INVESTIGATION ON POSSIBLE CHEMICAL POLLUTION OF THE BOUGHRARA LAGOON, SOUTH OF TUNISIA, BY CHEMICAL WASTES

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ملخص

تقييم نسبة تلوث بحيرة بوغرارة من جراء نفايات الفسفوجيبس : تعرف بحيرة بوغرارة خلال السنوات الأخيرة بتدني مردود إنتاج الصيد البحري وذلك من جراء عدة أسباب: أهمها الصيد المفرط والظر وف المناخية الخاصة بفصل الصيف من جهة وبتسرب النفايات الصلبة والسائلة بدون معالجة مسبقة من جهة أخرى. وهذا ما أدى إلى تراجع الإنتاج حيث بلغ 1.118 طن سنة 2002 بعد أن كان قد بلغ أقصاه سنة 1992 ب 4.786 طن.

وقد اثر مشروع تربية الأسماك الذي بلغ 252 طن من الإنتاج سنة 1990 سلبا على هذه المنظومة البيئية المائية مما أدى إلى التفكير بجدية في متابعة علمية عن قرب لحالة البحيرة ومعرفة الأسباب المؤدية لها.

ومن خلال دراسة العوامل الهيدرو بيولوجية (الأملاح المعدنية و المواد العضوية، الأكسيجين المنحل، الخ....) أردنا تشخيص حالة البحيرة استنادا إلى نسبة التلوث في الماء ولدى عدة كائنات بحرية... قد يكون سببها الرئيسي تسرب النفايات المتأتية من خليج قابس (الفسفور، الكادميوم، الفليور...)، تحت تأثير التيارات البحرية.

النتائج المتحصل عليها لا تنفي وجود عدة مصادر تلوّث أخرى قد تؤدي إلى تعكر حالة البحيرة وانعدام فائدتها مما أدى إلى وجوب تدخل فوري وسريع لمعالجة الأمر والنهوض بقطاع الصيد البحري بصفة خاصة والاقتصاد الوطني بصفة عامة الشيء الذي تدعو إليه كل المشاريع التنموية.

الكلمات المفاتيح: بحيرة بوغرارة، المنظومة البيئية المائية، العوامل الهيدروبيولوجية، الأكسيجين المنحل، تشخيص، الكادميوم، الفليور، الفسفور.

RESUME

Contribution à l'étude de la pollution de la lagune de BouGhrara par les rejets de l'industrie des phosphates : La mer de BouGhrara, un milieu quasi-lagunaire de cinquante milles hectares environ, a contribué d'une manière remarquable à la production halieutique Tunisienne jusqu'au 1992 4.786 tonnes, année à partir de laquelle cette production n'a cessé de décroître (1.118 tonnes en 2002). Par ailleurs le premier projet industriel d'aquaculture marine y a également vu le jour, atteignant une production aquacole en cages flottantes de 252 tonnes en 1990. Malheureusement cette activité a cessé en 1995, après une dizaine d'années et la société qui assurait cette production a cessé ses activités et les quelques cages ont été déplacées de la lagune vers le bassin du port de Zarzis à la recherche de conditions environnementales meilleures. Plusieurs raisons ont été invoquées à la dégradation de la qualité de la lagune, principalement la surpêche, les conditions océanographiques et environnementales.

Par la présente étude nous avons tenté d'apporter une contribution scientifique visant à mieux comprendre les conditions environnementales qui sévissent dans la lagune et à en déceler les causes.

Parallèlement au suivi des paramètres océanographiques classiques (Température, Salinité, pH, Oxygène dissous et sels nutritifs), l'étude a porté sur le diagnostic des fonds, de la colonne d'eau et dans quelques

organismes benthiques de la lagune du point de vue de leur contamination par des polluants pouvant provenir du golfe de Gabès, à savoir la matière organique, le fluor, le phosphore et le cadmium qui accompagnent le phospho-gypse rejeté par les usines d'engrais chimiques phosphatés et azotés de Gannouch.
Les résultats trouvés confirment cette appréhension sans toutefois exclure d'autres sources d'eutrophisation et/ou un phénomène de confinement naturel accentué par la topographie et l'hydrodynamisme de la lagune.
Mots clés : Mer de BouGhrara –Paramètres océanographiques - Diagnostic – Eutrophisation - pollution chimique.

