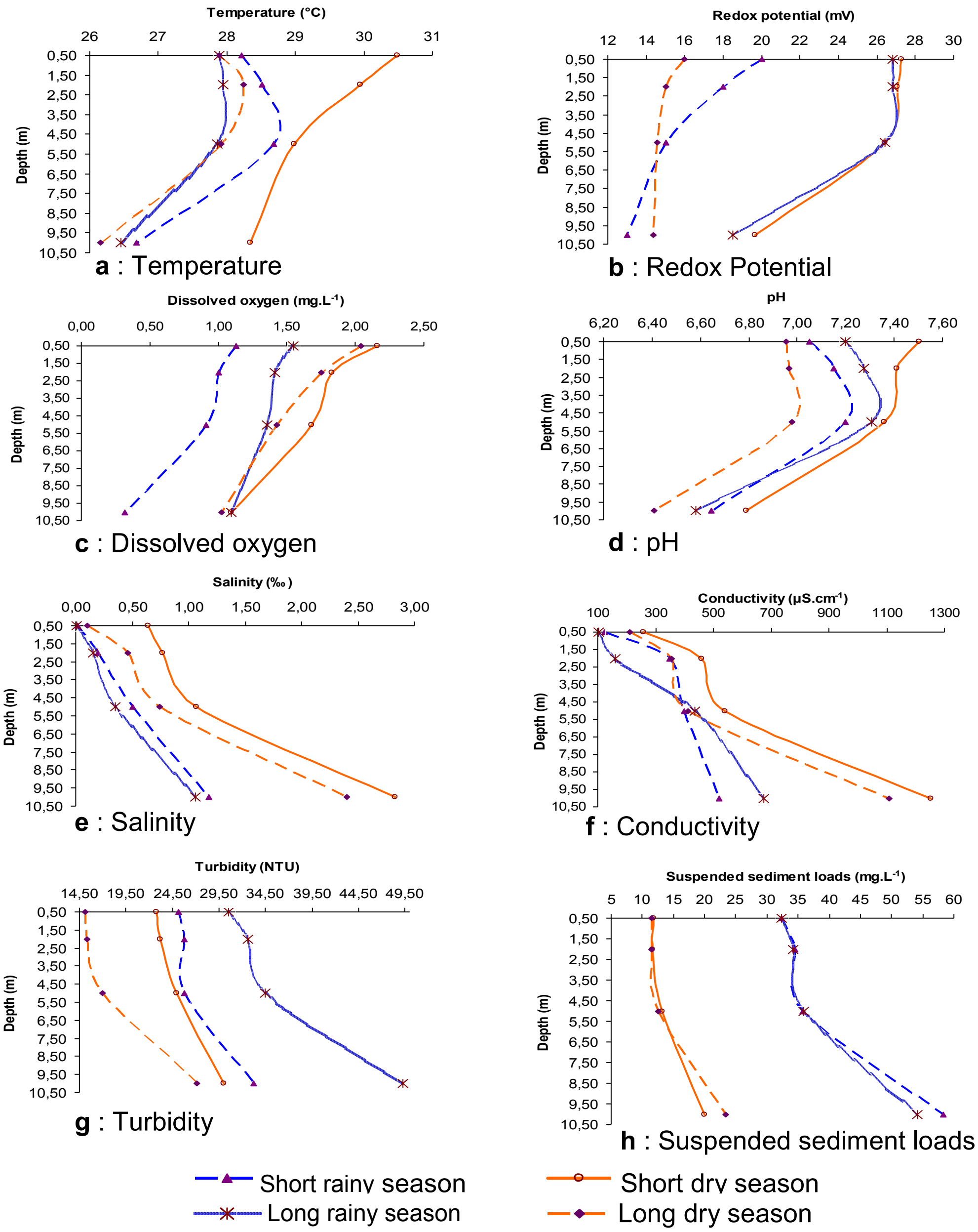

Fig. 3. Seasonal average variations of physicochemical parameters according to the depth at the estuary of Comoe River

3.3 Longitudinal Seasonal Evolution

Longitudinal distribution of physicochemical parameters was followed from the river to the mouth. The space of the physicochemical parameters was carried out on a distance approximately 30 km along the river, from the station S_{YC} (Yakasse-Comoe station) to the station S10 (Fig. 4).

