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TYPOLOGY OF WATER QUALITY IN THE LOUKKOS RIVER ESTUARY (MOROCCO)

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ABSTRACT

Water plays an important role in the Moroccan economy: including tap water by humans. However in the last decades, we noticed the deterioration of stream water quality due to industrialization and human activities.
The study of the physico-chemical effluents characteristics proved of the industrial units of the Loukkos river estuary shows, that they are at the origin of important organic discharges. Indeed, the waters of draining of the rice fields are at the origin of important organic discharges dragging strong concentrations in suspended matter and nitrate, the general effluents present a high salinity, a strong concentration in organic carbon. These emissions cause risks of poisoning for the receiving environment. It especially conjugates him by the deterioration of the quality of the waters of the Loukkos river estuary to the level of the section downstream of this estuary.

Key words: Hydrobiology ; quality ; effluents ; estuary ; Morocco

INTRODUCTION

Estuaries have several original and have important ecological socio-economic activities, due to the practice of artisanal fish and mollusks fish. Since the 1930s, the estuary has attracted the attention of researchers, but studies conducted there for a long time remained limited. It was not until early 1980 that this site was the subject of several research works (Bazairi et al., 2005; Cheggour et al., 2005; Fekhaoui, 2005; El Morhit, 2005; Yahyaoui and Azeroual, 2005) to define its organization hydrological, sedimentological and biological. These studies have highlighted the perpetual evolution of the estuary over time, resulting in progressive obstruction of the mouth which ensures the exchange between the estuary and the Atlantic Ocean. Many organic pollutants introduced into these aquatic environments are likely to concentrate in plants and animals at levels sometimes considerably higher than rates recorded at their biotope (water and sediment) and can cause environmental problems, health and economic (El Morhit et al., 2012).

However, the cutting of the estuary into different zones is necessary for an understanding of water quality in the Loukkos river estuary. In this objective, a typological study of the estuary has been undertaken on the basis of seasonal measures of physicochemical parameters during the sampling campaigns.

MATERIALS AND METHODS

Study Site

The study area is the Loukkos river estuary, which is one of the major estuaries of Morocco. It is located on the Atlantic coast of Morocco whose perimeter is between the following coordinates: 35° 9' and 35° 14' north latitude and 6° 5' and 6° 30' west longitude (El Morhit 2009). To make this work and taking into account the various activities identified in the area, five stations distributed along the estuary were selected and defined as follows (Figure 1) :

- **Dhiria** (S1) : it is located upstream of estuary, at the dam guard, 21 km from the mouth,
- **Ain Chouk** (S2) : it is located near a channel 16 km from the mouth,
- **Baggara** (S3) : it is located at 9 km from the mouth,
- **Grangha** (S4) : it is located 3 km from the mouth, right near the urban sewage of the city,
- **Port of Larache** (S5) : it is situated at the mouth of Loukkos.

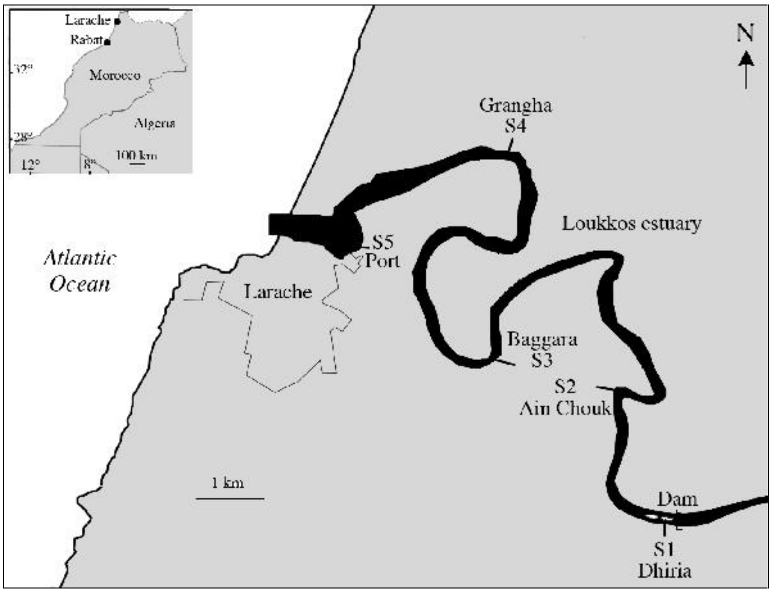

Figure 1: Site of sample collection (Loukkos river estuary in Morocco).

Sampling and analysis methods

The study of the typology of the Loukkos river estuary was based on principal component analysis (PCA) combined with analyzes discriminating (AD). Eleven hydrological parameters were chosen to characterize the estuary: the air temperature (Ta) and water (Te), salinity (Sa), conductivity (Ce), dissolved oxygen (DO), pH, suspended matter (SM), total organic carbon (TOC), nitrates (NO), chemical oxygen demand (COD) and biological oxygen demand (BOD).
In the context of quality control, water samples were made on the surface at high tide and low tide of dead waters during campaigns (March, May, July, September and November 2006 and January, March and May 2007) at 5 stations, distributed and numbered in ascending order from upstream to downstream in the Loukkos river estuary.