ABSTRACT

The BouGhrara lagoon, situated at south of Tunisia, is a 50 000 ha water surface area which has been highly contributing to the Tunisian fisheries production with a maximum of 4.786 M.T in 1992. Since that year the production has been steadily decreasing, (1.118 M.T in 2002). Several reasons have been referred to to explain the fisheries collapse and the lagoon environmental quality decrease. This study was intended to investigate on the water quality of the lagoon, especially with regard to those which have been at the origin of the lagoon environmental depletion.
Along with the investigation on the current oceanographic parameters (temperature, salinity, pH, nutriments, etc.), focus has been made on the impact of the main pollutants which would come into the lagoon from the Ghannouch chemical factories, releasing organic matter, phosphates, fluoride, and cadmium.
The study results are confirming such an expectation without excluding other eutrophication sources.
Keywords: BouGhrara lagoon, depletion, eutrophication, oceanographic parameters.

INTRODUCTION

The Mediterranean coastal lagoons are communally known as by their high biological productivity, particularly high fishery production; which attract fishermen and other fishery related activities like fin fish aquaculture and which often leads to over fishing and to create severe environmental crises generated by eutrophication and harmful phytoplankton species blooms....).
The Tunisian BouGhrara lagoon which is close to the marine area of the Gulf of Gabès, south of Tunisia is very sensitive to environmental aggressions. It is a semi closed little sea with a limited access to the open sea, making it as an increasingly fragile and vulnerable to anthropic and natural constraints.
In addition the lagoon is submitted to severe hydrodynamic and climatic conditions (with a negative water exchange balance, low depth, limited water circulation and intense evaporation).In the near past the lagoon was also suffering of negative effects generated by aquaculture activities, fishing ports outfalls and other industrial wastes which are coming to the lagoon from land-based sewages and which are increasing its .As a result the fish production drastically dropped and the fin fish farm bankrupted ten years ago.
The present work is intending to investigate about the possible pollution of the lagoon by the industrial wastes coming from the nearby factories producing phosphoric acid and other phosphate related chemical products. Those factories are located on the shore of the Gannouch marine area and are out falling hedge amounts of a by product known as phosphor-gypse, which encompasses several organic matter, fluorides, cadmium, acids, suspended matters, etc.

METHODS

Study area:

The lagoon of BouGhrara is located at the southern part of Tunisia, between 10°40 ' to 10°57 ' east longitude and 33°28 ' and 33°45 ' north latitude; making it as a very wide lagoon open to the Gabes golf and close to the Djerba island (Figure 1).