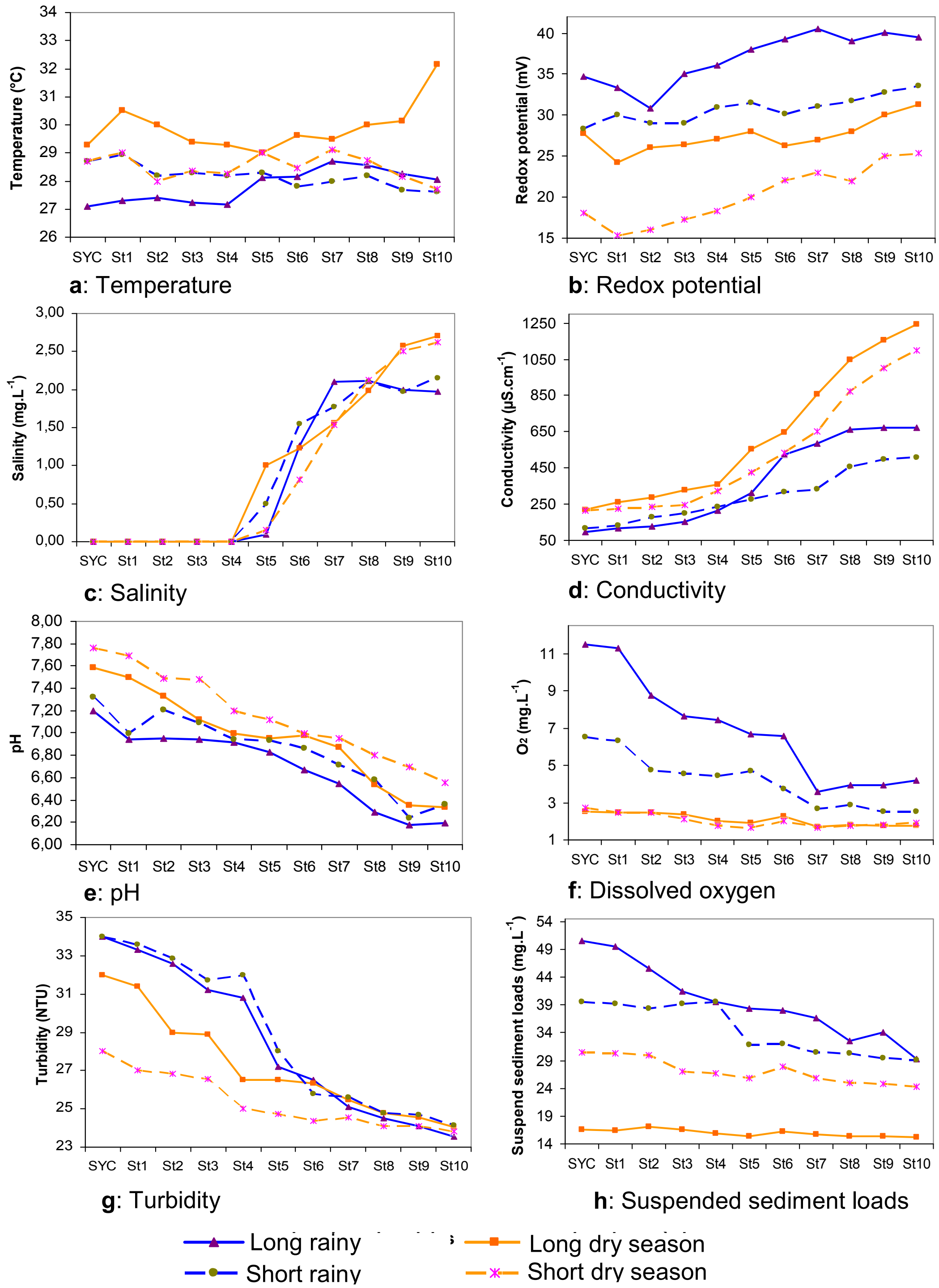

Fig. 4. Seasonal average variations of physicochemical parameters from the upstream towards the outlet of Comoe River

The temperature does not undergo significant fluctuations from the river to the mouth except during the long dry season where waters are hotter especially in the estuary (Fig. 4a).