Statistical Analyses

Data processing was performed by PCA with the XL-STAT software. An analysis of variance (ANOVA) was also applied using the same software to test the significance of differences of hydrological parameters between stations and months (Sokal and Rohlf, 1995).

RESULTS

Spatiotemporal variation of hydrological parameters

To study the spatial and temporal variation of hydrological parameters, we analyzed, initially, the evolution of the mean value of each parameter, calculated over the entire estuary over time. In a second time, we studied the variation of the mean annual value of these parameters based stations. The results are presented in Table 1.

Table 1: Hydrological characteristics of the Loukkos river estuary during 06/07 (mean ± standard deviation, limit values).

	S1	S2	S3	S4	S5
Ta (°C)	22.4±3.9 (27.7−5.1)	22.2±3.2 (26.8−16.8)	22.8±3.9 (26.9−15.4)	21.3±2.7 (25.4−17.0)	20.3±2.6 (24.7−16.5)
Te (°C)	23.1±4.6 (28.3−4.3)	23.0±4.5 (29.7−14.8)	23.5±4.4 (28.9−15)	22.1±4.1 (27.5−15.0)	21.1±4 (27.0−15)
pH	7.7±0.4 (8.4−7.2)	7.6±0.4 (8.5−7.2)	7.5±0.2 (7.8−7.1)	7.8±0.3 (8.3−7)	7.8±0.2 (8−7.4)
Sa (g/l)	6.0±2.1 (8.7−2.6)	12.2±3.5 (18.5−8.2)	21.5±6.4 (31.0−12.5)	27.2±3.9 (34.1−22.2)	33.5±1.1 (34.8−31.7)
Ce (mS/cm)	0.8±0.2 (1.4−0.5)	11.6±8.3 (27.5−0.7)	19.8±11.8 (48.1−10.5)	30.2±12.6 (52.2−13.1)	44.5±7.2 (54.7−36.4)
DO (mg/L)	5.6±3.3 (11.1−1.3)	6.3±4.1 (12.3−0.2)	7.0±4.6 (13.6−0.4)	7.6±5.1 (15.0−1.2)	7.4±5.0 (15.4−1.6)
SM (mg/L)	73.2±29.1 (108.0−31.2)	55.4±25.2 (86.0−12.8)	53.7±19.2 (80.0−29.4)	55.5±26.6 (82.0−10.5)	42.2±28.5 (81.0−14.3)
TOC (mg/L)	8.3±1.56 (10.5−6.3)	8.8±2.5 (12.1−5.2)	9.1±5.1 (15.4−3.1)	11.8±8.4 (24.6−3.7)	19.9±10.5 (33.4−3.5)
NO (mg/L)	2.4±4.24 (12.8−0.3)	2.1±1.9 (5.7−0.6)	2.9±4.2 (12.4−0.1)	5±5.2 (13.8−0.8)	4.8±5.8 (13.5−0.2)
COD (mg/L)	20.2±9.3 (38.4−10.0)	20.9±7.3 (30.5−11.6)	37.3±36.2 (98.2−10.5)	27.6±14.5 (50.0−9.7)	26.7±12.3 (46.7−12.3)
BOD (mg/L)	8.4±4.08 (13.1−2.2)	9.8±4.6 (16.9−3.7)	11.8±7.8 (24.4−3.9)	5.7±2.8 (11.5−2.7)	10.6±7.8 (23.5−2.8)

The variation in the mean temperature of the waters of the estuary follows closely the variation in atmospheric temperature. Indeed, it varies between 21.09 and 23.50 °C with a maximum concentration (27.78 °C) was recorded in Station 1. The amplitude of the variation between the sampling points not exceeds in any case 29 °C. The temperature of the basin is relatively homogeneous.

The pH is relatively stable and alkaline for all stations. It varies between 7.02 and 8.52 with a maximum concentration (8.52 mg/L) was found in station 2. The mean values of this parameter remain relatively high along the estuary except at station 3 (7.58 mg/L) where there was a slight decrease from contributions of runoff discharges.

Salinity and conductivity mean of the waters of the Loukkos river estuary range between 6.08 and 33.54 g/L for salinity and between 0.84 and 44.58 mS/cm for conductivity. They follow by moving against the tide, the maximal limit is 34.80 g/L for salinity and 54.70 mS/cm for conductivity and minimal is 2.60 g/L for salinity and 0.59 mS/cm for conductivity.

Analysis of results of dissolved oxygen shows that the mean minimum and maximum values recorded are 5.68 and 7.63 mg/L with a concentration of dissolved oxygen maximum (15.40 mg/L) was observed in station 5. The peak in this station is due to the influence of marine waters well oxygenated.

Suspended matters represent all the mineral and organic particles contained in water. Their effects on physical and chemical characteristics of water are very harmful (change in turbidity, reducing light penetration thus photosynthesis). In the Loukkos river estuary, in relation to the relatively low erosive potential of the basin, the water is sufficiently charged in the suspended matter. The mean concentrations are of the order of 42.28 in the S5 and 73.27 mg/L in S1. The high load (108 mg/L) recorded exceptionally at the S1 is probably the result of a brutal event hydrological (flood), which suspended matters show a large difference between the minimum and maximum values recorded. This could be related to seasonal variations very important. The mean increase, from station 5 to station 1, can be attributed to an intense erosion of the Loukkos basin, due to sudden rainstorms.