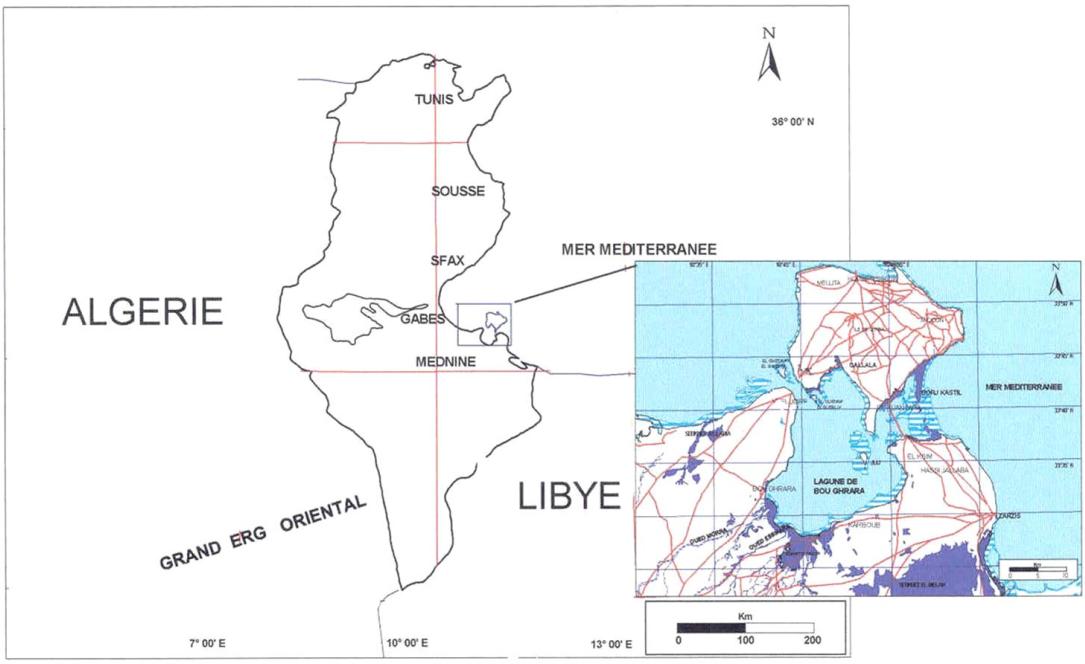

Fig 1: Study area location

its catchments area, whose surface is up to 239 km² is drained by six main little intermittent rivers (which local name is oued) which flow in the lagoon. The water lagoon surface covers up to 50 000hectares, with an average depth of about 5m; it is surrounded by 5 sebkhats (sort of salt area which go dry during summer time), which correspond to plane depressions, easily flooded and whose salted grounds prevented any vegetation on the most part of their ground..

The lagoon water exchanges with the sea through the golf of Gabes are limited to a channel known as Ajim-jorf channel and with the open Mediterranean Sea through a 12 meters pass under a Romanian jetty, which is linking the Djerba Island to the continent. The maximum of the tide amplitude in the lagoon is reaching up to 80 cm in period of sharp water (recorded at the Ajim. channel level)

The current stranding at El Kantara bay, near the Romanian little bridge and the setting up of he Roman roadway itself are likely to be responsible of the reduction of the sea- water entering the lagoon, as said in2000 by the study Eco resources who has proceeded to the lagoon water modelling; the model showed that the water exchanges through the Ajim channel are very weak, (about 0.4 per cent of the whole water volume) and that the stagnation of water is unavoidable in the western, northern and southern parts of the lagoon. It was also noted that the wind is remaining as the main factor in the water circulating and homogenising process inside the lagoon.

Sampling and data analysis

g two campaigns during the biennium 2002-2003 according to the following calendar: August 28th 2002 and December 28th 2002, (Figure 2).

The samples were related to ten stations distributed on the whole lagoon. These stations were fixed according to a systematic grid and referred to by Global Positioning System (GPS navigator).

RESULTS

I / physical and chemical parameters:

The seasonal variation of the surface water temperature is remarkable(about a 10°C average difference between the hottest season (summer 24.7°C) and the coldest one (winter 11.2°C) is about 13.5°C, with a gradient growing from the North to the South of the lagoon.

The salinity of the BouGhrara lagoon is high when compared to the salinity of the surrounding sea, especially during the summer season with an average salinity up to 42.19 PSU. From the north to the south of the lagoon there is a gradient of salinity which reflects the distance to the marine current which is entering into the lagoon alongside of the Ajim-Jorf channel.

Salinity measurements show that the lowest salinity is detected at station 3 (near the channel of Ajim) during the winter period and that the highest ones are occurring at the level of the low depth stations, i.e. ,stations 8, 9 and 10 which undergo a strong evaporation during the summer period.

With regard to pH it fluctuates between an average of 7.92 in winter time and a very slightly basic value of up to 8.31 during the summer period.
The space distribution of the pH in the lagoon surface water differs according to the stations' considered and depends on the period of sampling. The highest values were observed at the low depth stations and at the level of the areas which are invaded by vegetation, during the summer season. During the winter season, the lowest values have been recorded on the level of the major stations.