The redox potential and salinity increase from the river towards the mouth during every season (Figs. 4b and c). Salinity passes from zero value at station S1 with approximately 0.01‰ to station S5 and undergoes fast increase to reach the values of 2.5‰ at the mouth.
In addition, pH values, dissolved oxygen concentration, turbidity and suspended matters know, a reduction from the river to the mouth (Figs. 4e, f, g, and h). This reduction is more marked during the rainy seasons than the dry seasons.

Conductivity values diminish when one moves away from the mouth (Fig. 4d). This diminution is more marked during the rainy seasons.

3.4 Solid Transport in Suspension at the Mouth of the Comoe River

Suspended sediment loads carried by Comoe River undergo some inter-seasonal fluctuations stronger than the inter-annual fluctuations (Table 2). The solid loads in suspension are 30 $mg.L^{-1}$ on the average during the rainy seasons and 15 $mg.L^{-1}$ during the dry seasons. Particulate floods are higher during the short rainy season where the flows - 43 395 tons of the river and suspended sediment concentration register at the same time high values. During each of two hydrological cycles, the estuary received, approximately 72 000 tons of suspended matters from which about the half was transported during the short rainy season.

Table 2. Seasonal average variations of suspended sediment loads in the estuary of Comoe River (16 campaigns/year)

		Long dry season	**Long rainy season**	**Short dry season**	**Short rainy season**	**Annuel suspended sediment transport (tons)**
2005-2006	Seasonal flows of Comoe river ($m^3.s^{-1}$)	17.0	40.5	349.3	274.5	
	Suspended sediment loads $g.L^1$)	0.02	0.04	0.01	0.03	
	Suspended sediment flux ($kg.s^{-1}$)	0.34	1.62	3.49	8.23	
	Suspended sediment contributions (tons)	1789	8540	18410	43395	72134
2006-2007	Seasonal flows of Comoe river ($m^3.s^{-1}$)	16.9	41.4	355.3	280.6	
	Suspended sediment loads($g.L^1$)	0.02	0.03	0.01	0.03	
	Suspended sediment flux ($kg.s^1$)	0.27	1.30	3.55	8.42	
	Suspended sediment contributions (tons)	1427	6874	18724	44371	71396

The observation of particles collected on the filters with the binocular magnifying glass shows that suspended matters are made up with organic and inorganic components. The inorganic fraction mostly formed from clays and detrital quartz is abundant. The organic components contain especially vegetable remains and insects.

3.5 Particle Size Analysis

3.5.1 Description of sedimentary facies

Brief description of the surficial sediments of the estuary of the Comoe River highlights three lithological facies. It is sand, mixed sediment and vases (Table 3)

Sands evolve fine to coarse. Their color is yellowish-brown to varying degrees. There are few plants and shellfish debris. The grain size increases when tends to the floodplain of the river. In addition, the sands are coarser upstream and downstream.

The vases are of variable color. Vases were greenish color rich in organic material from largely the decomposition of aquatic plants. Blackish fluid muds are rich in organic matter. They are concentrated near the riverbanks and islands.

"Mixed" sediments (Samples 7, 12, 15) consist of muddy sands and sandy muds. Their color varies from dark olive to olive gray. They contain plant and shell debris.

3.5.2 Size parameters of sediment sands Comoe River

The average particle size of sand from the estuary of the Comoe River is between 240 and 765 microns. These are generally fine to medium sand with a mean particle size of 425 microns. The classmark is between 0.58 and 1.12 with an average of 0.85. This indicates that the sands in the estuary are moderately classified misclassified. The asymmetry indices (skweness) extend from 0.06 to 0.25 showing a strong asymmetry to small sizes.

Table 3. Sediments lithology of Comoe estuary

Sample	Contact information	Sedimentary description	Mz	Sk	So	Md	IT	A
1*	429324 / 581026	Blackish fluid mud; rich in organic matter	< 63	(-)	(-)	(-)	(-)	(-)
2	429324 / 580827	Coarse sand, red, moderately sorted	765	0.66	0.95	124	0.48	0.19
3	429324 / 580477	Gray coarse sand; moderately classified misclassified	515	0.82	0.23	355	0.75	0.33
4*	425629 / 580028	Blackish fluid mud; rich in organic matter	< 63	(-)	(-)	(-)	(-)	(-)
5	425629 / 579728	Coarse sand, red, moderately sorted	625	0.75	0.55	420	0.29	0.44
6	425629 / 579479	Gray fine sand; moderately classified misclassified	135	0.85	0.25	612	0.38	0.45
7	421485 / 578181	Sand vases olive black olive gray; moderately classified	73	0.81	0.29	615	0.45	0.17
8	421485 / 577981	Medium sand, brown to greyish; moderately sized	482	0.68	0.45	587	0.66	0.42