The mean concentrations of total organic carbon are recorded in the order of 8.33 in S1 and 19.96 mg/L in the S5. They show an increasing gradient from upstream to downstream. This increase in mean total organic carbon can be attributed to municipal wastewater from the city of Larache and tidal dynamics.

The mean concentrations of nitrate vary between 2.19 and 5.04 mg/L. These concentrations may be due to discharges from waste water of rice fields during this month. Other months showed very low levels. These low nitrate concentrations can be attributed in part to the action of the aquatic microflora might use for the synthesis of new organic molecules. The high level (13.80 mg/L), recorded in station 4, is due to a very active nitrification during this period of reoxygenation of the site. Moreover, the results reveal strong contributions of nitrates from marine and downstream of the estuary.

The mean values of chemical oxygen demand recorded in the waters of the Loukkos river estuary are proportional to that of dissolved oxygen. They show the presence of mineral filler important with mean values oscillating between 20.28 and 37.31 mg of O_2 of the COD/L. These values can reach 98.20 mg/L in S3. With such high rates, we can speak of a rather intense pollution and a little dangerous situation. This is noticeable at the S3 (transition zone) subjected to continuous rejections of the city of Larache (downstream) water and drain rice fields (upstream). However, through the mean concentrations obtained we see a slight reduction of this charge at the S4, with an increase of the oxygen we can probably closer to an uncompleted oxidation of organic pollutants and to dilution water effect of dam guard. The enrichment of the S3 by oxidizable and organic matter is mainly due to discharges from the city of Larache reinforced occasionally by marine inputs during the flood tide.

The biological oxygen demand expresses the quantity of oxygen required for biodegradation of organic matter from water. It is substantially proportional to the content of the water in biodegradable organic matter and thus the amount of microorganisms is inversely proportional to the dissolved oxygen content. It expresses the quantity of oxygen required to degrade organic matter. It has partly to the nature of dissolved organic matter, the dissolved oxygen content and the presence or absence of elements of the microbial inhibitors (hydrocarbons, detergents ...). Indeed, the concentration of biological oxygen demand shows the presence of important mineral load with mean values oscillating between 5.76 and 10.68 mg/L of BOD. These values can reach 24.40 mg/L in S3.

Typology of variables studied in water of the Loukkos river estuary

PCA allows a synthesis of all data collected throughout the river system of the Loukkos river estuary, and describes the structure by two main gradients F1 and F2. It was conducted on a data matrix consisting of 40 samples (5 x 8 stations campaigns) during which the 11 variables (air temperature and water pH, salinity, conductivity and dissolved oxygen, suspended matter, total organic carbon, nitrates, chemical oxygen demand and biological oxygen demand) were measured (Table 2).

Table 2: PCA codes and correlations of variables with the axes.

Variables	Code	F1	F2	Stations	Code	Campaigns	Code
Air temperature	T°a	−0.42	−0.60*	Dhirai	D	March-06	R
Water temperature	T°e	−0.35	−0.67*	Ain Chouk	A	May-06	M
pH	pH	0.26	−0.45	Baggara	B	July-06	J
Salinity	Sa	0.92*	−0.12	Grangha	G	Sept-06	S
Conductivity	Ce	0.88*	0.11	Embouchure	E	Nove-06	N
Dissolved oxygen	OD	0.31	−0.63*			January-07	j
Suspended matter	MS	−0.36	0.67*			March-07	r
Total organic carbon	CO	0,46*	−0.19			May-07	m
Nitrate	NO	0.31	0.56*				
COD	DC	0.05	0.06				
BOD	DB	0.01	0.10				

The values mentioned with star (*) are also significant $p<0.05$.

The values of the two components F1 and F2 and their contribution to the total inertia are shown in Figure 2A. Variable codes that are highly correlated and their coordinates are shown in Table II.
The results (Table II and Figure 2A) can perform an initial typological approach of the different variables according to their affinities and their combinations on the first two principal components from their contribution. The F1 and F2 axes determine 44.13% of the total information (23.35% for axis F1 and 20.78% for axis F2). The values of the PCA, the circle of correlation and factorial maps are shown in Figure 2.