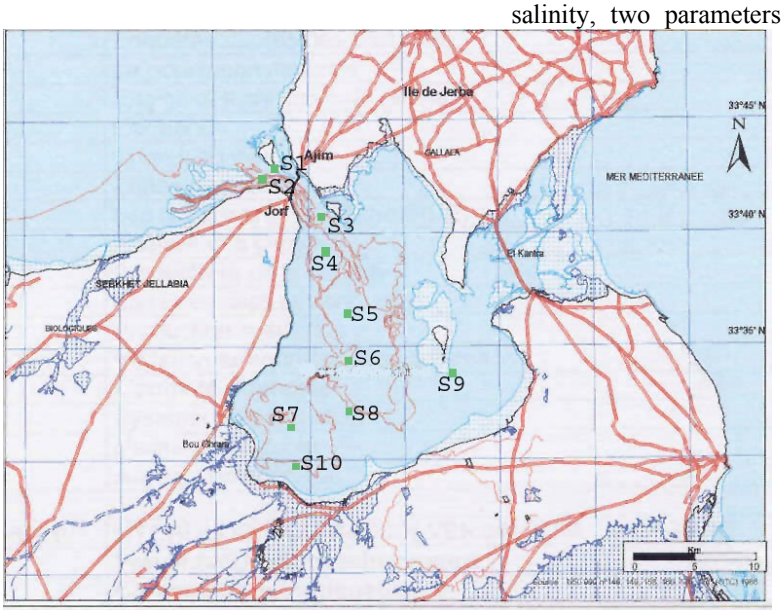

Fig 2: Geographical Localization of the sampling Stations within the BouGhrara lagoon

During the summer time the values of turbidity have been measured at an average of 1.65 NTU, something that could mean that the transparency of the sea water in the BouGhrara lagoon would be acceptable if we consider the average depth of this system which seldom exceeds 7 to 8 meters. Nevertheless the turbidity was increasing during the winter time, due to the presence of various organic particles (more than 5.4 NTU).
As usually known the dissolved oxygen concentration is inversely proportional to the temperature and salinity, two parameters which are influencing the oxygen solubility in the water.
In the summer period, the dissolved oxygen concentrations values present a "peak" which corresponds to the period where the phytoplankton blooms are occurring and where likely to produce large quantities of oxygen (particularly in the day time period).
The dissolved oxygen concentration, during this period, is fluctuating from a station to another highlighting a heterogeneous distribution. ssolved oxygen ı the lagoon as a whole (6 mg. L^{-1}).
During the summery time period the dissolved oxygen values as measured in the surface water vary between 4.89 and 7.94 mg.L^{-1}, the strongest concentration being observed at the level of the stations 8 and 10; something that could be due to the action of the winds on the water surface.

Suspended particulate matter (SPM):
During the estival season, the suspended particles in the lagoon water vary between 75 and 115 mg.L^{-1}, with an extreme value of 115 mg. L^{-1} at stations 3 and 4 whereas they do not exceed 63.3 mg. L^{-1} during the winter time.
Nutriments
The nitrites concentrations do not exceed 0.3 µatg. L^{-1}. Whereas, nitrates values oscillate between 0.87 and 2.255 µatg. L^{-1}, during the estival season. The nitrates contents measured during the winter season reach more significant values (at station 10 a concentration of 2.143 µatg. L^{-1} was detected).
The phosphates concentrations remarkably differ within the same season, they are indeed slightly higher during the estival season than in winter period. The results found during the later season show that phosphate concentrations vary according to the stations and the depth.
The phosphates high concentrations which where measured in the summer time period could be caused by the water masses which are penetrating the lagoon

through the channel of Ajim-Jorf, at the level of stations 1, 2, and 3 where the measured concentrations are situating in the fork 0.60 – 0.77 µatg. L^{-1} and are increasing in the central basin of the lagoon (at the level of stations 6 and 7 where those concentrations reach 0.78 µatg.L^{-1}

The silicates concentrations in the lagoon of BouGhrara are in a fork 7.226 – 47.604 µmole. L^{-1} in winter and 4.3 – 10 µmole.L^{-1} in summer (Table I). Silicon, being used by the diatoms for the constitution of their frustules, the surplus noted in the lagoon of BouGhrara could be referring to the decrease in the growth of the diatoms, benefiting to dinoflagellés blooms, in particular *Gymnodinium cf nogasakiens*, species; such species were described by Ben Rejeb as the phytoplankton predominant ones; they are causing clothe occurring of coloured water; a signal of an eutrophication phenomena.

Fluoride

The fluorine, ninth element of the periodic classification of the elements is very electronegative. Being very reactive, it can not be found in its chemical simple state; but as fluoride ions. The fluorine measured as fluorides in the BouGhrara waters both in summer and in winter are two to three times higher than the values usually recorded in the marine sea waters (1-1.3 mg.L^{-1}),(Table II).