Sample	Contact information	Sedimentary description	Mz	Sk	So	Md	IT	A
9	421485 / 577731	Gray fine sand; moderately classified misclassified.	240	0.85	0.26	590	0.58	0.54
10*	419885 / 577132	Cream vase greenish; presence of plant and shell debris	< 63	(-)	(-)	(-)	(-)	(-)
11*	420085 / 577132	Fluid mud greenish; rich in organic matter	< 63	(-)	(-)	(-)	(-)	(-)
12	420387 / 577132	Sandy mud gray olive black olive; moderately sized	68	0.83	0.27	325	0.68	0.75
13*	419638 / 577931	Blackish fluid mud; rich in organic matter	< 63	(-)	(-)	(-)	(-)	(-)
14	420636 / 577931	Medium sand, brown to greyish; moderately sized	412	0.76	0.50	258	0.66	0.80
15	420037 / 577931	Sandy mud olive gray to dark olive moderately sized	67	0.84	0.29	210	0.50	0.69
16	419438 / 576384	Medium sand, brown to greyish moderately classified misclassified	358	0.66	0.52	200	0.54	0.65
17	420087 / 576384	Medium sand, yellow brown to greyish; moderately sized	459	0.78	0.55	463	0.78	0.56
18	420489 / 576384	Medium sand, brown to greyish color; moderately sized	476	0.77	0.48	198	0.81	0.55
19*	419138 / 575584	Greyish cream vase; rich in organic matter	< 63	(-)	(-)	(-)	(-)	(-)
20*	419488 / 575584	Greyish cream vase; presence of plant and shell debris	< 63	(-)	(-)	(-)	(-)	(-)
21*	419788 / 575584	Blackish fluid muds; rich in organic matter	< 63	(-)	(-)	(-)	(-)	(-)
22	419388 / 574836	Gray fine sand; moderately classified misclassified	158	0.86	0.30	410	0.46	0.68
23	419588 / 574836	Gray fine sand; moderately classified misclassified	213	0.80	0.31	521	0.39	0.52
24	419887 / 574836	Gray fine sand; moderately classified misclassified.	120	0.82	0.28	498	0.37	0.37

**Stations close to the shore; (-) Settings unidentified; Scale: Sample; Mz: Medium; Sk: Skweness; So: Classification index; Md: median; IT: Index sorting; A: angularity*

4. DISCUSSION

The physicochemical characteristics registered in the estuary of the Comoe River during this study show a fairly mineralization and pH values close to neutrality. The environment is slightly oxygenated over every season and presents relatively weak salinities. The dissolved oxygen contents are about 0.5 $mg.L^{-1}$ and 1.6 $mg.L^{-1}$ respectively during the rainy and dry seasons. This weak oxygenation of waters can be related to the confinement of the estuary and the oxidation of organic matters transported in the estuary by streaming waters. [15, 19] made the same observations, and reported that the discharges of polluted waters in Ebrie Lagoon constitute a significant source of organic matters supplying in the estuary of Comoe. The dissolved oxygen concentrations, relatively higher in the surface zones of the estuarial water could be due to the mixing of water by the wind and the photosynthetic activities which generally occur with a greater intensity according to the strong penetration of the light in these less turbid zones. According to [20] oxygenation through exchange with the atmosphere and oxygenation through photosynthesis are the basis of strong dissolved oxygen concentration in the surface water. The oxidation of the organic matters leads to a deoxygenation of waters in the deep zones. So, the mineralization of the organic load which increases the conductivity, mobilizes the dissolved oxygen consumed by micro-organisms intervening in this process. Thus, after the rainy seasons, the following dry seasons constitute the period with in the mineralization of the brought loads rainy seasons reaches its peak. The mineralization of the organic matters, combined with the effect of the evaporation of water, leads to some high values of the conductivity (Fig. 3f).