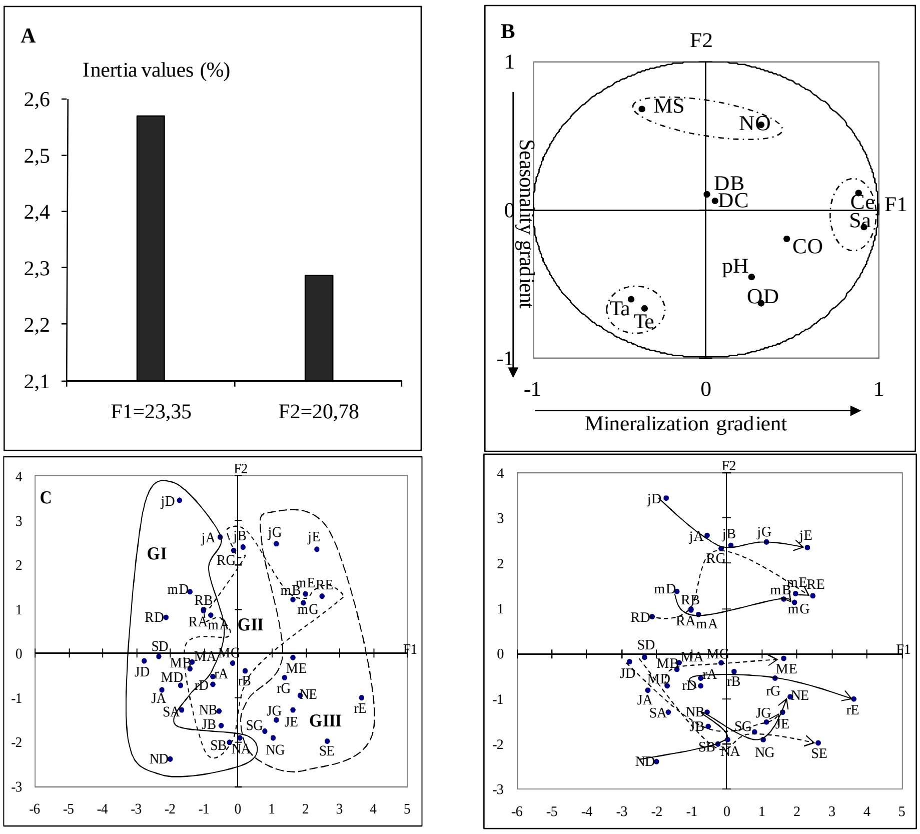

Figure 2: Graphical approach of the PCA of the hydrological parameters according F1XF2.

A: Distribution of the inertia between the axes.
B: Correlation circle of the variables.
C: Factorial map of the stations.
D: Factorial map of the campaigns.

In the factorial axes F1 X F2

Axis F1 is determined by salinity (r = 0.92) and conductivity (r = 0.88). It defines a gradient of mineralization. Axis 2 is represented by air temperature and water (r = -0.60 and r = -0.67) (Figure 2B). It defines a thermal gradient which results in cold water during the hot months of March and during July opposite the contamination gradient in suspended matter (r = 0.67) and nitrate (r = 0.56). However, the influence of seasonality, particularly temperature, seems less noticeable. No relationship emerged between this parameter and the content of salinity (conductivity).

The global analysis is used to define a typology dominated by individualization of three station groups GI, GII, GIII (Figure 2C). This spatial organization releases the exact location of stations relative to their situation:
Group I (GI) includes the upstream stations S1 (RD, MD, JD, SD, ND, jD, rD, MD) and S2 (AR, MA, JA, SA, NA, jA, rA, MA) located in a area of low mineralization. This group is opposed to Group III (GIII) represented by the stations S4 (RG, MG, JG, SG, NG, jG, rG, mG) and S5 that is furthest downstream (RE, ME, ME, SE, NE, jE, rE, mE). It is characterized by a significant mineralization related to marine influences. Between the two is the group II (GII) represented by the station 3 in all seasons (RB, MB, JB, SB, NB, jB, rB, mB), denoting a moderate quality water quality.
Seasonal variations do not seem to change the level of water quality by salinity (conductivity) with the exception of May, 2006 where there was a slight decrease in salinity at station 1 (ME) and March 2007, where the level of the water quality of a station (rD) is low compared to other seasons (Figure 2D).

Hydrosystem dynamics

The overall synthesis offered by the PCA conducted on the estuary of Loukkos, we provided an approach of the structure function of the aquatic ecosystem. It can be summarized by the presence of two main gradients: a growing mineralization from upstream to downstream, and a nitrogenous organic enrichment, which seems conditioned by seasonal variations (the positive pole of this gradient is in winter). This seems minor compared to the first.
Analysis by campaigns allows understanding the functioning of the hydrosystem. Thus the figure 2D illustrates this representation by the factorial plan F1XF2, we can distinguish two situations A (broken line) and B (continuous line) different from each other by their position identified (stations).

Situation A

This shows a very different quality of water from one station to another because these values are spaced from each other in the factorial design (F1XF2). It brings the campaigns for months in July 2006, September 2006, January 2007 and May 2007, which are characterized by very specific hydrological conditions as to their position on the factorial design; it is on side highly mineralized. Station values of S4 and S5 are widely spaced from each other on the factorial plan and are subjected to tidal effects. These values are slightly moved to the positive pole with a croissant gradient of mineralization from upstream to downstream. They are more pronounced in summer than winter.

Situation B

It concerns only the campaigns of March 2006, May 2006, November 2006 and March 2007. It is characterized by a change in hydrological conditions (rainfall). Concentration of stations occupy on factorial plan a position fairly pronounced toward the center. However compared to the previous situation, there was a displacement of all values towards the negative pole of the thermal gradient except values of March 06. The marine influence is excluded because it is a situation at low tide. In the second gradient, Lower mean mineralization was detected in station 1. In addition, higher concentrations of suspended matter during flood were contributed to the increase of the organic load. In the station 3 that made the exception by its surprising position in the center compared to the two gradients. It had to receive a positive effect by dilution with flood waters relatively less loaded.