Table 1: Range of values of the recorded parameters within the BouGhrara lagoon

Variables	Summer	winter	comments
Temperature (°C)	**22.0 - 24.7**	**11.20 – 16.10**	
Salinity (PSU)	**39.7 - 44.4**	**36.90 – 38.20**	
Dissolved oxygen (mg. L^{-1})	**4.892 - 7.949**	**5.68 – 6.74**	
Nitrate (µatg. L^{-1})	**0.86 – 2.25**	**0.87 – 2.14**	
Nitrite (µatg. L^{-1})	**0.18 – 0.63**	**0.07 – 0.32**	
Phosphate (µatg. L^{-1})	**0.60 – 0.77**	**0.32 – 0.80**	
N-NO^{-}_3 / P-PO^{3-}_4	**2.68 – 8.44**	**3.93 – 11.33**	
Silice (µatg. L^{-1})	4.30 – 10.0	7.22 – 47.60	

Table II: The fluorine measured as fluorides, in the BouGhrara waters, south Tunisia.

Station	Summer time measurements (mg. L^{-1})	Winter time measurements (mg. L^{-1})
1	3.003	4.553
2	3.426	4.352
3	3.181	4.442
4	3.248	4.159
5	2.665	4.074
6	3.315	3.830
7	3.188	3.783
8	3.026	3.441
9	2.035	3.426
10	2.186	3.315
Sample. ref	1.016	1.121

The high fluoride concentrations in the lagoon water can originate from the golf of Gabes water which are entering the lagoon through the Ajim channel. (Darmoul B., 1979).

Heavy metals:

. ***Cadmium in the marine sediments:***

Cadmium, a chemical element with 112.41 as atomic mass, is, with mercury and lead, classified among the heavy metals which are expected to cause acute pollution to the marine medium, including its living resources and fisheries. This pollutant is expected to be released by phosphate industry, especially within the by product communally known as phospo-gypse. Such industry is producing phosphoric acid by processing the phosphate minerals through acid attack by sulphuric acid. The by product is released into the Golf of Gabes sea as gypseous pulp which empcompasses, among other components, cadmium in trace amounts.

Once released in the sea water, cadmium is particularly found as adsorbed on the suspended particulate matter; this heavy metal is also known by its capacity to accumulate in the living organisms, in particular in their body parts which are known as rich in lipid (liver and kidneys concentrate approximately 50 per cent of them). It is also reported that, under the action of sequestering agents, cadmium can be remobilised starting from the sediments.

During our study cadmium has been measured in the lagoon of BouGhrara sediment and compared to the reference samples coming from the area situated off shore Gar El Melh marine zone in the Gulf of Tunis, an area which has been considered as unpolluted by such a pollutant.

According to the sediment analyses the cadmium concentrations have ranging between 2.26 and 7.48 $mg.kg^{-1}$ (dry weight) , the highest values have been detected at the stations 2, 3, and 4 which are located close to the channel of Ajim and Jorf zone which is characterized by an active change of the water masses. These significant concentrations of cadmium could be attributed to the fact that the activation of the water masses, under the effect of the surface currents generating a tide of the semi diurnal type; (Jedoui et al., 1978) does not have an effect on agitation of the water column in these major zones.

According to the values given by [FAO FIRI / R471], we notice that the averages of the cadmium concentrations in the sediment of BouGhrara lagoon largely exceed the usual sea values, in particular during the winter season with 6.15 mg. kg^{-1}in dry weight.(Darmoul B., 1979).

It has been also noted that the cadmium contents in the sediment decrease from the north to the south parts of the lagoon, with a value at the extreme bottom of the lagoon which is close to the one we have measured at the reference station situated at the Tunis golf; such a distribution has been noted both in summer and winter seasons, except at the station 9 for winter measurement (9.88 $mg.kg^{-1}$)

These figures are fitting with those found by Soussi in the marine sediments of the gulf of Gabès. The cadmium concentrations are laying between 1 to 15 ppm ($mg.kg^{-1}$), the most affected sector being located at the south east part of the golf which is close to the entry of the BouGhrara lagoon. .

Soussi has even used this metal element as a tracer of the chemical pollution of the Gulf of Gabès by the industry of the phosphates (review Article of project «Study of marine pollution in the Gulf of Gabès», March 1992. The cadmium concentrations as measured in the marine sediments are reported in the table III.