The closing of the mouth which causes the confinement of the estuary has as a consequence the reduction of salinity and the development of the floating macrophytes [5,6]. The values of the salinity of the estuary of Comoe are at least 20 times lower than those found by [6] on the same estuary (15 to 30‰) before the closing of the mouth and by [3] in the estuary of Bandama (12 to 25‰). The low values of salinity registered during the rainy seasons are due to the dilution of estuarial waters by streaming waters.

In addition, the closing of the estuary limits the tide of the salinity whose front is about 4 km far from the estuary (St4 station, Fig. 4c). Thus, the upper limit of the saline ascent in Comoe River is weak compared to the observations of [21,3] on Bandama River where the front of the tide of salinity is around 30 km from the mouth during the dry seasons and 15 km during the rainy seasons.

The decrease of the turbidity and suspended sediment loads from the river to the mouth are related to the phenomena of decantation which result in progressive deposits of the solid loads during the carrying action. In addition, the increase of these two parameters from the surface towards the bottom is due to the decantation which causes a displacement of the particles towards the bottom [22,23].

Turbidity and suspended solid loads in the estuary of Comoe River are twice higher than those of the estuary of Bandama River where [3] finds average concentrations of suspended sediment about 18 $mg.L^{-1}$during the rainy seasons and 7 $mg.L^{-1}$ during the dry seasons. The weak suspended sediment loads observed in Bandama River can be explained by the presence of two considerable dams (Kossou and Taabo) stopping a part of the sediments transported by the river [24].

The quantity of sediments, approximately 72 000 tons, transported each year by Comoe River to its estuary contributes to the closing of its mouth. [8] reported that the decrease in the flows of Comoe River related to the climatic fluctuations reduces intensity of the current and the penetration of this river in the sea. There is consequently sedimentation of materials transported by the Comoe River which, added to the sedimentary transit, accelerate the filling up of the mouth of the river. Water circulation is governed by freshwater inputs Comoe River and the pond from the induced channel Vridi [25]. Various works for the opening of the mouth to the elimination of flotantes plants must take into account this specific water circulation.

The mouth is closed; Comoe waters preferably borrow the Vridi channel direction through Moossou; where drainage is mainly superficial (1 to 3 m). Velocities values are almost zero depth with salinities up to 25‰, showing that these brackish waters have very little involvement in the evacuation of the flood [23]. Near the old outfall, part of freshwater Comoe river is found at surface (zero salinity at 1m), but salinities greater than 28‰ are observed at depth. It is an extension of brackish water layers observed at depth. They probably come from reserves saltwater lagoon arm Ouladine and Moudoukou [26]. These pockets of dense brines are fed through the sandy cordon set up by long shore drift. Various works for opening the mouth for the removal of floating plants should consider this specific water [24].

5. CONCLUSION

This work which fits into a study has in finality the installation of a model of sedimentation which permitted to determine the characteristics of the physicochemical parameters and to quantify suspended sediment contributions in the estuary of Comoe River.

Artificial reopening the Canal of Comoe River in Grand Bassam September 22, 1987 has led to profound changes in the hydro-sedimentary environment of the lagoon area with a dominant maintained in the direction of channel flow Vridi. The dynamics of saline intrusion after the penetration of the first tide following the cutting of the cord determines the creation of three distintes areas: i) a first marine influence high salinity corresponding to the mouth (confluence Ouladine-channel); ii) a second intermediate-average salinity between the confluence Ouladine and Northern Island Bouet; iii) Finally, the area under influence of Permanente Comoe River or salinities are low. Waters of the estuary are fairly mineralized and the values of pH are close to neutrality. The estuary of Comoe River is turbid and slightly oxygenated over every season. It has relatively low salinities owing to the closing of the mouth of this river, limiting in this way increase of the salinity in the river.

The suspended solid loads are 30 $mg.L^{-1}$, during the rainy seasons and 15 $mg.L^{-1}$ during the dry seasons. Each year, Comoe River transports approximately 72 000 tons of solid particles in suspension in its estuary. The significant reduction of the flows of this river during the periods of low water level, is because of the influence of climatic fluctuations, and supports the phenomena of sedimentation. The conjugation of river washes and the littoral transit causes fast filling up of the mouth of Comoe River.

Leaching of these confines funds short coarser facies: fine sand very fine lagoon in the second area; means coarse sand in the first zone. The specific area of very unstable channel translated progradation of marine medium sands to the internal field on fine sand lagoon in the form of shoals and free arrows.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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