State of stratification of water temperature and dissolved oxygen

Marked thermal stratification of temperature was detected at the spatial scale. She begins to settle from S4 due to increased surface water temperatures followed by a decline that began between S4 and S5 to be diffuse total mixing until the S5. This is inversely proportional to that observed in the same stations in dissolved oxygen. This dissolved oxygen deficit in the S1 shows in great biodegradation in the depth and in elevated temperature (Figure 3).

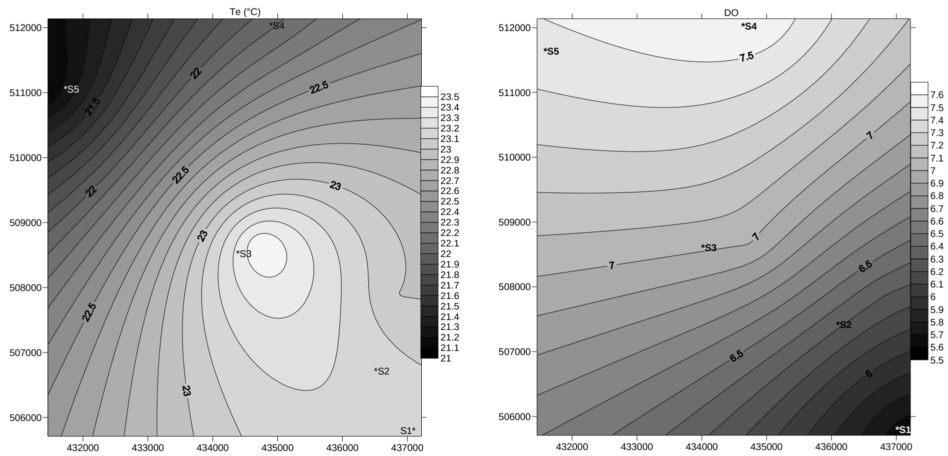

Figure 3: Vertical profiles of water temperature and dissolved oxygen in the the Loukkos river estuary

Thus, the model of thermal stratification and dynamics observed at the estuary Loukkos is typical of a river can be classified as warm monomictic.

DISCUSSION

The typological study undertaken during the sampling campaigns in the water of the Loukkos estuary helped define the main characteristics of the hydrological quality. The PCA results showed that the percentage of the spatial and temporal variability (44.13%) is low (Figure 2A). The percentage of variability is attributed to salinity (conductivity) showed that a significant spatial and temporal variation ($p<0.01$) and a significant seasonal variation for total organic carbon ($p<0.01$). For suspended matter and nitrates, their differences are considered significant for a ($p<0.05$). While concentrations of other hydrological parameters (temperature, pH, chemical oxygen demand and biological oxygen demand) measured in the water of the Loukkos river estuary are relatively homogeneous and show no statistically significant deference nor depending on the station or nor by season (Table 3).

Table 3: Results of the ANOVA of the hydrological parameters

Parameters	**Stations**		**Saisons**	
	F	P>F	F	P>F
Te (°C)	ns	0,061	ns	0,598
pH	*	**0,040**	*	**0,035**
Sa (g/L)	**	**0,009**	**	**0,002**
Ce (mS/cm)	**	**0,003**	*	**0,039**
DO (mg/L)	ns	0,148	ns	0,126
SM (mg/L)	ns	0,133	**	**0,006**
TOC (mg/L)	ns	0,178	*	**0,048**
NO (mg/L)	ns	0,081	**	**0,005**
COD (mg/L)	ns	0,250	ns	0,165
BOD (mg/L)	ns	0,372	ns	0,243

values of the statistic test *(F)* and those of the probability are mentioned [ns : $(p>0,05)$; * : $(p<0,05)$; ** : $(p<0,01)$].

The mean temperature near to 20 °C remains related to the local conditions. These concentrations are similar to those found in other site (Hatje, 2003). El Morhit et al. (2008) explained this situation by hydraulic planning in the basin of the Loukkos river estuary. Compared to other studies, the water temperature of Loukkos river estuary is low compared to that found in the Ganges River where it fluctuates from 15 to 35 °C. Compared to other studies, the water temperature of Loukkos river estuary is low compared to that found in the river