Table III: Cadmium as measured in the marine sediments of the BouGhrara lagoon, south Tunisia

Station	Summer time measurements (mg. Kg^{-1}) DW	Winter time measurements (mg. Kg^{-1}) DW
1	4.98	7.39
2	7.19	4.96
3	7.14	7.42
4	7.48	7.33
5	4.90	4.89
6	4.99	4.87
7	4.92	4.82
8	4.93	4.97
9	2.44	9.88
10	2.26	4.96
Sample. ref	2.09	2.24

. ***Cadmium in the marine living resources***

During our survey we were interested in two heavy metals, namely cadmium and lead, cadmium being the pollutants which is currently released with phosphogypsum by the phosphates factories. We have been seeking these two heavy metals in two benthic marine organisms, i.e. the red mullet, *Mullus barbatus* and the royal shrimp, *Penaeus kerathurus* .Cadmium and lead were proportioned into the shrimp flesh and the fish liver respectively.

According to their chemical features and their biological behaviour the micro-pollutants metals, usually named heavy metals, concentrate in the live marine organisms primarily by digestive tract, especially seeking for the sites which are rich in lipids such as liver; internal organs and cerebral cells.

The metals traces analysis on living resources which are coming from the BouGhrara area show that, during both summer and winter seasons, such fishes are not highly polluted by cadmium and lead. Nevertheless we noted very few differences between the concentrations of these elements as measured during the two seasons the cadmium concentration as detected in *Penaeus kerathurus flesh* in the estival period being slightly more significant than that those found during the winter season. However, these measured concentrations are likely to not imply any intoxication if we consider the Concentration limits which are already settled by the World Health Organization (WHO) and the Mediterranean Action Plan [UNEP/FAO/WHO, 1987]; the cadmium concentrations as measured in the shrimp *Penaeus kerathurus flesh* are reported in the table IV.

Table IV: Cadmium as measured into *Penaeus kerathurus* And *Mullus barbatus* of the BouGhrara lagoon, south Tunisia

	Summer time measurements (28/08/02)		**Winter time measurements (28/12/02)**		
	[Cd] (mg/kg) DW	**[Pb] (mg/kg) DW**	**[Cd] (mg/kg) DW**	**[Pb] (mg/kg) DW**	**Size (cm)**
Shrimp lot1	0.8396	0.5274	0.251	0.824	**>43**
Shrimp lot2	0.6348	0.8573	0.249	0.92	**<4.2**
Shrimp lot1. Sample. ref	0.5104	0.3421	0.229	0.721	**>4.3**
Shrimp lot2. Sample. ref	0.3823	0.2789	0.203	0.894	**<4.2**
Flesh: M. barbatus			0.055	0.02	
Liver : M. barbatus			0.288	0.392	
Flesh: M. barbatus Sample. ref			0.038	0.017	
Liver : M. barbatus Sample. ref			0.223	0.368	

Site	**[Cd] ($\mu g.g^{-1}$) fresh weight**	**[Pb] ($\mu g.g^{-1}$) fresh weight**	**Reference**
OMS thresholds	2.0	2.0	Kakulu et al, 1987

As far as fish is concerned, the phenomenon of bio accumulation is complex and seems to be related to a various factors such as the biotic parameters inherent to the considered species (size and sex), the analyzed body part, the pollutants behaviour, etc....
The *Mullus barbatus fish* collected in the BouGhrara area does not show significant concentration by

significant pollution by these two heavy metals, (0.05 ppm and 0.02 ppm for cadmium and lead respectively); however some heavy metals bio accumulation could be detected at the level of the fish liver.
When we compare the cadmium contents both in fish and shrimps we note that the detected amounts are higher than the average contents reported in the Mediterranean (46 ppb or left by balk) for Mullus barbatus (UNPE/FAO, 1986). Cadmium contents in the shrimp captured from the lagoon of BouGhrara are approaching 1 ppm (0.8396 ppm, dry weight in winter time), whereas those detected in the flesh and the liver of the mullet fish are very low(up to 0.038 and 0.288 ppm respectively); these concentrations remain far below those which are currently considered as limit by the environmental legislation (1 ppm); that does not mean that the living resources of the lagoon should not be no longer controlled with regard to their contamination by heavy metals.