Ganges where it fluctuates from 15 to 35 ° C, suggesting that this increase is due to natural influences and anthropogenic (Sarkar et al., 2007; El Morhit et al., 2012).
The difference between the concentration of salinity and conductivity between the upstream and downstream of the Loukkos river estuary was explained by the influence of marine waters and industrial discharges that penetrate inside the estuary, favored by the low slope of the water main courtyard, leads to a significant increase in chloride ions. This influence can define a gradient of decreasing mineralization from downstream to upstream and dilution of fresh water input upstream where the geological characteristic salty and gypsiferous stations upstream influence the load of dissolved salts (Fekhaoui, 2005; El Morhit et al., 2009).
The mean values of conductivity observed in the all ecosystem are high compared to those measured in the Babughat and Diamond Harbor station of the Ganges River (Sarkar et al., 2007) where they fluctuate between 0.8 and 3.9 mS/cm, in the Sebu estuary between 0 and 29 mS/cm (Malki et al., 2008) and in the river Sebu (Mergaoui et al., 2003) between 1 and 1.4 mS/cm. While the mean values of extreme salinity recorded during the various campaigns are relatively high compared to those determined in other sites (Sarkar et al., 2007), explaining this situation by the influence of the natural and anthropogenic inputs. Works done by Snoussi (1984) and by Fekhaoui (2005) had shown salinity concentration similar to those in our study. El Morhit et al. (2008) explained this phenomenon by the influence of tidal dynamics and fresh water.
The mean dissolved oxygen in our study is lower to those reported by El Blidi et Fekhaoui (2003) in Sebou estuary. The concentration has been found in our study is close to that determined by Fekhaoui (2005); it ranges between 6 and 9 mg/L. This situation has been explained by the increase of the temperature in period 2005 (Fekhaoui, 2005). In addition, El Morhit et al. (2008) explained the concentration of dissolved oxygen by the movement of the tide creates by continuous mixing of the water mass and therefore an enrichment of the dissolved oxygen. Other studies have found that the dissolved oxygen concentration is low and depends on the tidal dynamics (Hatje, 2003; Yurkovskis, 2007; Malki et al., 2008). The spatiotemporal evolution of the content of dissolved oxygen in the Loukkos river estuary, shows that the load of biodegradable organic matter from domestic, industrial and agricultural rejected and accumulated, contributing to a significant drop oxygenation of the medium and especially in station 3 of our study. The excessive contributions of the organic fermentable matter rejected by sewers of the Larache city are results of an increased consumption of the dissolved oxygen.
In Loukkos river estuary with an erosive potential low of the basin, the water is sufficiently charged by suspended matter. The high suspended matter load (108 mg/L) recorded exceptionally in January 2007 is probably the result of a brutal event hydrological, which it shows a great difference between the minimum and

maximum values recorded. This could be related to seasonal variations and also very important to the tidal dynamics. The mean increase of the suspended matter can be attributed to agricultural activity and to an intense erosion of the basin, due to sudden rain storms (El Morhit et al., 2011). During rain period, transportation by runoff of soil particles into rivers causes an increase of the suspended solids. An increase of the suspended matter is usually accompanied by an increase in turbidity, which makes the treatment of the water for purposes of drinking water more difficult and more expensive. Such an increase may also result in warmer water, which will reduce the quality of habitat for cold-water organisms (Himmi et al., 2003). The values of total organic carbon show significant temporal variations denoting upstream-downstream gradient. This probably can be attributed to the tidal dynamics. These values are very high compared to those determined in the estuary of Port Jackson (4.54 mg/L) (Hatje, 2003), suggesting that this situation can be explained by tidal movements.

Mean values of nitrate they are relatively low compared to those observed in the same estuary Fekhaoui (2005). These have been explained by the presence of phytoplankton. While other authors have found that nitrate can reach higher values (24 mg/L), suggesting the presence of organic matter (Mergaoui et al., 2003). Violette and Gassama (2002) explained the increase by the presence of nitrogen fertilizers.

Moreover, the PCA has shown that other hydrological parameters (pH, chemical oxygen demand and biological oxygen demand) contributed only slightly in the Loukkos river estuary in the spatial and temporal variation. This result shows that water dynamics played a role in mixing of different water masses, preventing establishment of a vertical stratification and lowering the upstream-downstream gradient.

The waters of the Loukkos river estuary show a pH varies in relation to probable fluctuations in salinity following the tidal cycle and possibly fluctuations in organic load (El Morhit et al. 2008). Mean values are alkaline pH and show spatio-temporal differences significant ($p < 0.05$, Table 3). This alkalinity is due to the buffering effect of ocean waters. Other authors have shown that the pH of the water of estuaries (Sebou and Om Rbia River) is buffered. The pH is about 8 because of the buffer system developed by the carbonates and bicarbonates (Ezzaouak, 1991; El Blidi and Fekhaoui, 2003; Himmi et al., 2003).

Low concentrations of the pH which have been registered at the station 3 may be due to the presence of organic matter. Fekhaoui (2005) confirmed this result in the same ecosystem by the presence of biodegradable organic matter. Moreover, the values of this parameter found in the Loukkos river estuary are similar to those found by other authors (Hatje, 2003; Sarkar et al., 2007). Sarkar et al. (2007) explained the low concentration of chemical oxygen demand by the presence of organic matter. The same phenomenon was described by Romero et al. (2004). Moreover, maximum values were recorded at high tide during the

winter season (March 2007). This confirms the origin of a domestic wastewater from the town of Larache.
Throughout the site, the concentration of biological oxygen demand is relatively high compared to that detected in other sites such as the Ganges River where it fluctuates between 2.7 to 5.95 mg/L in the Babughat station and between 0.75 to 2.8 mg/L in the Gangasar station (Sarkar et al., 2007). Compared to other estuaries in Morocco, the concentrations of biological oxygen demand of the estuary Loukkos are lower vis-à-vis the values usually identified (Mergaoui et al., 2003), suggesting the release of excess pollutants of organic origin. The BOD/COD is about 0.36. This result supports the conclusion that the waters of the Loukkos river estuary are polluted by a fairly strong inorganic pollution. In addition, the report COD/BOD and SM/BOD are of the order of 2.76 and 2.81 respectively, very high values, indicating that the oxidizable material in waters of the estuary bottom Loukkos is easily biodegradable. This could be attributed to the release of a textile industry connected to the stream. Our results agree with those found in previous studies (Aboueloufa et al., 2002; El Guamri et al., 2006). In addition, the rice paddies could be an important source of supply of suspended matter in estuaries (El Morhit 2009).
Comparing the different results obtained in the waters of the Loukkos river estuary with standards (Table 4), shows the water quality of the Loukkos river estuary is characterized by water temperature without significant difference between the different stations. The temperature mean about 20 °C is related to weather conditions and it is less than 30 °C, considered to limit direct discharges into the receiving water (CNS 1994). The overall mineral content of water estimated by the analysis of conductivity and salinity remains very high along the estuary. Indeed, the water conductivity greater than 1.5 mS/cm makes the water unusable for irrigation of crops (Rodier, 1996). Meanwhile the pH remains near neutrality. It is acceptable according to Moroccan standards and oh the (WHO 2009).

Table 4: Standards for water quality for human consumption

Parameters	Results	Standards *	Quality
NO (mg/L)	3.50	50	Excellent
T°a (° C)	21.88	25 (1)	Good
T°e (°C)	22.50	25 (1)	Good
pH	7.70	6.5−8.5 (2)	Good
DO (mg/L)	6.80	5−8 (2)	Good
SM (mg/L)	56.00	50	Good
COT (mg/L)	11.40	---	Good
COD (mg/L)	26.30	500	Medium
BOD (mg/L)	9.20	100	Medium
Sa (g/L)	20.10	35	Poor
Ce (mS/cm)	21.40	2.7	Poor

*Joint Order of the Equipment Minister and the Minister for Physical Planning, Urban Planning, Habitat and Environment N° 1275-1201 of 10 Sha'ban 1423 (October 17, 2002).

CONCLUSIONS

Through analysis of the mean of the physicochemical parameters of the water in the Loukkos river estuary, the current state of water quality, reflects the presence of a moderate to permanent pollution and localized near the city of Larache with significant spatiotemporal variations.

Given the heavy load produced by industrial activity and urban highly active. Several questions take such as: Absent of a significant and substantial impact on the hydrochemistry of the water system since the concentrations measured in water do not reflect accurately the relative contributions of pollution. This could be explained in the intervention of some physico-chemical phenomena such as precipitation, trapping, settling and storage of pollutants in sediments without neglecting the phenomena of bioaccumulation in fauna and flora. The situation might be acceptable if there were not, storage in sediments and bioaccumulation by plants and animals.

Thus, this study will adopt a better methodological approach to determine the types of pollutants that disrupt the water quality of this ecosystem, for a thorough understanding of the hydrological quality of the site to ensure its protection.

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REFERENCES

ABOUELOUFA M., EL HALOUANI H., KHARBOUA M., BERRICHI A. (2002). Caractérisation physicochimique et bactériologique des eaux usées brutes de la ville d'Oujda : Canal principal et Oued Bounaîm. *Actes Inst. Agron. Vet.*, (Maroc), 22 (3), 143−150.

BAZAIRI H., GAM M., KALLOUL S., ZOURARAH B. (2005). Caractérisation bio-géologique des habitats benthiques d'un écosystème côtier de l'Atlantique marocain : l'estuaire du bas Loukkos. *3ème journée internationale des géosciences de l'environnement*, El Jadida, Maroc 8−9−10 juin.

CHEGGOUR M., CHAFIK A., FISHER N.S., BENBRAHIM S. (2005). Metal concentrations in sediments and clams in four Moroccan estuaries. *Marine Environmental Research,* 59, 119–137.

COMITE NORMES ET STANDARDS (CNS). (1994). Ministère de l'environnement du Maroc. Rabat.

EL BLIDI S., FEKHAOUI M. (2003). Hydrologie et dynamique marégraphique de l'estuaire du Sebou (Gharb, Maroc). *Bull. Inst. Sci.*, 25, 57−65.

EL GUAMRI Y., BELGHYTI D. (2006). Etude de la qualité physico-chimique des eaux usées brutes de la commune urbaine de Saknia, rejetées dans le lac Fouarat (Kénitra, Maroc). *Journal Africain des Sciences de l'Environnement*, 1, 53−60.

EL MORHIT M. (2005). Évaluation de la pollution métallique de la côte atlantique marocaine (port laâyoune, foum l'oued et laâsilia). Diplôme d'Etudes Supérieurs Approfondies. Université Ibn Tofail. Faculté ès sciences Kenitra, Maroc, 76 p.