DISCUSSIONS

Within this survey, of the BouGhrara lagoon during two seasons our interest has been brought on the physicochemical, environmental and fisheries features of this important but fragile water body which has been few years ago one the most productive lagoon in the Mediterranean, adding to its pioneer role in the marine fin fish aquaculture. Our main aim was to contribute to the enhancement of knowledge on one part and to try to propose solutions to decision makers to improve the water quality of that lagoon and by the way to develop its related fisheries.
The measured physicochemical parameters show that the overall values of salinity, oxygen, turbidity, etc. are characteristic of a lagoon with weak water renewal rate. The influence of the adjacent sea on the lagoon through the single narrow channel of Jorf is often weak and tends to disappear when the bottom of

the lagoon is reached and where contamination is at its maximum.

This situation would originate partly from the geographical position of the lagoon which is bordered by sebkhats and which communicates with the open sea only through passages of irregular and limited depths. The main water exchange of the lagoon is determined by the tide as it was noted by Zaouali in 1980 and SEPIA in 1983.

The high diurnal dissolved oxygen saturation percentage should be apprehended as an eutrophication sign which is occurring into the lagoon; to confirm that expectation the dissolved oxygen should be controlled at a relevant area, especially on a whole period of 24 hours (including both night and day time measurements) since the oxygen fluctuation would be expected to occur depending on the a biotic conditions related to sea dynamic factors (wind, currents, etc.).

These global observations do not prevent the existence of some heterogeneity within the water body which could reflect by differences between the locations which have been selected during the present survey.

At the level of the central basin of the lagoon which has been quoted by SEPIA, 1983, as «lung of the lagoon», the hydrological conditions could be considered as critical since the organic matter amount is very high. These two observations reveal an eutrophication phenomena, something which has been observed in the framework of the study already made by Eco resources International (Eco-Resources International, 1998) and which could be confirmed by the large amounts of suspended particulate matter and related turbidity (due to the phytoplankton blooms) that have been measured during the summer time period.

With regard to the high salinity which is occurring in the lagoon it is understood that the semi-arid climate of the area and the according intensive evaporation in summer are at the origin of significant increase of salinity (above 40 PSU), something that increases the degradation of the organic matter and consumes dissolved oxygen whose concentrations drastically decrease, even to reach values nearing the anoxia conditions, especially in the Eastern part of the lagoon.

As far as nutriments are concerned , in particular phosphorus and nitrogen compounds their values are very highly variant in terms of space and time distribution ; that could be relevant to two main causes, i.e. sea-based incomes from marine waters of the Gulf of Gabès, the organic matter degradation and the phosphorous and nitrogen compounds released by the sediments.

When considering some chemical elements which could be used as tracers of the pollution which may be coming from the nearby gulf of Gabès industry, namely fluorine, organic matter, phosphorus and cadmium, we may affirm that:

- The lagoon of BouGhrara waters present relatively high amounts of fluoride ions which would come from the industrial wastes which are currently released by the phosphoric acid factories situated within the chemical complex of Gannouch, north Gabes (Darmoul, 1979).
- The waters phosphates contents are also twice higher than those which are measured at the reference zone (Gulf of Tunis).
- The cadmium amounts as measured both in the sediments and the benthic organisms such as mullet fish *Mullus barbatus* and royal shrimp *Penaeus kerathurus coming the lagoon* are largely higher than those detected in these same species coming from the of above mentioned reference zone

It is also to be recalled that cadmium which is trapped in the sediment of the lagoon will be released into the water column under favourable marine hydro dynamism, as it has been brought back by several studies on pollution by cadmium.

CONCLUSIONS

The results which have been obtained confirm our expectation about the lagoon environment difficulties, including those coming from eutrophication, but not excluding other human-based activities and pressures, especially from over fishing and bad fishing practices.

Our present study findings require, however, to be confirmed by a more complete study, integrating other aspects such as current measurements and monitoring and other related hydro dynamism features, sedimentlogy, etc.

In order to get a comprehensive and quantitative idea of the cadmium amounts in the lagoon sediment, our findings have to be supplemented by a specific study covering the lagoon as a whole and at definite depths. Further investigations should be carried out in the future to elucidate the relative part of the threats that are occurring on the lagoon especially when we consider the importance of this water body in matter of fisheries and possible fin fish aquaculture industry. This is why the government, through the Ministry of Agriculture, already ordered a study aiming to the improvement of water circulation into the lagoon.

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