EL MORHIT M., FEKHAOUI M., SERGHINI A., EL BLIDI S., EL ABIDI A., BENNAAKAM R., YAHYAOUI A., JBILOU M. (2008). Impact de l'aménagement hydraulique sur la qualité des eaux et des sédiments de l'estuaire du Loukkos (côte atlantique, Maroc). *Bull. Inst. Sci.*, 30, 39–47.

EL MORHIT M. (2009). Hydrochimie, éléments traces métalliques et incidences Ecotoxicologiques sur les différentes composantes d'un écosystème estuarien (Bas Loukkos). Thèse Doctorat ès science, Université

Mohammed V - Agdal, Rabat. *IMIST. Series/Report* N° Th-571.95/MOR : 33 p.

EL MORHIT M., FEKHAOUI M., ELIE P., GIRARD P., YAHYAOUI A., EL ABIDI A., JBILOU M. (2009). Heavy metals in sediment, water and the European glass eel, Anguilla anguilla (Osteichthyes : Anguillidae) from Loukkos river estuary (Morocco, eastern Atlantic). Cybium, 33 (3), 219–228.

EL MORHIT M., FEKHAOUI M., EL ABIDI A., YAHYAOUI A., HAMDANI A. (2011). Impact des activités humaines sur la dégradation de la qualité des sédiments de l'estuaire de Loukkos (maroc). *D.S.T*, 61, 8–17.

EL MORHIT M., FEKHAOUI M., EL ABIDI A., YAHYAOUI A. (2012). Contamination des muscles de cinq espèces de poissons de l'estuaire du bas Loukkos et qualité de l'alimentation animale au Maroc (côte atlantique marocaine). *ScienceLib.*, 4, 1–21.

EZZAOUAK M. (1991). La caractérisation hydrodynamique physico-chimique et bactériologique des eaux superficielles de l'estuaire de Bouregreg (Maroc) soumis aux rejets des villes de Rabat et Salé. Thèse Doct. 3ème cycle. Univ. Mohammed V (Rabat), 140 p.

WHO ., (2009). Code of practice for fish and fishery products, first edition, WHO, FAO, Codex Alimentarius, Rome.

FEKHAOUI M. 2005. Gestion intégrée du complexe des Zones Humides du Bas Loukkos (Larache, Maroc) Phase du Diagnostic : Hydrologie. Projet financé par la fondation Ciconia, Lichtenstein et géré par le GREPOM, 40p,.

GASSAMA N., VIOLETTE S. (2002). Contributions à l'étude hydro-géochimique du bassin versant de Kaluvelly, Sud-Est de l'Inde. DEA Hydrologie, Hydrogéologie, Géostatistique et Géochimie Filière Hydrologie et Hydrogéologie Quantitatives. Université Pierre et Marie Curie, Université Paris-Sud, École des Mines de Paris & École Nationale du Génie Rural des Eaux et des Forêts, 34 p.

HATJE V. (2003). Particulate trace metal and major element distributions over consecutive tidal cycles in Port Jackson Estuary, Australia. *Environmental Geology*, 44, 231–239.

HIMMI N., FEKHAOUI M., FOUTLANE A., BOURCHICH H., EL MAROUFY M., BENAZZOU T., HASNAOUI M. (2003). Relazione plankton-parametri fisici chimici in un bacino di maturazione (laguna mista Beni Slimane – Morocco. *Rivesta Di Idrobiologia*, 110−111.

MALKI M., MARIN I., ESSAHALE A., AMILS R., MOUMNI M. (2008). Physico-chemical parameters and bacterial diversity in the Moroccan´s Sebou River. *Journal of Food, Agriculture & Environment*, 6, 172−176.

MERGAOUI L., FEKHAOUI M., BOUYA D., GHEÏT A., STAMBOULI A. (2003). Qualité des eaux et macrofaune benthique d'un milieu estuarien du Maroc : cas de l'estuaire de Sebou. *Bull. Inst. Sci.*, 25, 67−75.

RODIER J. (1996). L'analyse de l'eau naturelle, eaux résiduaires, eau de mer, 8ème Edition, Dénod, Paris, 1383p.
ROMERO A.H., HERNANDEZ C.T., MALO E.A., BELLO-MENDOZA R. (2004). Water quality and presence of pesticides in a tropical coastal wetland in southern Mexico. *Marine Pollution Bulletin,* 48, 1130−1141.
SARKAR S.K., SAHA M., TAKADA.H., BHATTACHARYA A., MISHRA P., BHATTACHARYA B. (2007). Water quality management in the lower stretch of the river Ganges, east coast of India: an approach through environmental education. *Journal of Cleaner Production,* 15, 1559−1567.
SOKAL R.R., ROHLF J.F. (1995). Biometry, third ed., W.H. Freeman and Co., New York.
YAHYAOUI A., AZEROUAL A. (2005). Etude de diagnostic : « Poissons du Complexe de Zones Humides du Bas Loukkos (Larche, Maroc) ». Projet Gestion Intégrée du Complexe de Zones Humides du Bas Loukkos, Actions Opérationnelles, 36 p.
YURKOVSKIS A. (2007). Dynamics of particulate major and trace elements in the lower reaches of the Daugava River and adjacent area of the Gulf of Riga (Baltic Sea). *Marine Pollution Bulletin,* 49, 249–263.